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Seamless steel pipe integrity assessment based on SINTAP procedure and numerical analysis

A. Bajtarević-Jeleč [a], M. Manjgo [b], N. Vukojević [c],

F. Hadžikadunić [d], J. Kačmarčik [e]

[a,c,d,e] Faculty of Mechanical Engineering of University of Zenica, Fakultetska 1, 72000 Zenica, B&H, amna.bajtarevic@unze.ba

[b] Faculty of Mechanical Engineering of University 'Džemal Bijedić' Mostar, Sjeverni logor bb, 88104 Mostar, B&H, mersida.manjgo@unmo.ba

Abstract

The focus of this paper is the SINTAP procedure based structural integrity assessment of seamless steel pipe that is subjected to internal pressure. In order to detect geometrical parameters of crack and intensity of pipe pressure that could be potentially unsafe for construction, numerical, analytical and experimental methods are applied. Numerical analysis is performed in order to determine stress intensity factors for considered values of crack dimensions and internal pressure using ANSYS commercial software. Material mechanical properties are defined experimentally. Failure assessment diagrams are created for different values of crack dimensions and internal pressure.

Keywords: SINTAP, structure integrity, fracture mechanics, stress intensity factor.

1. INTRODUCTION

Pipelines are systems that serve to transport various liquid or gaseous fluids and are indispensable parts of every modern society and industry. As pipes and pipelines are very important for industry, there are various international standards that treat their construction, however, their structural integrity is still often the subject of research [1].

The stability of the pipe system or its component depends on the mechanical characteristics of the material, geometry and loading method. The material of such constructions, which are used in conditions of constant internal pressure, should be resistant to the occurrence of brittle fracture despite the presence of geometric defects of the pipe or the occurrence of overloading [2].

In a general sense, the expected values of the crack stress intensity factor and material strength are difficult to determine analytically due to a wide range of structural configurations of elements, load conditions and crack geometries, as well as geometric nonlinearities that depend on the behaviour of the material under load. In order to assess the structural integrity of a structure containing defects, it is necessary to be able to assess the fracture strength as well as the plastic collapse of critical elements containing cracks.

Prediction of structural behaviour based on fracture mechanics parameters (by determining the crack stress intensity factor, J-integral or crack tip opening displacement – CTOD) does not correspond to yield conditions and limit conditions of plastic collapse. For this reason, other so-called, two-parameter methods were developed that take into account two possible boundary conditions during the calculation, i.e. plastic collapse and completely brittle fracture.

One of the procedures that applies the described methods is the so-called SINTAP procedure (Structural Integrity Assessment Procedures for European Industry). According to the SINTAP procedure, the analysis can be based on a FAD (Failure Assessment Diagram) or failure curve diagram – CDF (eng. Crack Driving Force) [3,4].

2. TECHNICAL DESCRIPTION

2.1. Description of the conducted research

In the paper [5], the authors considered the integrity of the element of the connecting accessories numerically and analytically through the SINTAP procedure. In [6], an analytical and numerical calculation of the crack stress intensity factor was performed on the example of a seamless pipe in order to check the deviation of the numerical and analytical results, without further consideration of the safety of the structure. The goal of this research is to determine the dimensions of the crack and the value of the internal pressure, at which the crack potentially impairs the safety of the structure. In this sense, an analytical calculation was carried out using the SINTAP procedure, i.e. the FAD method was used for the example of a crack of critical orientation on the inner surface of the pipe. The values of the stress intensity factor were determined numerically. Fig. 1 shows the geometry of a semi-elliptical crack (which was considered in the paper) with marked basic sizes, where "a" and "c" are the semi-axial cracks, and t represents the wall thickness of the element with the crack.

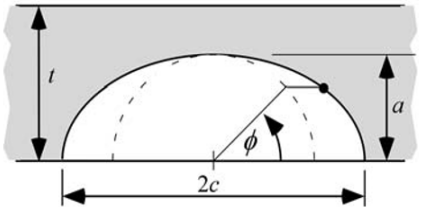


Fig. 1. Basic geometric sizes of the crack [7]

The critical orientation implies that the semi-axis "a" of the crack is perpendicular to the direction of action of the maximum stresses in the pipe wall that occur as a result of the action of internal pressure (Fig. 2).

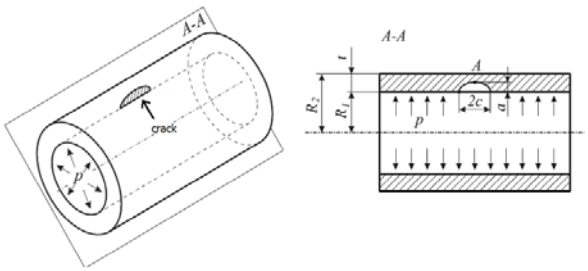


Fig. 2. A crack in a critical orientation on the inner surface of a pressure pipe [2]

The analysis was performed for a total of six different crack dimensions and a total of 4 different pressure values. Table 1 presents the values of the geometric characteristics of the crack and the internal pressure of the pipe applied during the analysis.

Table 1. Analyzed crack geometries and internal pipe pressures

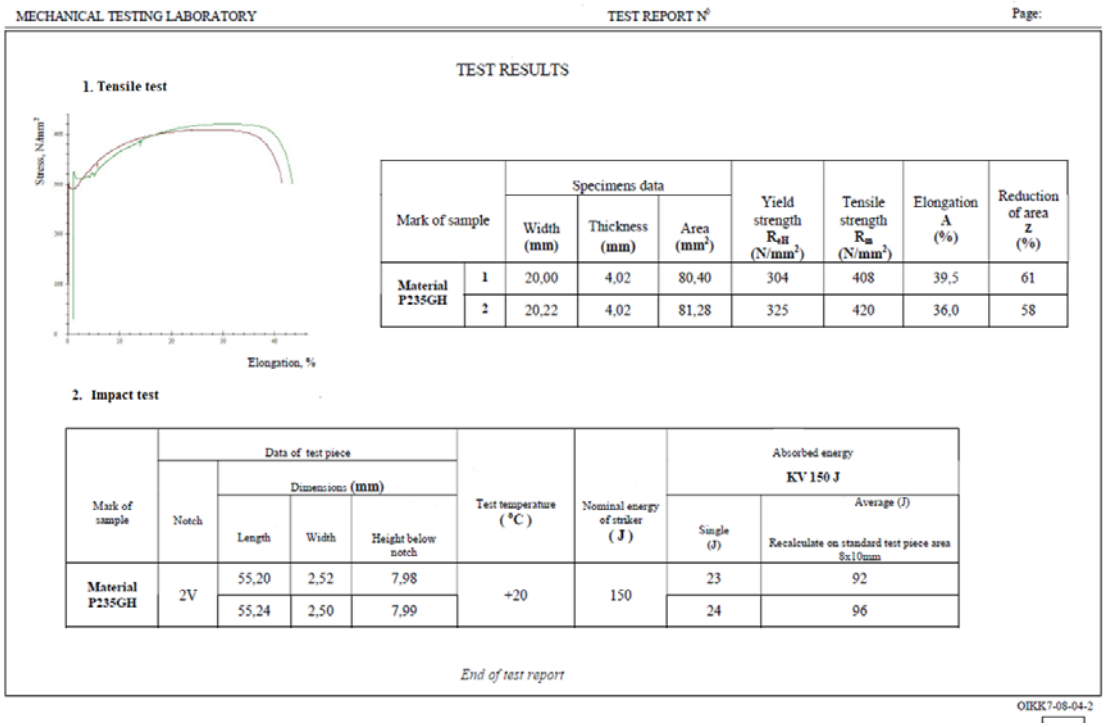
Internal pressure p=1MPa	Internal pressure p=5MPa	Internal pressure p=9MPa	Internal pressure p=12MPa
a=1.125mm c=1.125mm	a=1.125mm c=1.125mm	a=1.125mm c=1.125mm	a=1.125mm c=1.125mm
a=1.125mm c=2.25mm	a=1.125mm c=2.25mm	a=1.125mm c=2.25 mm	a=1.125mm c=2.25mm
a=2.25mm c=2.25mm	a=2.25mm c=2.25mm	a=2.25mm, c=2.25mm	a=2.25mm c=2.25mm
a=2.25mm c=5.625mm	a=2.25mm c=5.625mm	a=2.25mm, c=5.625mm	a=2.25mm c=5.625mm
a=3.375mm c=3.375mm	a=3.375mm c=3.375mm	a=3.375mm, c=3.375 mm	a=3.375mm c=3.375mm
a=3.375mm c=6.75mm	a=3.375mm c=6.75mm	a=3.375mm, c=6.75mm	a=3.375mm c=6.75mm

Therefore, the structural integrity of the pipe was analyzed through a total of 24 characteristic points whose position in relation to the FAD curve is defined by the SINTAP procedure.

2.2. Basic technical characteristics of the investigated pipe

The analysis was performed on a DN80 steel pipe with an outer diameter of 87.9 mm and a wall thickness of 4 mm. The total length of the

pipe is 800 mm. The material of the considered pipe is P235GH (EN 10028).



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TEST RESULTS

1. Tensile test

Stress, N/mm²

Elongation, %

Mark of sample		Specimens data: Width (mm)	Thickness (mm)	Area (mm²)	Yield strength R_{eH} (N/mm²)	Tensile strength R_m (N/mm²)	Elongation A (%)	Reduction of area Z (%)
Material P235GH	1	20,00	4,02	80,40	304	408	39,5	61
	2	20,22	4,02	81,28	325	420	36,0	58

2. Impact test

Mark of sample	Data of test piece: Notch	Dimensions (mm): Length	Width	Height below notch	Test temperature (°C)	Nominal energy of striker (J)	Absorbed energy KV 150 J: Single (J)	Average (J) Recalculate on standard test piece area 8x10mm
Material P235GH	2V	55,20	2,52	7,98	+20	150	23	92
		55,24	2,50	7,99			24	96

End of test report

OIKK7-08-04-2

Fig. 3. Report on the examination of mechanical characteristics

A laboratory test of the mechanical characteristics was performed on the subject pipe sample made of P235GH material. The test was carried out in the mechanical laboratory of the Institute "Kemal Kapetanović" in Zenica. Tests were performed on the subject sample on testing machines – an UTM and a Charpy impact test machine. The achieved results are presented in Figure 3.

Table 2. The results of the mechanical characteristics test

No.	Sample material	R_{eH} [N/mm²]	R_m [N/mm²]	Impact energy [J]
1.	P235GH	304	408	23
2.	P235GH	325	420	24

The fracture toughness characteristics from [8] presented in table 3 were used.

Table 3. Critical stress intensity factor and J integral of steel P235GH [8]

Type of sample	J integral [kJ/m²]	Stress intensity factor, K_{IC} [MPa√m]
P235GH pipe	240,0	233,6
P235GH pipe	239,8	233,5

3. NUMERICAL CALCULATION OF THE CRACK STRESS INTENSITY FACTOR

The calculation of the required values of the crack stress intensity factor at the first mode of failure (K_I) was performed numerically with the help of the software Ansys Mechanical R1 2020.

In according to the fact that an inadequate setting of the boundary conditions can reduce the accuracy of the numerical analysis, the boundary conditions were set analogously [5], where it was proven that the applied setting of the boundary conditions does not affect the accuracy of the results. The load was introduced in the form of the effect of internal pressure. A semi-elliptical crack is introduced as in Fig. 2.

All applied values of internal pressure and crack geometry are given in Table 1.

Figure 4 shows the results of the numerical calculation of the crack stress intensity factor for the case of a crack a=3.375 mm, c=3.375 mm under the action of an internal pressure in the pipe of 5 MPa.

Fig. 4. Results of the numerical calculation of the crack stress factor, a=c=3.375 mm, p=5MPa

4. APPLICATION OF SINTAP ANALYSIS

4.1. Defining of yield parameter L_r

The yield parameter L_r, according to the SINTAP procedure, is defined as the ratio between the applied pressure and the limit value. The pressure values that were applied for the purpose of the analysis are already shown in Table 1.

On the other hand, according to [2], the limit pressure values in pipes with cracks of defined geometries were calculated using the expression:

$$p_y = \frac{t}{R_1} \cdot \sigma_y \cdot \frac{\frac{t}{a} - 1}{\left(\frac{t}{a} - \frac{1}{M}\right) \cdot \left(1 + \frac{a}{R_1}\right)}, \quad (1)$$

where:

- a – semi-axis (depth) of the crack,
- c – semi-axis of the crack,
- t – pipe wall thickness,
- R_1 – inner radius of the pipe,
- M – an auxiliary quantity that is determined by expressions:

$$M = \sqrt{1 + 1{,}255 \cdot \alpha^2 - 0{,}0135 \cdot \alpha^4}\,, \quad (2)$$

$$\alpha = \frac{c}{\sqrt{R_1 \cdot t}}, \quad (3)$$

$$\mu = \frac{c}{\sqrt{R_1 \cdot t}} \cdot \left(12 \cdot (1 - 0{,}3^2)\right)^{0{,}25}. \quad (4)$$

4.2. Defining the fracture line f(L_r)

To define the fracture line, the basic (Basic) level was applied in this work. The data on tensile strength and yield strength, which are required for the application of analysis at this level, were obtained by laboratory tests, while the data on fracture toughness were adopted from [8].

Expressions were used to define the fracture line according to [2]:

$$f(L_r) = \left[1 + \frac{1}{2} \cdot L_r^2\right]^{-\frac{1}{2}} \cdot \left[0{,}3 + 0{,}7 \cdot e^{-\mu L_r^6}\right], \quad (5)$$

for $0 \le L_r \le 1$,

$$\text{where } \mu = min \begin{cases} 0{,}001 \cdot \dfrac{E}{R_{p0,2}}\,, \\ 0{,}6 \end{cases} \quad (6)$$

$$f(L_r) = f(1) \cdot L_r^{\frac{N-1}{2N}} \qquad for\ 1 \le L_r \le L_r^{max}, \quad (7)$$

where:

$$N = 0{,}3 \cdot \left[1 - \frac{R_{p0,2}}{R_m}\right], \quad (8)$$

$$L_r^{max} = \frac{1}{2} \cdot \left[\frac{R_{p0,2} + R_m}{R_{p0,2}}\right]. \quad (9)$$

Based on the data obtained by laboratory tests, the limit value against plastic collapse was calculated:

$$L_r^{max} = \frac{1}{2} \cdot \left[\frac{314{,}5 + 414}{314{,}5}\right] = 1{,}15, \quad (10)$$

which represents the end point on the abscissa of the FAD diagram.

4.3. Defining a parameter K_r

Within this work, the values of the parameter Kr for the observed points on the FAD diagram are defined by the expression:

$$K_r = \frac{K_I}{K_{IC}}, \quad (11)$$

in which the fracture toughness parameter is K_{IC}, adopted from the literature (Table 2), while

the values of the crack stress factor were obtained by numerical analysis with the help of Ansys software.

5. ANALYSIS OF RESULTS

As mentioned, a total of 24 observed points were analyzed, i.e. for 4 different values of internal pressure and 6 different crack geometries. The maximum value of the internal pressure, which was applied in the work, is defined according to [9], through the expression:

$$P_{max} = \frac{2 \cdot f \cdot z \cdot e_a}{D_m}, \tag{12}$$

$$P_{max} = \frac{2 \cdot \frac{314,5}{1,5} \cdot 1 \cdot 4}{83,9} = 19,9 \text{ [MPa]}, \tag{13}$$

where:

- P_{max} – maximum internal pipe pressure,
- D_m – the central diameter of the pipe,
- f – permissible stress (f=R_{eH}/1,5),
- e_a – pipe wall thickness,
- z – coefficient of the welded joint,

  $z = (0,7\text{-}1)^2$, no influence $z = 1$.

So, with an optimal degree of safety (S = 1.5-2), the maximum allowable pressure in the pipe according to the mentioned standard and known mechanical characteristics is 12 MPa, which is also the maximum analyzed value within this paper.

When it comes to crack geometry, three crack thickness values (semi-axes "a") are defined, according to the ratios: a/t=0.28; a/t=0.56 and a/t=0.84.

On the other hand, the semi-axes "c" are defined according to the relations: a/c=1; a/c=0.5 and a/c=0.4.

A failure curve was created for all analysis cases. Fig. 5 presents diagrams for all four cases of analysis.

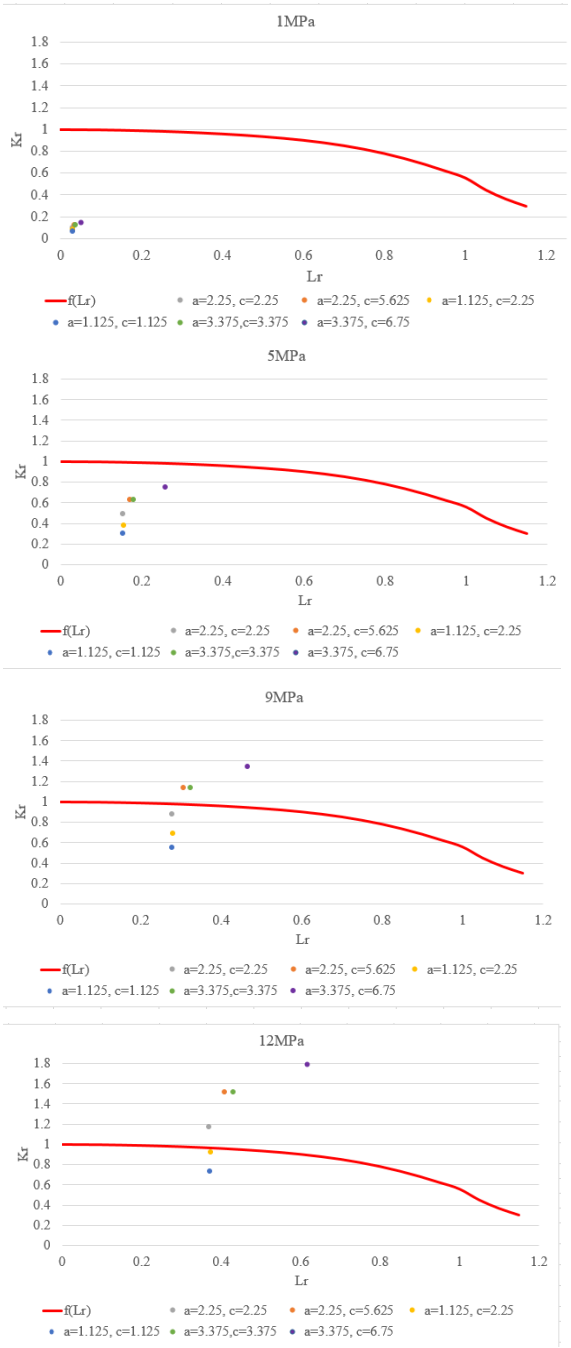

Fig. 5. Fracture curve diagrams for p=1MPa, p=5 MPa, p=9 MPa, p=12 MPa

6. CONCLUSIONS

In the first case of analysis, i.e. in the case when the internal pressure in the pipe is 1MPa, all the analyzed dimensions of the crack are not potentially unsafe for the structure, as can be seen in Fig. 5.

This is a completely expected result, given that the pressure value is low for the geometry and material of the pipe (e.g. circumferential stress in the pipe wall in that case is about 11 MPa).

A slightly worse situation for the stability of the structure is in the case of a pressure of 5 MPa. The observed points are closer to the FAD line, but still within the stability zone.

Under the effect of a pressure of 9 MPa, which was also analyzed in [6], cracks with a larger geometry are potentially unsafe for the construction, i.e. there is a possibility of brittle fracture. It is interesting to mention that the existence of a crack with semi-axes a=2.25 mm; c=5.625 almost identical for the stability of the structure as the existence of a crack with semi-axes a=3.375; c=3.375, according to the SINTAP procedure.

Finally, for the highest analyzed pressure value, which was determined in the paper as the maximum allowable pressure value for this type of pipe, almost all analyzed crack geometries are potentially unsafe for construction.

In order to verify the accuracy of the performed analysis, a diagram of the change in the position of the characteristic point with the defined crack geometry (a=3.375mm and c=3.375mm) was created for different pressure values (Fig. 6). It is shown that by increasing the pressure, the point moves along the expected path.

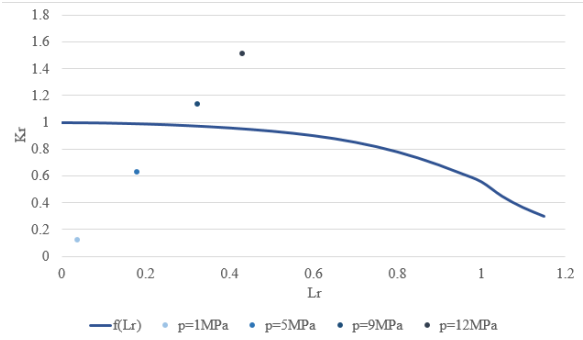

Fig. 6. Displacement of characteristic point with load change

7. REFERENCES

[1] Standard EN 13480-1:2017, Metallic industrial piping - Part 1: General.

[2] N. Gubeljak: Application of SINTAP to the failure assessment of gas pipes, NATO Security through Science Series C: Environmental Security (2008).

[3] S. Al Laham: Stress Intensity Factor and Limit Load Handbook, British Energy Generation Ltd, (1999).

[4] U. Zerbst, M. Schodel, S. Webster, R. Ainsworth: Fitness for Service Fracture Assessment of Structures Containing Cracks, A Workbook based on the European SINTAP/FITNET Procedure, Elsevier (2007).

[5] J. Kačmarčik, M. Hadžalić, P. Konjatić: Structural integrity assessment of a mine hoist rope attachment element with a crack, Structural Integrity and Life, The Scientific Journal of the Society for Structural Integrity and Life, Vol 21, No.1 (2021).

[6] A. Bajtarević, J. Kačmarčik, N. Vukojević, F. Hadžikadunić: Numerical and analytical determination of stress intensity factors for a crack in a pipe, 5th INTERNATIONAL SCIENTIFIC CONFERENCE, University of East Sarajevo, Faculty of Mechanical Engineering (2020).

[7] T.L. Anderson: Fracture mechanics, Fundamentals and applications, Third edition, Taylor and Francis Group (2005).

[8] R.L. Sindelar, P.S. Lam, G.R. Caskey, Jr: Mechanical properties for fracture analysis of mild steel storage tanks, Georgia Institute of Technology, Atlanta, Georgia (1999).

[9] Standard BS EN 13445-3:2002: Unfired pressure vessels - Part 3: Design, British standard (2002).

Investigation of the wrinkling characteristic using deformation maps

R. Borbély [1a], M.L. Kölüs [1b],G.J. Béres [1c]

[1] John von Neumann University, GAMF Faculty of Engineering and Computer Science, Izsáki road 10., 6000 Kecskemét, Hungary,

[a] borbely.richard@gamf.uni-neumann.hu

[b] martin.kolus@gamf.uni-neumann.hu

[c] beres.gabor@gamf.uni-neumann.hu

Abstract

In sheet metal forming operations, the most common forms of failure are tearing and wrinkling. The challenge in technology design is to predict and prevent these failure modes. In the field of rupture failure, a lot of research has been carried out in order to correctly and accurately define the so-called FLC curves. In this paper, we investigate how to establish a wrinkling criterion using as an input parameter for process design by examining the deformation field, i.e. the deformation map. A high strength DP (Dual Phase) steel material under deep drawing process with variable blank holder forces was applied for monitoring the wrinkling characteristics of the flange area. The physical tests were also implemented into a finite element software, for subsequent validation. Our results show that the deformation measuring could be a useful tool for the wrinkling definition, with the proper selection of the border values of the phenomenon.

Keywords: Wrinkling, Strain measurement, Blank holder force.

1. INTRODUCTION

Dual Phase steels are widely used because of their excellent mechanical properties. Their microstructure is ferrite-martensitic, which allows good formability while maintaining high strength parameters. Their main applications are in the automotive industry, where they are used both in the production of structural elements for cars and in the manufacture of bodywork components. Their importance is confirmed by the number of studies on the subject [1,2].

Studies that explore the limits of formability include FLC studies, where the failure of the work pieces is formed under different stress conditions and then summarised into one diagram to give the FLC curve, which indicates the limit of global formability from shearing up to biaxial failure [3,4]. These studies aim to help define the FLC curve as accurately as possible. Merklein, Kuppert and Geiger [5] have developed a new time-dependent method to determine the nodal zone as accurately as possible. The theory is based on the fact that the strain deformation speed rate accelerates as the onset of necking occurs. In turn, more accurate FLC curves facilitate the technology design as an input parameter in, for example, the finite element software.

The second most common failure in sheet metal forming is wrinkling, which is particularly

problematic on work pieces that require the aesthetic appearance mentioned above [6]. Besides, wrinkles formed in the first drawing step can cause unpleasant complications in the later operations. Some of the parameters affecting this phenomenon are friction conditions, initial work piece size and blank holder force [7,8]. The latter was studied in Wang and Cao's [9,10] article where they sought to find the optimal blank holder pressure using stress based equations [11,12]. Although the definition of a rupture is still not completely exact, the onset of wrinkling is also based on individual subjective judgement. It was therefore necessary to define the boundary condition for wrinkling in the mentioned study. This was the transition from a semi-sinusoidal to a sinusoidal characteristic of the surface wrinkles. In another way, Hutchinson and Neale [13] developed an equation (not detailed here), which states that wrinkling occurs when the sum of the energy members of the equation representing different stress values is zero.

In the following study, we try to eliminate wrinkling by varying the blank holder force and to define a wrinkling criterion from the results that can serve as a useful input boundary for the design of the technology. Furthermore, we investigate the variation of the deformation field, in order to set up a condition system. In addition to empirical tests, the investigations are reproduced in a simulation environment to gain a deeper understanding of the process.

2. METHODS AND MATERIALS USED FOR RESEARCH

In this section the description of the details of the experimental tests and the input parameters of the finite element software can be found.

2.1. Material

The work pieces used for the test were made of commercial DP 600 material, with a nominal thickness of 1 mm. The work pieces were cut out from table by shearing, and then machined to the final shape by turning. The initial diameter of each work piece is Ø66 mm.

2.2. Grid application

After cutting to size, the surface of the work pieces was polished to remove contamination and to ensure an even surface for a good quality mesh. This was done at a speed of 300 rpm, while the sandpaper was progressively finer in the range 200-400-600 then 1200. The work pieces were then meshed, which was necessary to perform the digital image correlation measurements. For this, Sericol (PS001) stain and its catalyst (PS387) were mixed in 5 to 1 ratio, and 10% diluent (ZE570) and 10% retardant (ZE574) were added. The mesh size was chosen to be $2mm^2$ and the drying time was approximately 5 hours at ambient air temperature. The pieces were then deep drawn.

2.3. Deep drawing

The deep drawing was carried out on an ERICHSEN 142-40 universal sheet metal tester equipment. The deep drawing speed was constant 20±0.2 mm/min, while the deep drawing depth was 20+0.2 mm. The blank holder forces were chosen to be 3-4-5 kN ±0.2 kN in series. The end of the measurement was reached at the desired deep drawing depth. To achieve optimum friction, sandwich lubrication was used (oil and polyethylene film) on the die side of the sheets. The foil layer thickness was approximately 0.05 mm, and the oil type was BWS HK-280 deep drawing cold forming EP level lubricant. The average quantity of oil on the sheets was 87.85 g/m^2. The deformation in the flange region of the meshed and deep-drawn work pieces was investigated using the Vialux in-process® deformation measuring 4-camera system.

2.4. Simulation

The tests were built and simulated in Simufact 2021.1 finite element software. The input parameters used to set up the simulation were the following: the coefficient of friction between the sheet and the blank holder was 0.12

and between the sheet and the punch was 0.20. This is the reason of that the lubricant was applied on the die side of the blank only. The initial element size was 1.4 mm and the specimens contained 3 layers in the thickness direction. This resulted in a total of 6696 elements. The temperature was room temperature (20°C). The flow curve model from tensile test data series was described by the Hockett-Sherby equation [14]. Yield Criterion was determined from Hill'48 model [15], in which the R values were obtained from tensile test data. The results obtained in finite element software showed good correlation with empirically obtained results.

3. RESULTS AND ACHIEVEMENTS

In this section, the introduction of the empirical and the simulation results of the deformation is shown. Results will depict the images of work pieces clamped with 3-4-5 kN blank holder force. The appearance of wrinkles was examined on the rim of the deep-drawn cup. The different deformation values represent the appearance of wrinkles, as the formation of wrinkles on the rim surface deforms the individual squares of the recorded mesh at different rates. As shown in *Fig.1*., the wrinkles on the rim of the cup are illustrated by the different colour and the corresponding deformation value.

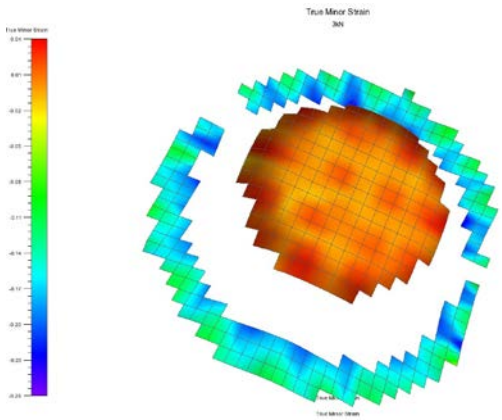

Fig.1. True minor strain of deformed work piece with 3kN blank holder force

In *Fig.2*., the image of the work piece formed in the finite element software under the same conditions is visible.

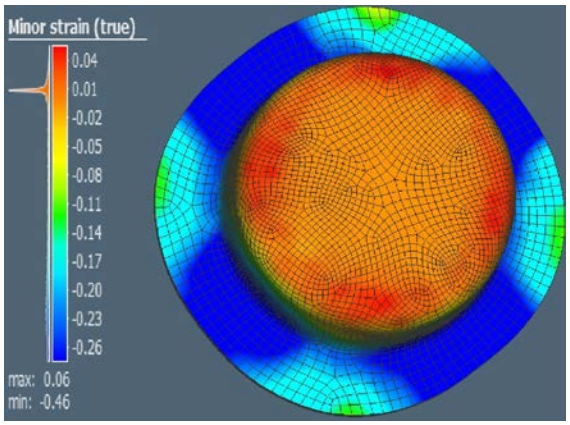

Fig.2. True minor strain of simulated work piece with 3kN blank holder force

The two images show relatively good correlation with each other. By changing the deformation scale to equal of the experimental scale, it can be seen that the deformation map is identical in both values and colour. This means that the blank holder force applied was not sufficient to prevent wrinkling of the work piece under the existing conditions.

In the next step, the blank holder force was increased to 4kN. This is expected to reduce or even eliminate wrinkling. As *Fig.3.* shows, the number of wrinkles reduced as excepted. There is also a minimal decrease in the range of deformation values.

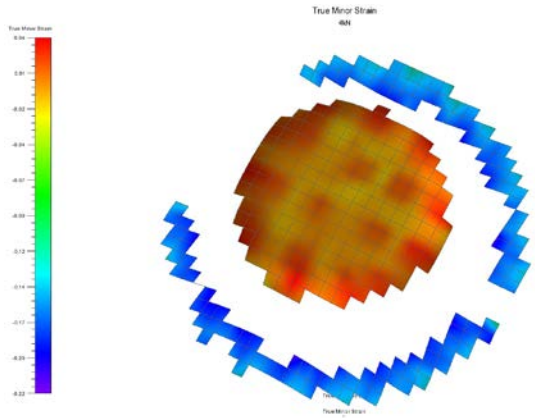

Fig.3. True minor strain of deformed work piece with 4kN blank holder force

The simulation results depicted in *Fig.4.* is are compatible with the experimental results again.

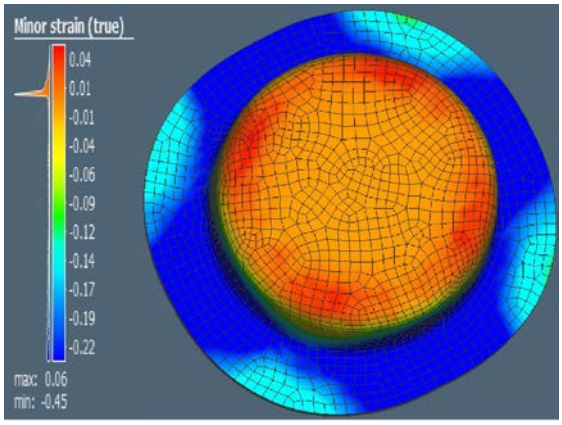

Fig.4. True minor strain of simulated work piece with 4kN blank holder force

After that, we increased the blank holder force to 5kN. There is a minimal decrease in the range of deformation values. *Fig.5.* and *Fig.6.* show that as the blank holder force is increased, the deformation values at the rim of the cup are almost equal.

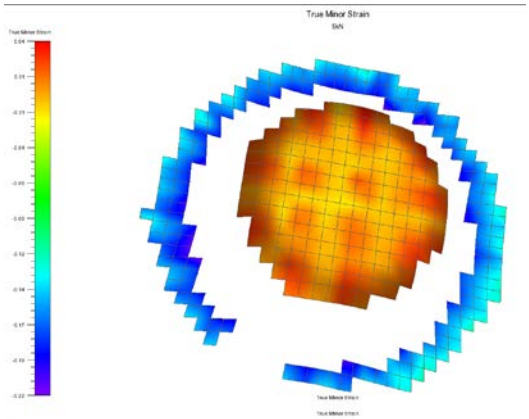

Fig.5. True minor strain of deformed work piece with 5kN blank holder force

The experimental and simulation results show good correlation too. It can also be seen that there is no marginal difference in the strain map compared to a cup formed with a 4kN blank holder force. This suggests that the optimal clamping force lies between these values, although further experiments are needed to determine the optimal downforce

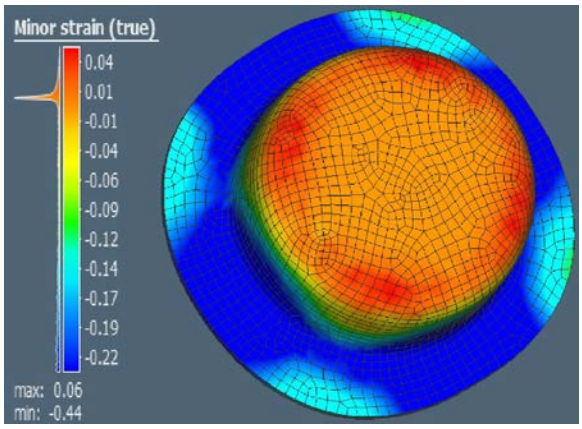

Fig.6. True minor strain of simulated work piece with 5kN blank holder force

4. CONCLUSIONS

In this article, we investigated the development of wrinkling by measuring the deformation map in experimental and simulation ways. The work piece material was DP600, with initial diameter of 66 mm and the nominal thickness was 1 mm. In the empirical test, the blank was formed by deep drawing and the simulations were performed using Simufact Forming 2021.1 version finite element software. As the perception of the presence of wrinkling is a subjective human factor dependent issue, the aim is to further investigate the presence of wrinkling to see if it is possible to establish a criterion that can further aid the design of the technology as an input parameter. It can be seen that by measuring the deformation, the presence of wrinkles can be detected and also that when they disappear. A further aim of the research is to establish a boundary condition that determines exactly when a work piece is considered wrinkled and when the wrinkles cease to exist, using deformation measuring.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

[1] R. Kuziak, R. Kawalla, S. Waengler: Advanced high strength steels for automotive industry, Archives of Civil and Mechanical Engineering, Vol VIII, 103-117 (2008.)

[2] S. Keeler, M. Kimichi: Advanced High-Strength Steels. WorldAutoSteel, Application Guidelines V5.0, (2015)

[3] S. Keeler, W.A. Backofen: Trans. ASM 56 (1963), pp. 25-48.

[4] G.M. Goodwin: Society of Automotive Engineers No. 680093 (1968), pp. 380-387.

[5] M. Merklein, A. Kuppert, M. Geiger: Time dependent determination of forming limit diagrams, Elsevier CIRP Annals - Manufacturing Technology 59 (2010) 295–298 doi:10.1016/j.cirp.2010.03.001

[6] D. Banabic, H.J Bunge, K. Pöhlandt, A.E. Tekkaya: Formability of Metallic Materials, Springer-Verlag Berlin Heidelberg (2000), pp. 173-178.

[7] A. Agrawal, N.V. Reddy, P.M. Dixit: Determination of optimum process parameters for wrinkle free products in deep drawing process, Journal of Materials Processing Technology 191 (2007), 51–54.

[8] T.X. Yu, W. Johnson: The buckling of annular plates in relation to the deep-drawing process, Int. J. Mech. Sci. 24, (1982) No. 3, 175-188.

[9] Xi Wang ; Jian Cao: An Analytical Prediction of Flange Wrinkling in Sheet Metal Forming, Journal of Manufacturing Processes, Vol. 2/No. 2 2000

[10] Jian Cao, Xi Wang: An analytical model for plate wrinkling under tri-axial loading and its application, International Journal of Mechanical Sciences 42 (2000) 617}633 PII: S 0 0 2 0 - 7 4 0 3 (9 8) 0 0 1 3 8 – 6

[11] S. Panich, M. Liewald, V. Uthaisangsuk: Stress and strain based fracture forming limit curves for advanced high strength steel sheet, Int J Mater Form 11 (2018), 643–661. https://doi.org/10.1007/s12289-017-1378-z

[12] B.M. Hance, L. Huang: A simplified stress-based forming limit criterion for advanced high strength steel (AHSS), Proceeding of IDDRG Congress (2018) IOP Conf. Series: Materials Science and Engineering 418, 012037

[13] J. W. Hutchinson, K. W. Neale: Wrinkling of curved thin sheet metal, Proceedings of International Symposium on Plastic Instability, Paris, France, pp. 1841–1914 (1985)

[14] J.E. Hockett, O.D. Sherby: 1975. J. Mech. Phys. Solids, 23, 87-98.

[15] R. Hill: 1947. A theory of the yielding and plastic flow of anisotropic metals. The hydrodynamics of non-Newtonian fluids. I, 281-297.

Biofuel from plastic waste

M. Bosnjakovic[a], M. Galovic[b], I. Lackovic[c]

[a] University of Slavonski Brod, Trg Ivane Brlić Mažuranić 2, Slavonski Brod 35000, Republic of Croatia, mbosnjakovic@unisb.hr

[b]Technical School, Eugena Kumičića 55, Slavonski Brod 35000, Republic of Croatia, mgalovic@unisb.hr

[c] University of Slavonski Brod, Trg Ivane Brlić Mažuranić 2, Slavonski Brod 35000, Republic of Croatia, ilackovic@unisb.hr

Abstract

Plastic waste is a major environmental problem and at the same time a great energy potential. One of the possibilities of disposing of waste plastics is the production of liquid fuel. In this paper, technological, ecological and economic aspects of liquid fuel production from plastic waste are analyzed. Analyzes show that the process of obtaining fuel by pyrolysis with a catalyst is a technologically mature technology, although there is still room for improvement. The most commonly used catalysts are zeolite based. Up to 800 liters of liquid fuel can be obtained from one ton of waste plastic, although up to 450 liters are usually obtained in real plants. The quality of the obtained fuel largely depends on the quality and contamination of the raw material, and its price is slightly higher than conventional oil-based fuel. The total amount of plastic waste in Croatia is 266,384 tons, which represents a potential for obtaining up to 213 million liters of fuel per year. Since a large amount of plastic waste without impurities is needed for commercial production, it is necessary to improve the existing infrastructure for separate collection of plastic waste in Croatia. The environmental benefits of disposing of waste plastics by producing liquid fuels are great, including the reduction of greenhouse gas emissions.

Keywords: plastic waste, biofuel, pyrolysis

1. Introduction

Economic development based on conventional fossil fuels such as oil, natural gas, or coal will not be sustainable in the near future due to their limited resources. In the International Energy Outlook 2019 [1] is stated that global consumption of liquid and petroleum products will increase from 101 million barrels per day in 2018 to 121.5 million barrels per day in 2050. If current practices continue, oil and gas reserves will not be available for 43 and 167 years, respectively. Therefore, more use should be made of alternative, i.e. renewable, energy sources such as biomass, hydropower, geothermal energy, wind energy, solar energy, etc.

Plastic waste is also an alternative energy source from which diesel-like biofuels can be obtained [2].

The Law on Waste Management (ZOGO) (2013) stipulates that municipalities and cities are required to collect plastic waste separately. However, according to the law, it was necessary to issue ordinances, so the separate collection of plastic waste will not be addressed more strongly until 2019, when the Environmental Protection and Energy Efficiency Fund (EPEEF) will allow the procurement of containers for the separate collection of municipal waste. The rate of separately collected plastic waste has increased very

sharply (300 percent in Zagreb). Plastic waste soon became a mixture of different types of plastic. The report of the Ministry of Environmental Protection and Energy for waste management in 2018 [3] shows that the estimated share of plastics in mixed municipal waste in Croatia in 2015 was 22.9%. These data lead to an extremely large amount of plastic waste in mixed municipal waste. Since mixed municipal waste (from households) is 1.25 million tons, we arrive at 286548 tons of plastic in mixed municipal waste.

Since different types of waste are collected separately in Croatia since 2020, the amounts of separated plastic waste are certainly higher [3]. The amount of plastic packaging waste collected for recycling has increased significantly in the EU, and waste sent to landfills has been reduced by more than 50%, i.e. to 3.3 million tons in 2018. Much more plastic waste is recycled and plastic is newly produced or waste is used for energy production [4].

Based on 2020 data, the share of separately collected municipal waste in Croatia (all types of municipal waste except mixed municipal waste) was 41% or 694,160 tons. The recycling rate of total municipal waste was 34%, which is lower than the planned 50% [5]. In 2020, 66,384 tons of plastic waste were collected (collected separately), and the share of plastic in this waste was 9.8% (Figure 1).

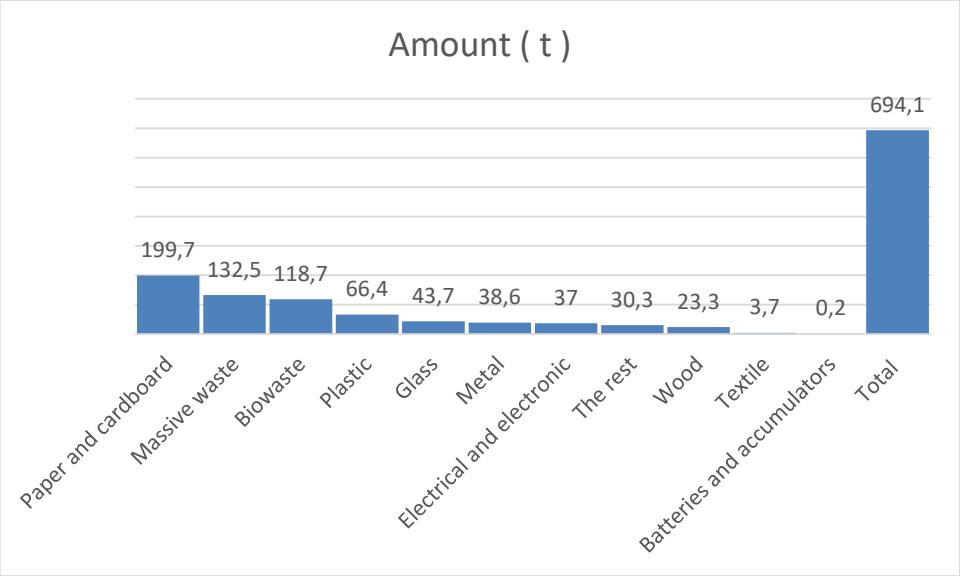


Fig. 1. Amount of waste collected during 2020 [3]

If we assume that about 20% of plastics (200,000 tons) are contained in mixed waste (998807 tons), the total amount of plastic waste is 266384 tons. Since up to 800 liters of fuel can be obtained from one ton of plastic, this results in a potential of 213 million liters of fuel per year.

However, if we take into account that not every type of plastic is suitable for obtaining liquid fuel, the production of 400 liters of fuel from one ton of plastic results in the amount of about 107 million liters of fuel per year.

1.1 Review of previous research

Madhukar et al. [2] describe the process and experimentally investigate the possibility of producing fuel from plastic waste - low density polyethylene (LDPE) and polypropylene (PP) - by thermal pyrolysis without catalysts. Physical analysis revealed a viscous liquid with a yellowish colour and an unpleasant odour. The flammability test showed: easily flammable and completely burned without formation of deposits. The main rheological properties are the flash point 22 °C, the flash point 29 °C and the calorific value 43796 kJ / kg.

Dai and et al. [6] studied the pyrolysis process applying different types and tandem catalysts. Susastriawan et al. [7] analysed the effect of

zeolite size on the low temperatures pyrolysis of LDPE plastic waste. Hazrat et al. [8] conducted a study on thermocatalytic processes for the conversion of plastic waste. The experiments compared different types of plastics and showed the process of fuel production. The optimum production temperature for diesel and gasoline was between 390 °C and 425 °C.

Patil et al. [9] described the impact of plastics on soils, oceans, animals, and humans and conducted an experiment to produce fuels from plastic waste. The experimental plant consisted of a reactor, a condenser, a pipeline, a regulator, and a heater. It was concluded that production can be simple. One kilogram of plastic can be used to produce 0.8 liters of fuel. The diesel obtained from plastic waste has better properties than kerosene and almost the same properties as conventional diesel, so it can replace both kerosene and diesel.

The production of diesel from plastic waste and used lubricating oil was described by Phetyim and Pivsa-Art [10]. The study was conducted with different oil ratios and different types of plastics (oil: high density polyethylene - HDPE: polypropylene - PP: polystyrene - PS) and by measuring the properties, it was found that the ratio 50: 30: 20: 0 has most of the properties of standard diesel according Thailand Ministry of Energy, except for the ignition point, which is lower than the standard. In addition, this ratio was used at different temperatures of the pyrolysis reactor (below 400 °C, from 400 °C to 425 °C and from 425 to 450 °C) and the properties of the oil obtained were analyzed. The oil at temperatures from 400 °C to 425 °C has the most similar properties to diesel [10].

Garib et al. [11] analyzed solid waste at a landfill site in Khartoum State (Sudan) and found that it contained 12.7% plastic. Studies show that oil recovery from thermal pyrolysis of plastic waste ranges from 80% to 90%. Modifications were made according to the Aspen Hysys thermal fuels program that increased process efficiency.

Sarker and Rashid [12] conducted a study in which they tested different types of plastics used separately and mixed in a stainless-steel reactor. In the study, the plastics were mixed in different random proportions before fuel production. The result of mixing plastics is a more productive process with a higher percentage yield compared to the process where the plastics are separated.

A study by Machirai et al. [13] showed that pyrolysis with a catalyst can produce a fuel with similar properties to conventional fuels. Pyrolysis is an ecological and economical method. One kilogram of plastic waste is converted into 0.75 kg of usable liquid hydrocarbon fuel without releasing any pollutants. At the same time, hazardous plastic waste is reduced and the import of crude oil is reduced. The resulting fuel is most similar to diesel and can be used to start diesel engines. The composition of the obtained biofuel is pyrolysis oil 48.6%, wax 40.7%, pyroplin 10.1% and carbon black 0.6% [13]. A study by Brindhadevi et al. [14] showed the results of catalytic decomposition of low-density polyethylene by synthesized catalysts in a solid reactor. The expected products of the experiment are gasoline and liquid fuel rich in hydrocarbons, coke and gas. The optimum yield of liquid fuel obtained with the TiO_2 catalyst occurs in the first reaction and decreases significantly as the reaction proceeds. During cracking in the presence of the TiO_2 / AlSBA-15 catalyst, a significant increase in gasoline content from 45.6% to 85.4%, liquid fuel efficiency (89.1%) and conversion (98.4%) was observed. The liquid fuel produced with the composite catalyst had a calorific value of 47.8 MJ/kg, which is higher than that of standard petroleum.

2. Materials and methods

There are different types of plastics, but not all of them are suitable for the production of plastic fuels. They must be classified and separated.

Plastic waste is mainly composed of low density polyethylene (LDPE), high density polyethylene (HDPE), polypropylene (PP), polyvinyl chloride (PVC), polystyrene (PS) and polyethylene terephthalate (PET) [15]. HDPE and PP account for the majority of plastic waste [15].

Plastics are also classified according to their chemical structure of the polymer chains. Some important groups are acrylates, polyesters,

silicones, polyurethanes, and halogenated plastics.

LDPE is used for its toughness, flexibility and relative transparency to make bottles. To take advantage of its strength and toughness, it is used to make commercial and garbage bags, dropper bottles and films. It is also used for toys, tank lids and various packaging.

PP has high melting point and is ideal for storing hot liquids that need to be cooled in a bottle (e.g. ketchup, juice, syrup). It can be made as a flexible or rigid part. PP is used for production of containers for yogurt, margarine, and take-out foods. It is also used for medical bottles, bottle caps, ... [2].

There are different types of recycling or reuse of plastic waste, which can generally be divided into three types:

- mechanical recycling
- energy recovery or incineration
- chemical recycling

Landfilling waste or incinerating plastics leads to the following problems:

- Toxic fugitive emissions are released during the polymerization process.
- Open burning of plastic waste is very common phenomenon in cities / towns that produces toxic gases such as, chlorine, hydrochloric acid, carbon monoxide, amines, nitrides, styrene, benzene, butadiene and acetaldehyde.
- Non-recycled plastic waste such as multi-layer and metalized bags and thermally bonded plastics such as SMC / FRP etc. pose various disposal problems.

This paper will analyze the chemical recycling of waste plastics in the production of liquid biofuels similar to diesel.

2.1 Pyrolysis

When we talk about chemical recycling, we are actually talking about pyrolysis. Pyrolysis is defined as the controlled heating of an oxygen-free material. During the pyrolysis of plastics, the macromolecular structure of a polymer breaks down into smaller molecules or oligomers and sometimes into monomeric units. Further decomposition of these molecules depends on a variety of conditions, including the presence of catalysts, residence times, temperature, and other process conditions. The pyrolysis reaction can be carried out with or without the presence of a catalyst. Furthermore, the reaction may be a thermal or catalytic pyrolysis. Since most of the plastics used are polyolefins, extensive research has been carried out based on this polymer, which is described in more detail below [2]. The main pyrolysis processes are listed in Table 1. The values for conventional, fast and flash pyrolysis at different parameters are given.

Table 1. Main process parameters for the pyrolysis process [16]

PARAMETERS:	CONVENTIONAL	FAST	FLASH
Pyrolysis temperature (K)	550-900	850-1250	1050-1300
Heating speed (K / s)	0.1-1	10-200	> 1000
Particle size (mm)	5-50	<1	<0.2
Solid state time (s)	300-3600	0.5-10	<0.5

In slow pyrolysis, the resulting liquid is usually fatty and not waxy. Oil yields can reach 93wt% when LDPE is processed at 550 ˚C, providing excellent yields and a wide range of applications. Plastic oil is versatile and can be used either directly in steam boilers for power generation or as a chemical platform for other applications such as transportation fuels, remediation monomers and carbon nanotube (CNTS) production. The solid residue yield is much lower than that of coal from biomass, which is due to the fact that plastic waste contains less solid carbon and more volatile components compared to biomass [17].

Fast pyrolysis is carried out in continuous systems, while slow pyrolysis is usually carried out in batch reactors. In continuous

processes, faster removal of carbon from the reactor space occurs. This prevents undesirable catalytic effects that lead to excessive vapour cracking, which, along with short vapour residence times, results in higher liquid production. In fast pyrolysis, up to 95% of the mass of the plastic waste can be converted to liquid/wax and a larger amount of liquid/wax is obtained than in slow pyrolysis [17].

Flash pyrolysis (milliseconds) is a suitable to avoid excessive cleavage reactions that occur in fast pyrolysis, especially above 700 ˚C, resulting in the conversion of a significant amount of liquid to gaseous products. In contrast to the faster pyrolysis of biomass, which produces the highest yield of bio-oils, the flash pyrolysis of plastic waste produces more gases than liquids, the most important of which are ethylene and propylene. The by-product in the form of oils can be used to provide the energy needed for the process [17].

Important steps in the pyrolysis of plastics are:

- Uniform heating of plastic waste in a narrow temperature interval without major temperature fluctuations.
- Removal of oxygen from the pyrolysis chamber.
- Management of the carbon by-product before it becomes a thermal insulator and reduces the thermal conductivity of the plastic,
- Condensation and pyrolytic water vapour fractionation to produce distillates of good quality and consistency [16].

Noncatalytic or thermal pyrolysis of polyolefins (POF) is a high-energy, endothermic process that requires a temperature of at least 350 °C to 500 °C. In some studies, high temperatures of 700 °C to 900 °C are important to achieve higher production yields. The extent and nature of these reactions depend on the reaction temperature and the presence of products in the reaction zone, which is primarily influenced by the reactor design.

In addition, the reactor design also plays an important role, as it must overcome the problems associated with the low thermal conductivity and high viscosity of the molten polymer. Various types of reactors are described in the literature, but the most commonly used are fluidized bed reactors, series reactors and screw reactors.

The characteristics of thermal decomposition of heavy hydrocarbons are:

- Olefins are less branched.
- High production of C_1 (methane) and C_2 (ethane).
- Some olefins are formed at high temperatures.
- Gasoline selectivity is poor, i.e., petroleum products have widely distributed molecular weights.
- High production of the gas and coke.
- The reaction is slow compared to the catalytic reaction.

The main product of pyrolysis is pyrolysis oil, which is an excellent source of biofuels. Unlike oils obtained from biomass, pyrolysis oils have a high calorific value, nearly three times that of bio-oils. Pyrolysis oils are more similar to diesel fuels because they do not contain highly oxygenated compounds or water. The acidity of pyrolysis oils is much lower than that of bio-oils, so additional processes to produce biofuels can be avoided. A by-product of pyrolysis is coal, which can be used as an adsorbent, and gas, which can be a source of energy for the pyrolysis process. A small amount of pyrolysis by-products are coke and ash [17].

The oil obtained by pyrolysis may be liquid or waxy. Liquid oil consists of aliphatic compounds, mono and polyaromatics. In addition to fuel production, pyrolytic oil can also be used as an intermediate for the production of ethylene and propylene.

2.2 Catalytic decomposition

By definition, a catalyst is a substance that can initiate, slow down, and/or control a chemical reaction without changing its own structure at the end of the chemical reaction. The catalyst is used

to enhance the cracking reaction. The type of catalyst has an important role in the pyrolysis of plastic waste and the characteristics of oil yield and quality [18].

The availability of catalysts reduces the reaction temperature and reaction time and increases the yield of gaseous products [16]. The process cost is lower, which makes this process more attractive from an economic point of view. The reuse of catalysts and the use of efficient catalysts in smaller quantities improve this option. This process can be developed into a cost-effective commercial polymer recycling process to solve the environmental problems of plastic waste disposal. Moreover, in this way, the ability to break down plastics is higher and the concentration of solid residues in the product is lower. Table 2 gives an overview of the catalysts, pore sizes and trade names used.

Table 2. Overview of catalysts used [16]

CATALYST	PORE SIZE (mm)	COMMERCIAL NAME
USY	0.74	H- Ultrastabilized, Y- zeolite
ZSM-5	0.55 x 0.51	H-ZSM-5 zeolite
MOR	0.65 x 0.7	H- Mordenite
ASA	3.15	Synclyst 25 (silica-aluminum)
MCM-41	4.2 - 5.2	-
SAHA	3.28	Amorphous silica-alumina
FCC-R1	-	Equilibrium catalyst
Silicate	0.55 x 0.51	Synthesized in house

The zeolite catalysts showed excellent catalytic efficiency in cleavage, isomerization, and aromatization, and the gas production is significantly higher. Although a similar mechanism occurs in clay (e.g., calcium bentonite [19]), less attention is paid to clay-based catalysts for these processes [20], although Fe-acidified clay showed excellent yield of the diesel fraction [21]. Being abundant in nature, both clay and zeolite materials can be found as cheap minerals [22, 23].

Pyrolysis in the presence of ZSM-5 catalyst produces significantly more aromatic and polycyclic aromatic compounds compared to uncatalyzed pyrolysis, which improves the biofuel production process [24]. When ZSM-5 catalyst and corn stalks were used in the co-pyrolysis of HPDE, it was found that with increasing biomass / HDPE ratio, higher hydrocarbon yield and better H/C ratio were obtained while decreasing coke content [25]. SAHA catalysts contribute significantly to the production of light olefins without significantly changing the aroma. USY catalysts enable the formation of both aromatics and branched chain hydrocarbons, with a significant increase in the content of gaseous hydrocarbons. Catalytic cracking of the MCM-41 catalyst contributes to the production of gasoline, with less impact on the production gas, probably due to the weaker acidic properties and larger pores of the catalyst [17].

Bimetallic catalysts are already widely used for the pyrolysis of plastic waste into biofuel [18], but are less popular than zeolite-based catalysts.

3. RESULTS AND DISCUSSION

The plastic fuel production plant is shown schematically in Figure 2.

After the waste is separated and classified, the plastic must be crushed to the desired granularity so that it can go onto the conveyor belts and then into the remelting machine. To achieve the desired granulation, various machines such as mills, shredders and crushers are used.

Figure 2 shows that, depending on the type of system, it is possible to melt plastic granules in furnaces and feed the melt into the reactor, or to feed the plastic granules into the reactor in solid form.

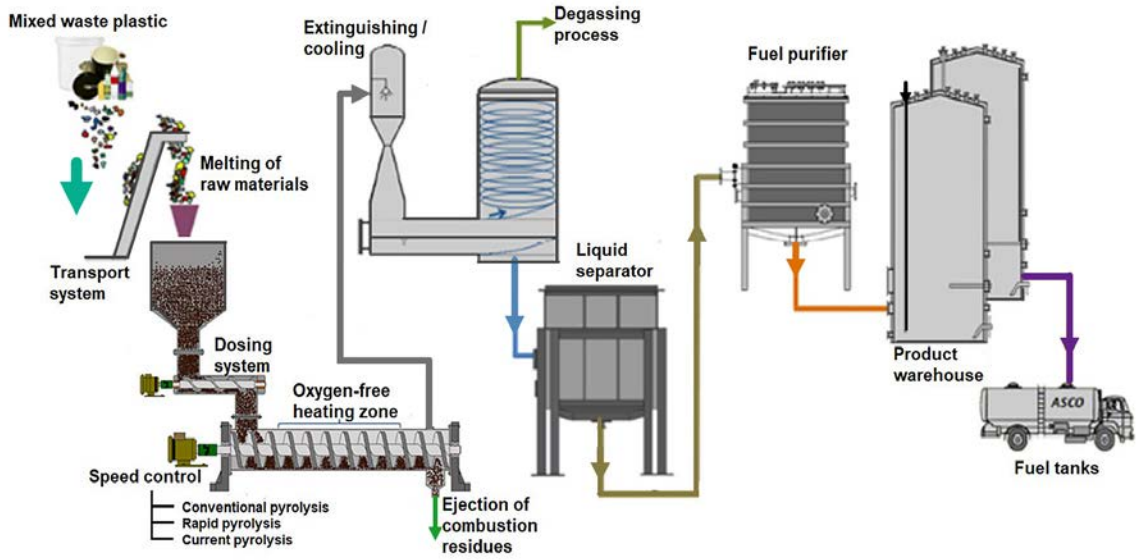


Fig. 2. Schematic representation of a plant for the production of plastic fuels

Injection of plastic in molten or solid form is done by a metering system that regulates the required amount of plastic injected into the reactor. It should be impermeable to ensure exclusion of oxygen supply.

In the reactor, the plastic is heated to a certain temperature at which the pyrolysis process takes place. In pyrolysis with catalyst, a catalyst is added to the reactor. The temperature of the process depends on the properties of the desired fuel and the pyrolysis process, but in most cases the process takes place at 400 °C to 500 °C without the presence of oxygen. The pyrolysis products are gaseous, liquid and solid, and the percentage may vary depending on the temperature and the raw material. At the end of the screw reactor there is an opening for the discharge of the combustion residues and a steam line to the heat exchanger (condenser). The solid product of combustion is soot, which occurs in very small quantities - less than 1% [26].

In the heat exchanger, the steam is cooled, i.e., a condensation process takes place. The condensation products are the gas and liquid phases. The gas is a mixture of the lightest organic substances and often returns to the process of heat generation. These gases are propane, ethane and methane. They make up about 10 to 15 percent of the mass of the processed plastic [25]. These gases burn in a similar manner to natural gas. This is not the combustion of plastic raw materials, but the use of non-condensable gases to reduce the need for external energy.

The liquid phase is a crude liquid fuel and a further distillation phase is always required to obtain a high-quality transportation fuel such as gasoline or diesel.

In order to perform the condensation process well, i.e. to separate all the vapour from the reactor into gas and liquid, several heat exchangers (2-3 pieces) are usually connected in series. After condensation, the resulting liquid is directed to the liquid separator. The fuel collected in the collection chamber is usually impure, with admixtures of wax, grease and other impurities.

The following procedures are performed to remove impurities [27]:

- Gravity separation (liquid separator).
- Filtration (fuel purifier).

The purpose of the liquid separator is to separate fuel by type and remove gross impurities. Colloidal substances can be removed during the filtration process. The filter paper allows molecules to pass that are smaller than its pores. Thus, different sizes of smaller pores result in a purer fuel [27].

To determine the quality and properties of the obtained fuel, various tests are performed in laboratories. The tested properties are: Colour, density, viscosity, heating value, flash point, ash content, time of appearance of the first crystals in the fuel cloud, end point of oil and fuel, gas chromatography and mass spectroscopy, Fourier transform infrared spectroscopy (FTIR test) [27]. From the test, the fuel has a broad spectrum of hydrocarbons from C_7-C_{30}, which is similar to the spectrum of hydrocarbons in diesel. This fuel has worse or better properties than diesel, which are listed in Table 3.

Table 3. Ranking of fuels for commercial use [27]

FUELS	LPG	Petrol	Kerosene	Diesel	Heavy Fuel Oil
HYDROCARBONS	C_3 to C_4	C_4 to C_{12}	C_{12} to C_{15}	C_{12} to C_{24}	C_{12} to C_{70}

Comparison of PP and conventional diesel fuels.

- The color of polypropylene oil is reddish-orange and its density of 711 kg/m^3 is lower than that of diesel and gasoline.
- The fuel is flammable at room temperature, which is 23 °C according to the test.
- The temperature (point) of the appearance of the first crystals in the fuel cloud and the temperature (point) of cessation of oil and fuel are -37.3 °C and -43.8 °C, an indicator of the possible work with this fuel and in extremely cold weather conditions.
- PP fuel has no ash content compared to diesel, which has a content < 0.01.
- The heating value of the fuel is 49163 kJ/kg, which is better than diesel and gasoline, so this fuel can be used in heavy diesel engines [27].

3.1 Impact of fuel from waste plastics on the environment

Pure plastic fuels have low sulfur content compared to conventional fuels. The sulfur content can be less than 10 ppm, while the sulfur content in other fuels ranges from 35 ppm to 50 ppm. A higher cetane value may also mean that synthetic diesel produced by pyrolysis has lower hydrocarbon and CO_2 emissions due to higher fuel efficiency.

Synthetically produced diesel also has higher lubricity, which can reduce wear on engine parts. This may ultimately have an impact on the longer life of engine parts [28].

3.2 Impact of waste plastic fuel production process on the environment

Plastic waste is a major threat to the environment. Apart from the aesthetic damage to the environment caused by disposal in inappropriate places in nature and the long time required for decomposition (about 500 years), the contents of various tanks (e.g. tank oils) can also endanger the environment by polluting watercourses and springs. Water, flora and fauna. In this way, the recycling and production of fuel from plastic waste reduce the impact on the environment.

In the production of fuels in plants, there is no greater way to pollute the environment. During production, soot escapes from the reactor, which is not harmful to the environment. When the steam coming out of the reactor cools, gas and fuel are produced. In most cases, the gas is used to heat the reactor, and if it is a small amount that cannot be used to heat the reactor, it is burned with a flare. When gas is burned, combustion gases are produced, which are not very harmful because it is a very small amount.

The water used to cool the heat exchanger does not come into contact with the gases or fuel, so there is no water pollution. If there is a medium that cools the water from the heat exchanger, it is not released into nature, just like the heated water, but it circulates in a closed process.

3.3 Economic aspects

In conventional methods, to extract the raw material (crude oil), various investigations must be carried out, such as drilling test holes, drilling in the ground or on the seabed, setting up and building a platform. Once the crude oil reaches the platform, it must be transported to the refinery for further processing.

When plastic waste is processed into fuel through pyrolysis, the raw material is first sorted by composition if it is mixed waste. In most cases, sorting facilities are located near the plants. If the plant produces enough waste gas that is not recycled, it heats the reactor, so there is no cost other than the electricity needed to start the pumps and conveyors.

Plastic fuel is still more expensive than conventional fuel, but it is much more environmentally friendly. The price of plastic fuel is expected to decrease over time as process efficiencies increase and the technology for plant construction becomes cheaper. On the other hand, the price of conventional fuel is constantly rising.

The trend of clean technologies and new regulations related to greenhouse gas emissions and the petrochemical industry create great potential for the development of the PTF (plastic fuel) industry. The production technology is developing rapidly and the payback time for the market is generally between two and five years [29]. A growing number of manufacturers in the USA and Europe owe their production to a well-developed waste management infrastructure. However, the current scenario of processing waste into fuels is not as cost-effective as that of conventional fuel production. Most manufacturers have found that the quality of the feedstock has a major impact on the quality of the fuel. In addition, the collected waste is often contaminated with food, organic or other types of chemicals, which increases the production cost [29]. Also, the commercial sustainability of production largely depends on end-user requirements, choice of depolymerization technology, and type of feedstock. Such trends are likely to hinder the growth of the PTF industry. The estimated growth of global industrial production of plastic biofuels until 2026 is more than 2.5% CAGR (Compound Annual Growth Rate) and will increase from $572.7 million in 2019 to $590 million in 2026 [28].

The European PTF market is expected to account for over 45% of the total production. This share is due to the higher presence of plastic-to-fuel conversion plants, which offer high recycling rates and energy recovery from plastic waste. Indirectly, the target is to reduce greenhouse gas emissions by 40% compared to 1990 [29].

4. CONCLUSION

The paper analyzes the problem of fuel production from plastic waste. The fuel produced by the pyrolysis process with a catalyst is better than without the use of a catalyst because it is cleaner and the reactor operates at lower temperatures and less heat is needed to heat the reactor. The obtained fuel can have different properties depending on the composition of the plastic waste.

Advantages:

- Biofuel can have better properties than conventional because if it is produced with quality, it has a higher cetane value and produces less CO_2.
- Biofuel can be used to start heavy diesel engines.
- It has lower fuel density, does not contain ash, and can be used at lower operating temperatures.
- The amount of waste in nature and landfills is decreasing.
- Pyrolysis products can be used in other industries or for independent work (reactor heating).
- Low energy consumption for the plant from external sources (electricity).

Disadvantages:

- Waste separation required.
- Complex technical system, so you need more trained personnel for maintenance.
- Required to build a facility near the landfill to reduce transportation costs.

It can be concluded that this method of fuel production should be used more in underdeveloped countries, which have a big problem with plastic waste, in order to protect the environment of people, plants and animals.

The paper analyzes the amount of plastic waste generated in Croatia that could be used for biofuel production. The amount of plastic waste is large and 213 million liters of fuel per year can be obtained from it.

However, separate waste collection in Croatia is not yet at a high level, which is a prerequisite for economically viable biofuel production.

In the absence of government incentives for this type of biofuel production, it is difficult to expect a large company producing biofuel from plastics to establish itself in Croatia in the short term.

Currently, the global market in the PTF industry is very fragmented and participants do not generate much revenue. High capital requirements, demanding fuel characteristics and lack of government subsidies are some of the main limiting factors for production.

5. LITERATURE

[1] International Energy Outlook 2019, US Energy Information Administration, Office of Energy Analysis, https://www.eia.gov/outlooks/ieo/ 15/08/2020

[2] M. Madhukar, et al. (2014): Conversion of LDPE plastic waste into liquid fuel by a thermal degradation, International Journal of Mechanical and Production Engineering (IJMPE), 2/4, pp.104-107

[3] Utility Report _ waste for 2017, Croatian Environment and Nature Agency, Zagreb, December (2018), 141 p. http://www.haop.hr/sites/default/files/uploads/dokumenti/021_otpad/Izvjesca/komunalni/OTP_I zvje% C5 % A1% C4% 87e% 20o% 20komunalnom% 20otpadu_2017.pdf

[4] Statistical data on the amount of plastic waste in the EU, Norway and Switzerland, https://www.statista.com/statistics/869674/ plastic-packaging-waste-treatment-european-union/ 25/08/2020)

[5] Utility Report _ waste for 2020, Croatian Environment and Nature Agency, Zagreb, October (2021), 154 p. http://www.haop.hr/sites/default/files/uploads/inline-files/OTP_Izvje%C5%A1%C4%87e%20o%20komunalnom%20otpadu%20za%202020.%20godinu_7_10_2021.pdf

[6] L. Dai; N. Zhou; H. Li; Y. Wang; Y. Liu; K. Cobb; Y. Cheng; H. Lei; P. Chen; R. Ruan, Catalytic fast pyrolysis of low density polyethylene into naphtha with high selectivity by dual-catalyst tandem catalysis. Sci. Total Environ. (2021), 771, 144995.

[7] AAP. Susastriawan; Purnomo; A. Sandria, Experimental study of the influence of zeolite size on low-temperature pyrolysis of low-density polyethylene plastic waste. Therm. Sci. Eng. Prog. (2020), 17, 100497.

[8] MA. Hazrat; MG. Rasul; MMK. Khan, A Study on Thermo-Catalytic Degradation for Production of Clean Transport Fuel and Reducing Plastic Wastes, Procedia Engineering, (2015), 105, pp.865-876

[9] BJ. Patil; CS. Raghvendra; NR. Manik, Extraction of Liquid Fuel from Waste, Plastic, International Journal of Engineering Technology Science and Research (IJETSR), 4/8, (2017), pp.1081-1087

[10] N. Phetyim; S. Pivsa-Art, Prototype Co-Pyrolysis of Used Lubricant Oil and Mixed Plastic Waste to Produce a Diesel-Like Fuel, Energies 11,2973, (2018), pp.11

[11] Garib; MM. Alla; IA. Ahmed; BK. Abdall, Conversion of plastic waste to liquid fuel, International Journal of Technical Research and Applications, vol. 2/3, (2014), pp. 29-31

[12] M. Sarker; MM. Rashid, First Simple and Easy Process of Thermal Degrading Municipal Waste Plastics into Fuel Reasearch, IOSR Journal of Engineering (IOSRJE), vol. 2/9, (2012), pp.38-49

[13] A. Machiraju; V. Marinath; K. Charan, Extraction of liquid hydrocarbon fuel from

waste plastics, International Journal of Creative Research Throughts, NTSE041, (2018), pp.202-207

[14] K. Brindhadevi et al. (2022): A study on biofuel produced from cracking of low-density poly ethylenes using thio $_2$ / alsba-15 nanocatalysts, https://www.sciencedirect.com/science/article/abs/pii/S0016236122011516

[15] S. Kumar; AK. Panda; R. Singh, A Review on Tertiary Recycling of High-Density Polyethylene to Fuel. Resource. Conserv. Recycl. (2011), 55, 893–910.

[16] N. Patni, et al. (2013): Alternate Strategies for Conversion of Waste Plastic to Fuels, Hindawi -International Scholarly Research Notices, vol. (2013), pp. 7

[17] S. Papari; H. Bamdad; F. Berruti, Pyrolytic Conversion of Plastic Waste to Value-Added Products and Fuels: A Review, Materials, (2021), 14, 2586. https://doi.org/10.3390/ma14102586

[18] G. Fadillah; I. Fatimah; I. Sahroni; MM. Musawwa; TMI. Mahlia; O. Muraza, Recent Progress in Low-Cost Catalysts for Pyrolysis of Plastic Waste to Fuels. Catalysts, (2021), 11, 837. https://doi.org/10.3390/catal11070837

[19] AK. Panda, Thermo-catalytic degradation of different plastics to drop in liquid fuel using calcium bentonite catalyst. Int. J. Ind. Chem. (2018), 9, 167–176.

[20] S. Budsaereechai; AJ. Hunt; Y. Ngernyen, Catalytic pyrolysis of plastic waste for the production of liquid fuels for engines. RSC Adv. (2019), 9, 5844–5857.

[21] K. Li; J. Lei; G. Yuan; P. Weerachanchai; J.-Y. Wang; J. Zhao; Y. Yang; Fe-, Ti-, Zr - and Al-pillared clays for efficient catalytic pyrolysis of mixed plastics. Chem. Eng. J. (2017), 317, 800–809.

[22] F. Pienkoß; C. Ochoa-Hernández; N. Theyssen; W. Leitner Kaolin, A Natural Low-Cost Material as Catalyst for Isomerization of Glucose to Fructose. Acs Sustain. Chem. Eng. (2018), 6, 8782–8789.

[23] M. Król; Natural vs. Synthetic Zeolites. Crystals, (2020), 10, 622.

[24] K. Akubo; MA. Nahil; PT. Williams, Aromatic fuel oils produced from the pyrolysis-catalysis of polyethylene plastic with metal-impregnated zeolite catalysts. J. Energy Inst. (2019), 92, 195–202.

[25] B. Zhang; Z. Zhong; K. Ding; Z. Song, Production of aromatic hydrocarbons from catalytic co-pyrolysis of biomass and high density polyethylene: Analytical Py –GC / MS study. Fuel, (2015), 139, 622–628.

[26] Kampuzano, F., Brown, R. C., Martínez, J. D. (2019.): Auger reactors for pyrolysis of biomass and wastes, Renewable and Sustainable Energy Reviews, vol. 102, (2019), pp.372-409

[27] A. Aadhik; V. Athmanathan; N. Hari, Synthesis of fuel from waste plastic, Project report in partial fulfillment for the award of the degree BACHELOR OF ENGINEERING, ANNA UNIVERSITY, 2016, 63 pages

[28] M. Terrell, Plastic to Fuel Market Review, Ricardo Energy & Environment, (2017), pp. 21

[29] Plastic To Fuel Market Size and Share, https://www.gminsights.com/industry-analysis/plastics-to-fuel-market

Workpiece oscillations in interrupted turning process

D. Ciboci [a], M. Duspara [a], K. Horvat [b], M. Stoic [a], A. Stoic [a]

[a] University of Slavonski Brod, Trg I.B.Mažuranić 2, 35000 Slavonski Brod, Croatia, dciboci@unisb.hr, mduspara@unisb.hr, mstoic@unisb.hr, astoic@unisb.hr

[b] Strojarska tehnička škola F. Bošnjakovića, Konavoska 2,10000 Zagreb, Croatia, katarina.stoic666@gmail.com

Abstract

The paper analyses the influence of parameters of interrupted turning process on workpiece oscillations. Alteration of undeformed chip cross section area is obtained on OD turning of slotted shaft as a source of impact on cutting tool and workpiece which could lead to deterioration of workpiece surface quality and dynamic process behaviour. The experiments were carried out on Ck 45 steel with conducting 14 oscillation setups. Measurement results are excluded from the time scale video of analogue sensing micrometre obtained during camera process recording. An analysis of the obtained results shows the influence of processing parameters on oscillations.

Keywords: workpiece oscillation, turning, camera recording, cutting parameters.

1. INTRODUCTION

Cutting process with single point tools on lathe encompasses a relatively wide range of applications. Cutting edge is exposed to high mechanical and thermal loads with mostly continuous (uninterrupted) nature. The workpieces with cylindrical geometry and groove over the outer diameter during machining are associated with alternated (interrupted) cutting conditions. Interrupted conditions arise as a result of different cross section area over the work piece. These conditions can be achieved by cutting tool oscillation (in the literature known as a modulation cutting processes) either by workpiece surface irregularities (remained by previous machining process or to ensure some functional demands). Uninterrupted turning brings many of long chips continually and the chips get entangled to the workpiece or tools. Interrupted turning produces chips into small pieces and prevents the appearance of long chips from getting tangled up. Interrupted cutting conditions generate vibrations because of discontinuity (variability) of the loading conditions during chip forming process. Examples of such processing which some easily can find in regular production are the processes with periodic variation of the cross section of the cutting area, interrupt cutting during the processing of the geared/grooved surfaces, the processing of the asymmetrical or eccentrically mounted shaft or the internal processing of the asymmetric hole.

Influence of oscillation (deflection) either the cutting tool either the workpiece on workpiece quality is of great importance for researcher and has been extensively reported in the literature [1]. Even the majority of research reports are focused on cutting tool oscillation and its implications, workpiece oscillation is also of great importance specially in the scope of errors compensation [2].

Obeidat and Raman [3] investigate the measurement location in order to determine the

position were maximal error of workpiece deflection can be determined.

Li and Du make step forward in workpiece error compensation showing that the new method can reduce the workpiece error by as much as 75% (average workpiece error is reduced to 8 μm from 14 μm) [4].

Too much oscillation can lead to chatter appearance and catastrophic failure on the tool and lead to workpiece surface roughness increase [5].

The cutting-induced oscillations plays a dominant role in process setup. It can be estimated in vitro based on selected cutting condition (speed, feed and depth of cut). During the cutting process (estimation in vivo) it can be used the motor currents (main spindle motor current and feed spindle motor current).

Our approach in this paper is to measure the workpiece oscillation in vivo and make a correlation of oscillations with cutting condition.

2. METHODS AND MATERIALS USED FOR RESEARCH

Interrupted cutting conditions have been achieved by OD turning where the cylindrical surface with groove (Figure 1). Ratio of grooved area and area to be cut is about 5%.

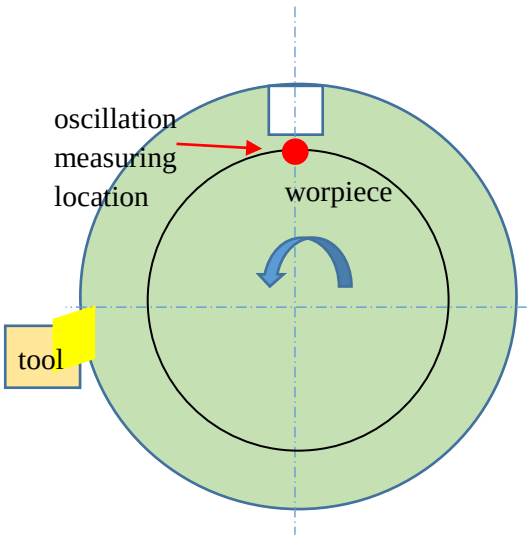


Fig. 1. Workpiece geometry

During the tool/workpiece contact it can be registered workpiece deflection, while tool is passing over the grove deflection is zero (Fig.2). Deflection values were recorded with camera and micrometre watch (Figure 3).

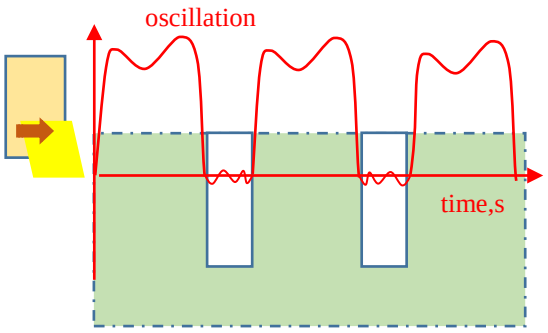


Fig. 2. Workpiece oscillation model

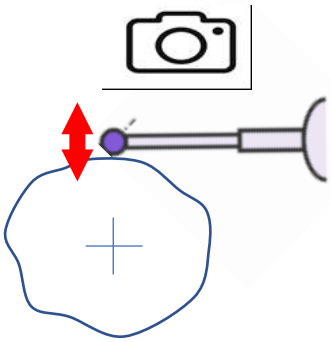


Fig. 3. Oscillation measurement method

The work piece on which the tests were performed is made of the hardening steel Ck 45 with mechanical properties as follows: hardness max 255 HB, strength (Rm) 630-780 N/mm^2, elongation (A_5) min 17%.

The test sample was heat-treated by quenching at 860 °C and annealed at 660 °C. The test sample was a slotted rod of 70 mm in diameter and 150 mm long with a grove of 8 mm wide and 10 mm deep (Figure 4) [6]. Groove had the purpose of obtaining so-called "discrete turning" during machining.

The measurements were performed with the help of an analogue vibrometer, the probe of which was constantly in contact with the test sample during the turning process. Vibration values were read from the measuring scale. When experimentally determining the oscillations/vibrations of the workpiece, we

changed the values of the processing parameters (cutting speed, feed and cutting depth) and then read the results from the measuring scale. Workpiece was machined with different regime setups. Each regime setup influence has been analysed separately as a single measurement. In total 14 measurements were made.

A workpiece was selected as the object on which the oscillation measurements will be carried out. There is a groove on the workpiece that makes an interrupting cut in the turning process and additionally stimulates the vibrations of the workpiece. The technique of analogue measurement of oscillations of the workpiece was used, where a comparator (measuring micrometre watch) was used (Figure 5), and the sampling and measurement of vibrations was carried out by analyzing the video of the comparator, which contains a large number of images per second (30 fps).

The results of two chosen measurements with highest oscillation are additionally analysed with FFT and the results are presented in this paper.

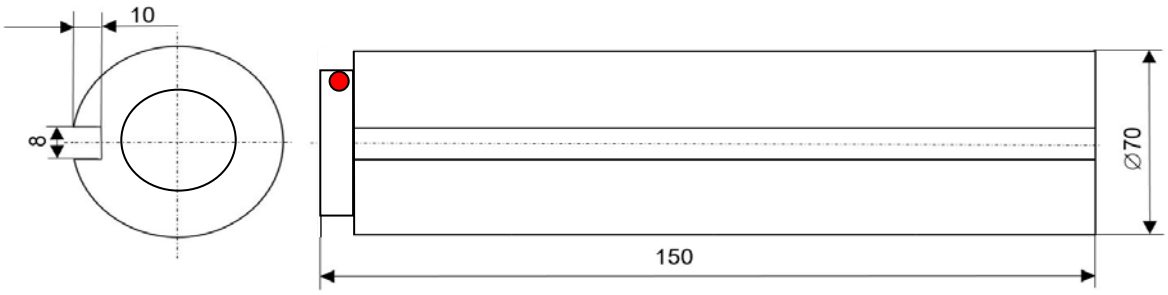


Fig. 4. Test sample geometry

Fig. 5. Measuring setup

3. RESULTS

The results of measurement are given in Table 1 and Figs 6, 7 & 8. Each measurement has been performed 3 times and used oscillation values are the averaged values of measurements. Measurements nr 1 and 8 were performed without loading (cutting condition (a_p=0mm)) in order to validate measurements.

Table 1 Measuring results

Measurement nr.	Spindle speed, *1/min*	Feed per revolution, *mm/s*	Cutting depth, *mm*	Average amplitude of oscillation, *µm*
1.	560	0	0	0
2.	560	0,075	1	1,1
3.	560	0,15	1	2
4.	560	0,3	1	3,9
5.	560	0,075	2	2,5
6.	560	0,15	2	3,7
7.	560	0,3	2	5,3
8.	800	0	0	0
9.	800	0,075	1	1,1
10.	800	0,15	1	2
11.	800	0,3	1	4
12.	800	0,075	2	2,5
13.	800	0,15	2	3,8
14.	800	0,3	2	5,4

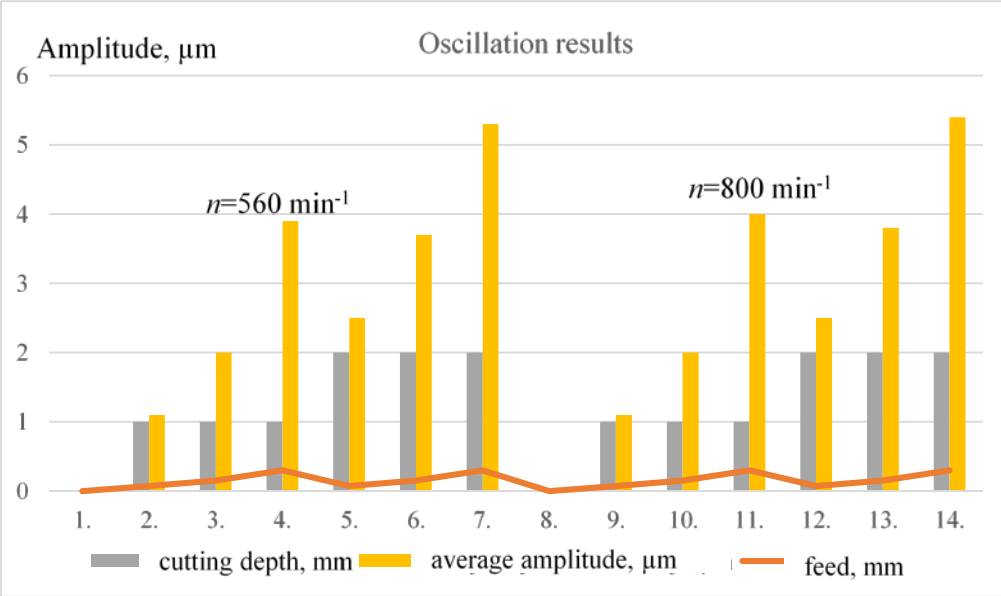


Fig. 6. Graph of measuring results

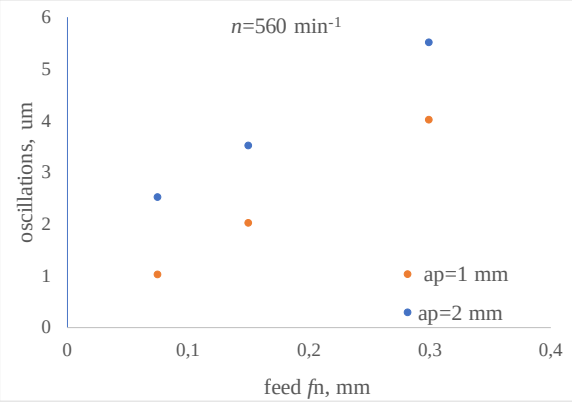


Fig.7. Influence of parameters on oscillations - 1

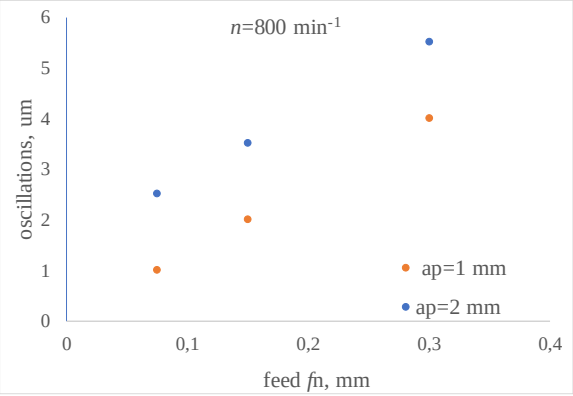


Fig.8. Influence of parameters on oscillations – 2

By increasing the feed (which is doubled for each pass in this example), and the depth of cutting there is a noticeable increase in oscillations amplitude (Fig.7). Very similar dependence can be found for higher spindle speed (Fig.8).

3.1. FFT analysis

FFT analysis (application of fast Fourier transformation) is based on data presented in the time domain as a relationship between time and amplitude and in the frequency domain as a relationship between amplitude and frequency. FFT analysis is carried out using computer algorithms, the results of the analysis give an insight into the correctness of the machine and possible deficiencies (looseness of joints, appearance of cavitation, resonance, imbalance, etc.). This analysis is performed on measurements with highest oscillation amplitude results (test nr.7 &14)

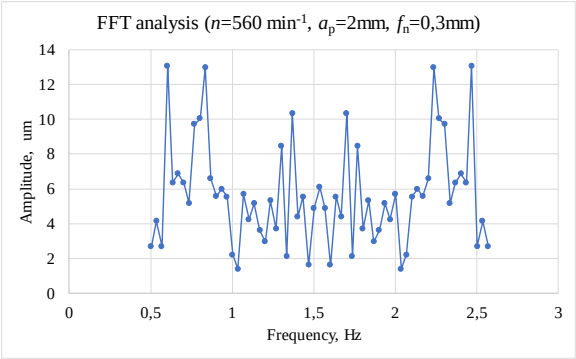


Fig.9. FFT results for measurement nr 7

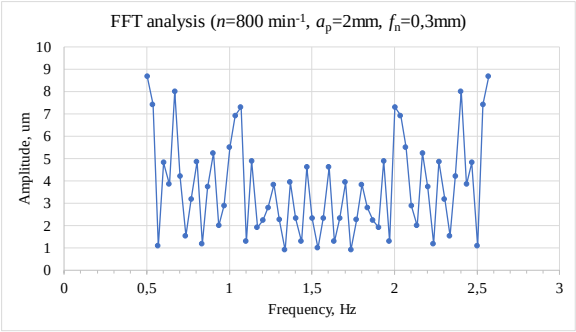


Fig.10. FFT results for measurement nr 14

FFT analysis was performed on 64 measured values of workpiece oscillations (for measurements 7 and 14) and shows higher expected amplitudes of oscillations for lower numbers of revolutions (n=560 min^{-1}) compared to processing with higher numbers of revolutions (n=800 min^{-1}).

The expected value of the largest oscillations of the workpiece should be in the period when the cutting blade passes over the groove made in the workpiece. Considering that there is only one groove on the circumference of the workpiece, the largest oscillations of the workpiece should occur at the frequency f= 13.3 Hz at n=800 min^{-1}= 13.3 s^{-1}, i.e. f = 9.33 Hz at n=560 min^{-1} = 9.33 s^{-1}.

Since the FFT analysis showed that the oscillation amplitudes appear for both measurements in the area of up to approx. 2.5 Hz, it can be concluded that the highest values of workpiece oscillations as a result of variable processing conditions (variable cutting depth due to the existence of grooves on the workpiece) were not recorded. In order to measure these oscillation values, the measurement should be carried out with a much larger number of measurements (larger number of images per second) in order to increase the probability of recording the deflection of the workpiece when the cutting blade passes over the groove.

4. CONCLUSIONS

The analysis of the influence of the turning processing regime on vibrations was carried out through fourteen different regimes. All measured values of vibration amplitudes were below 10 µm.

From the measured values of workpiece oscillations, it was determined that all three elements of the processing mode (cutting depth, feed and cutting speed) affect the value of oscillations (vibrations) of the workpiece. Increasing the feed rate and cutting depth almost linearly affects the increase in vibrations (Figs. 7 and 8), while the influence of increasing the cutting speed on the vibration amplitude is relatively small.

From these data, it follows that the change in the number of revolutions minimally affects the maximum values of oscillations. More detailed conclusions could be established if several hundreds of frames per second were taken. It is also considered that the measurements do not show the absolute value of the actual oscillations that take place during the turning process (rectilinear oscillations in the direction of the force action) due to the position and orientation of the cutting force components and the measurement location (the angle between the load point and the measurement point on the circumference of the workpiece is 90^o). Namely, in the measurement conditions of this experiment, there is a bending load (measured linear oscillations) and a twisting load (which were not measured). By positioning the comparator in a different way, i.e. on the part of the workpiece that is opposite the cutting blade (the angle between the load point and the measurement point on the circumference of the workpiece is 180^o), vibration amplitude values that are closer to the values of total oscillations would be measured.

The conducted frequency analysis (FFT analysis) for the vibrations of the workpiece with the highest amplitude values (the largest feeds and cutting depths) showed that the frequency of vibrations is below 3 Hz, while the expected value of vibrations in the event of a cut interruption should be 9.3 i.e. 13.3 Hz (for n= 560 and 800 min^{-1}). This means that the amplitudes of the vibrations during the interruption of the cut were not recorded by this measurement technique, even though the frequency of taking the image of the comparator was $30s^{-1}$ (more than 2.5 times higher than the expected frequency of the vibrations of the interruption cut). It is considered that a larger number of comparator shots per unit of time (eg more than 300 fps) would surely record this phenomenon and be able to analyze it later.

5. REFERENCES

[1] A. Agarwal, K. A. Desai, Tool and Workpiece Deflection Induced Flatness Errors in Milling of Thin-walled Components, Science Direct Procedia CIRP 53rd CIRP Conference on Manufacturing Systems, pp. 1411-1416, (2020), 10.1016/j.procir.2020.04.101

[2] W Y Yan, A M Al-Jumaily, Workpiece Deflection Compensation Using a Two-Dimensional Toolposts, Proceedings of the Institution of Mechanical Engineers, Part K: Journal of Multi-body Dynamics, 219 (4), (2005), pp. 393-400

[3] S. M. Obeidat, S, Raman, Process-guided coordinate sampling of end-milled flat plates. Int J Adv Manuf Technol, 53(9-12), (2011), pp. 979-991

[4] X. Li, R. Du Analysis and Compensation of Workpiece Errors in Turning, International Journal of Production Research 40(7), (2002), pp. 1647-1667

[5] M. Kiyak, B. Kaner, I. Sahin, B. Aldemir & O. Cakir : The dependence of tool overhang on surface quality and tool wear in the turning process, Int J Adv Manuf Technol 51, (2010), pp. 431–438

[6] Denis Smojvir, Istraživanje efekata promjenljivih uvjeta rezanja u obradi tokarenjem, Završni specijalistički rad, Strojarski fakultet u Slavonskom Brodu, 2018

[7] W.M. Smith Surface Materials Processing. Second Edition, Backmann Verlag, Berlin–London–Paris–Warsaw, (2006).

Computer application in the function of managing student service data

M. Cobović [a], I. Matasović [b], M. Kokanović [c]

[a] University of Slavonski Brod, Ivane Brlić Mažuranić 2, HR-35000, Croatia, mcobovic@unisb.hr

[b] Technical School Slavonski Brod, Eugena Kumičića 55, HR-35000, Croatia, ivan.matasovic1@gmail.com

[c] Technical School Slavonski Brod, Eugena Kumičića 55, HR-35000, Croatia, kokanovic.mato@gmail.com

Abstract

This paper describes a software solution for managing student service data on a high school level. The goal of this solution is to facilitate the work of the student service and reduce paperwork by using database and web technologies. Moreover, the current state of the student service data management is also being analyzed in this paper. Furthermore, a web form has been created through which all information is stored in a database for easier use. Finally, the creation of accounting reports is shown.

Keywords: PHP, web application, student service

1. INTRODUCTION

Keeping a good care of the complete student service documentation sometimes requires a lot of time and effort from employees. In this paper, a software solution is proposed to facilitate the work of the student service of a high school that is a mediator for the employment of minors.

Because we are dealing with employment of minors, special legal provisions apply to them. Underage students may perform jobs only under the previously determined conditions by the Labor Act («NN» br. 93/14.)[1] and Regulation on jobs in which a minor may not be employed («NN» br. 89/15.)[2], Regulation on jobs in which a minor may work and on activities in which he may participate («NN» br. 62/10.)[3] and the Regulation on the performance of activities related to employment («NN» br 28/19.)[4].

Due to the above regulations, it is stated that schools and dormitories may be a mediator for their full-time students for occasional work in the country, and exceptionally for full time students at other high schools located in the same regions/county, based on a written agreement which they are obligated to submit to the ministry of labor. Also, mediation for occasional work of full-time high school students is only allowed during winter, spring, and summer holidays. Furthermore, in order to mediate for the work of an underage full-time student, high school institutions must have the written consent of his/her legal guardian or representative.

The price of an hour of work is determined according to the price list of the intermediary or according to the agreement of the client or executor, provided that the agreed price of the hour of work cannot be lower than the determined price of the hour of the intermediary.

2. ANALYSIS OF THE CURRENT SITUATION OF DATA MANAGEMENT

When developing a specific and new software solution, it is first necessary to get to know the way things are currently working and the needs of the student services.

Student data is collected in a way that students fill out the necessary paperwork through the student services, given that they already know where they will work. It is important to emphasize that in this case school is only an intermediary for issuing contracts and not in job search. Moving forward, the documents that students need to fill out are the student service enrollment form, signed statement from the student and signed consent of the parent that the student can work on the previously founded job. In addition to that, students also must fill out a copy of a contract, sign it in the provided space (both the student and the parent/guardian) and send it by e-mail. After the student sends, via email, all the necessary documents listed in the enrolment form, the school first checks the documents, enrolls the student in the student services, and to the same email, sends him a membership card in the PDF format as well as completed, signed, and certified contract.

From everything mentioned above, it is clear that there is room to create a web application where new users (students) could register and enter all the required data for creating forms and having data saved in the database. Based on the entered user (student) data, the above-mentioned forms would be generated. In addition to new users, the web application could also be accessed by users with administrator privileges for managing user data, for example, accounting often needs payment data.

What is also worth noting when creating a web application is that the website is responsive, is. adapted for mobile devices, especially because the younger generations use mobile devices for everything nowadays.

3. DATABASE DEVELOPMENT

For database development MySQL RDBMS was chosen, which is one of the most well-known database development and management systems. It is also free to use, scalable, and can run on different platforms (Windows, Mac, Linux…)[5]. On top of that, it is relatively easy to link it up with PHP language. The *mysqli* extension and database function are used to link up PHP language to the MySQL database. A lot of focus should be on security, as user's personal data is being handled. When registering, users enter their passwords, so for password protection we can use the built-in PHP function *password_hash()* and use the *CRYPT_BLOWFISH* algorithm to get a compressed password.

Figure 1. Shows a physical database data model containing all the necessary tables and their relationships. When developing a model, it is necessary to know what data is available and what data is important. In continuation, it is necessary to know how the entered data is stored and how is it used later while running the student service.

The main table in the model is the user representing the student who registers via the web form. All links from user to other tables are many-to-one. The "user" table contains all the necessary data for making a student card (student ID) and payment data needed for accounting.

In this specific case, the user (student) can have only one employer as well as work on one type of job and an account in one bank. Due to the relatively short duration of work of the user (around 2 months) mentioned data usually does not change. Even if some change is needed, it is relatively easy to make it.

When physical database data model is done, it is necessary to start creating a web application.

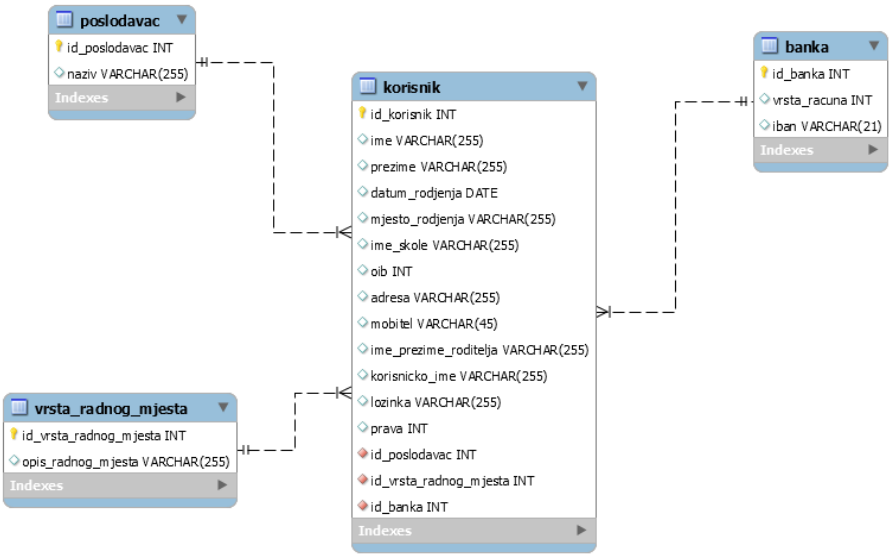


Figure 1. Physical database model

4. WEB APPLICATION DEVELOPMENT

As the internet is available to almost everyone today and most schools have their own Wi-Fi networks, a web application was selected as the solution. The PHP programming language together with HTML, CSS, and JavaScript was used to create the web application. PHP is a dynamic object-oriented programming language that is primarily used to create dynamic web pages [9]. It is also one of the first programming languages implemented directly in HTML. Visual Studio Code was chosen as the integrated development environment. Visual Studio Code has additional extensions installed that make it easier to work with above mentioned web technologies.

The frontend was created using HTML, CSS and JavaScript, while the backend was done in PHP. When creating the frontend, a lot of attention was put into the appearance and responsiveness of the website as well as functionality.

When opening the website, the user has the option of registering or logging in, if he has previously registered (Figure 2. and Figure 3.).

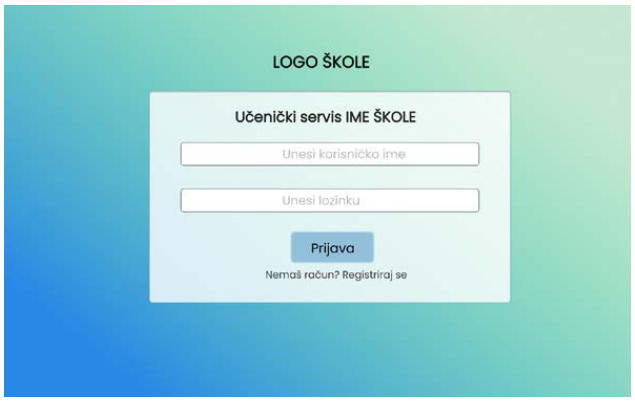


Figure 2. Login to the system

Figure 3. New user registration

During the registration, the user enters their personal information. When entering the data, in PHP, it is necessary to perform code remediation to prevent XSS attacks. After the user successfully registers, he accesses the website and completes the process by entering more work and account information. All this information and data is permanently stored in a database. The data can also be updated if any changes occur. The user also has access to additional documents that still have to be filled out. (Statement, consent, contract) (Figure 4.)

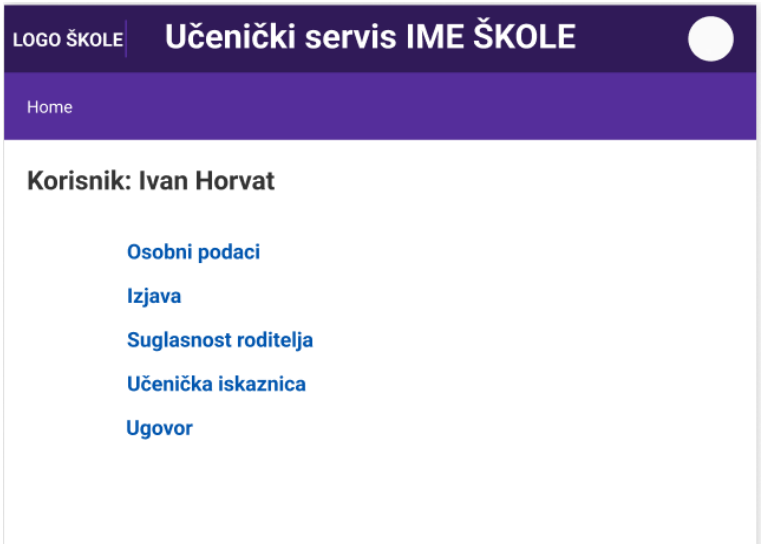


Figure 4. User interface layout

The administrator has an overview of all the data entered by the user and its web interface looks different from other users (Figure 5).

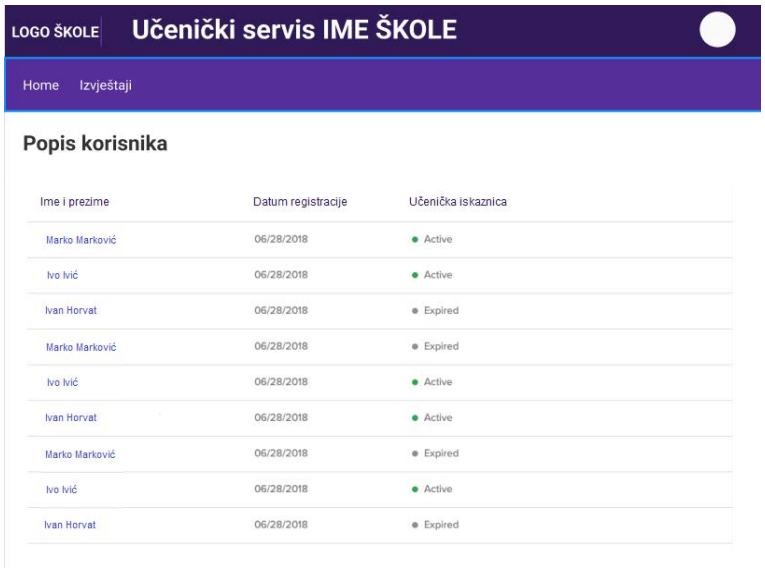
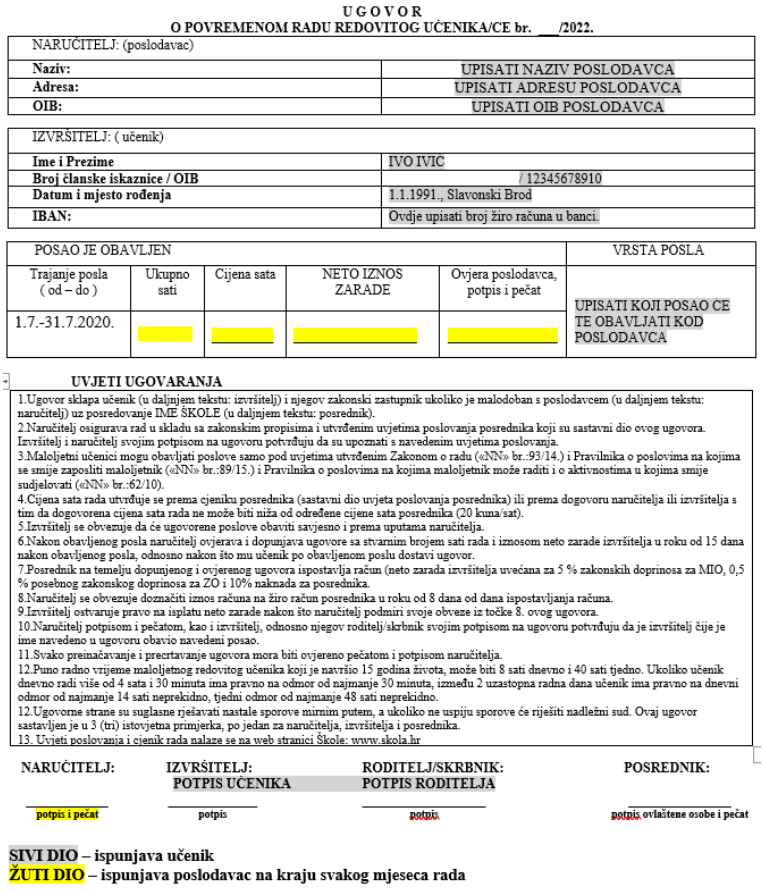


Figure 5. Admin interface layout

After all the data has been checked, the administrator sends a signed student card to the user (Figure 6).

Figure 6. Student card (ID)

After that, a contract is generated that the user can download (Figure 7). The contract already contains information about the user and the employer. The user takes the printed version of the contract to the employer who fills it out and brings it at the end of each month for billing.



UGOVOR
O POVREMENOM RADU REDOVITOG UČENIKA/CE br. ___/2022.

NARUČITELJ: (poslodavac)	
Naziv:	UPISATI NAZIV POSLODAVCA
Adresa:	UPISATI ADRESU POSLODAVCA
OIB:	UPISATI OIB POSLODAVCA

IZVRŠITELJ: (učenik)	
Ime i Prezime	IVO IVIĆ
Broj članske iskaznice / OIB	/ 12345678910
Datum i mjesto rođenja	1.1.1991., Slavonski Brod
IBAN:	Ovdje upisati broj žiro računa u banci.

POSAO JE OBAVLJEN					VRSTA POSLA
Trajanje posla (od – do)	Ukupno sati	Cijena sata	NETO IZNOS ZARADE	Ovjera poslodavca, potpis i pečat	
1.7.-31.7.2020.					UPISATI KOJI POSAO CE TE OBAVLJATI KOD POSLODAVCA

UVJETI UGOVARANJA

1.Ugovor sklapa učenik (u daljnjem tekstu: izvršitelj) i njegov zakonski zastupnik ukoliko je malodoban s poslodavcem (u daljnjem tekstu: naručitelj) uz posredovanje IME ŠKOLE (u daljnjem tekstu: posrednik).
2.Naručitelj osigurava rad u skladu sa zakonskim propisima i utvrđenim uvjetima poslovanja posrednika koji su sastavni dio ovog ugovora. Izvršitelj i naručitelj svojim potpisom na ugovoru potvrđuju da su upoznati s navedenim uvjetima poslovanja.
3.Maloljetni učenici mogu obavljati poslove samo pod uvjetima utvrđenim Zakonom o radu («NN» br.:93/14.) i Pravilnika o poslovima na kojima se smije zaposliti maloljetnik («NN» br.:89/15.) i Pravilnika o poslovima na kojima maloljetnik može raditi i o aktivnostima u kojima smije sudjelovati («NN» br.:62/10).
4.Cijena sata rada utvrđuje se prema cjeniku posrednika (sastavni dio uvjeta poslovanja posrednika) ili prema dogovoru naručitelja ili izvršitelja s tim da dogovorena cijena sata rada ne može biti niža od određene cijene sata posrednika (20 kuna/sat).
5.Izvršitelj se obvezuje da će ugovorene poslove obaviti savjesno i prema uputama naručitelja.
6.Nakon obavljenog posla naručitelj ovjerava i dopunjava ugovore sa stvarnim brojem sati rada i iznosom neto zarade izvršitelja u roku od 15 dana nakon obavljenog posla, odnosno nakon što mu učenik po obavljenom poslu dostavi ugovor.
7.Posrednik na temelju dopunjenog i ovjerenog ugovora ispostavlja račun (neto zarada izvršitelja uvećana za 5 % zakonskih doprinosa za MIO, 0,5 % posebnog zakonskog doprinosa za ZO i 10% naknada za posrednika.
8.Naručitelj se obvezuje doznačiti iznos računa na žiro račun posrednika u roku od 8 dana od dana ispostavljanja računa.
9.Izvršitelj ostvaruje pravo na isplatu neto zarade nakon što naručitelj podmiri svoje obveze iz točke 8. ovog ugovora.
10.Naručitelj potpisom i pečatom, kao i izvršitelj, odnosno njegov roditelj/skrbnik svojim potpisom na ugovoru potvrđuju da je izvršitelj čije je ime navedeno u ugovoru obavio navedeni posao.
11.Svako preinačavanje i precrtavanje ugovora mora biti ovjereno pečatom i potpisom naručitelja.
12.Puno radno vrijeme maloljetnog redovitog učenika koji je navršio 15 godina života, može biti 8 sati dnevno i 40 sati tjedno. Ukoliko učenik dnevno radi više od 4 sata i 30 minuta ima pravno na odmor od najmanje 30 minuta, između 2 uzastopna radna dana učenik ima pravno na dnevni odmor od najmanje 14 sati neprekidno, tjedni odmor od najmanje 48 sati neprekidno.
12.Ugovorne strane su suglasne rješavati nastale sporove mirnim putem, a ukoliko ne uspiju sporove će riješiti nadležni sud. Ovaj ugovor sastavljen je u 3 (tri) istovjetna primjerka, po jedan za naručitelja, izvršitelja i posrednika.
13. Uvjeti poslovanja i cjenik rada nalaze se na web stranici Škole: www.skola.hr

NARUČITELJ:	IZVRŠITELJ:	RODITELJ/SKRBNIK:	POSREDNIK:
	POTPIS UČENIKA	POTPIS RODITELJA	
potpis i pečat	potpis	potpis	potpis ovlaštene osobe i pečat

SIVI DIO – ispunjava učenik
ŽUTI DIO – ispunjava poslodavac na kraju svakog mjeseca rada

Figure 7. Contract example

User data can be exported as an excel file which is needed by accounting for easier calculation. It would be an aggregate data on all users. PHP itself does not have the ability to read and write from this type of file and therefore a library written in PHP called PHPSPREADSHEET was inserted into the project. This library offers a set of classes that allow you to read and write various spreadsheet file formats such as excel and LibreOffice. An example of one such table is shown in Figure 8.

IME ŠKOLE - POPIS KORISNIKA UČENIČKOG SERVISA

id	ime	prezime	datum_rodjenja	ime_skole	oib	poslodavac	vijeme rada	iban
1	Ivo	Ivić	2.6.2006.	TSSB	12345678900	Hlad d.o.o.	1.7.2022 - 31.7.2022.	HR
2	Ivan	Horvat	23.4.2006.	ESSB	12345678900	Hlad d.o.o.	1.7.2022 - 31.7.2022.	HR
3	Marko	Marković	2.7.2006.	TSSB	12345678900	Hlad d.o.o.	1.7.2022 - 31.7.2022.	HR
4	Josip	Josipović	3.4.2006.	IOSSB	12345678900	Hlad d.o.o.	1.7.2022 - 31.7.2022.	HR
5	Pero	Perović	21.6.2006.	TSSB	12345678900	Hlad d.o.o.	1.7.2022 - 31.7.2022.	HR

Figure 8. Report example

5. CONCLUSION

The development of information technology has greatly facilitated and simplified the way we work and do business. Information technology penetrates all spheres of economy, science, social and private life, and brings certain changes. Information technology is changing the

ways people live and work as well as the structure and way of doing business.

The aim of this paper was to facilitate and simplify the business and work of the student services through the development of a web application for user data management. Benefits from this application are numerous; users do mostly everything on computers, unnecessary paperwork is reduced, and accounting gets all the necessary information. Also, any changes needed are relatively easy to make.

The next logical step is to gather the experience of users and administrators in the work and responsiveness of the application and the possible modification and expansion of the software solution.

6. REFERENCE

[1] Labor Law, https://narodne-novine.nn.hr/clanci/sluzbeni/2014_07_93_1872.html, last access 10/6/2022

[2] Rulebook on jobs in which minors may not be employed, https://narodne-novine.nn.hr/clanci/sluzbeni/2015_08_89_1742.html, last access 10/6/2022

[3] Rulebook on jobs in which minors can work and on activities in which they can participate, https://narodne-novine.nn.hr/clanci/sluzbeni/2010_05_62_1979.html, last access 10/6/2022

[4] Rulebook on the performance of activities related to employment, https://narodne-novine.nn.hr/clanci/sluzbeni/2019_03_28_591.html, last access 10/6/2022

[5] R. Nixon (2018). Learning PHP, MySQL, JavaScript, CSS & HTML5, 5th edition, O'reilly, 2018.

[6] Stack Overflow, PHP Notes for Professionals, Creative Commons BY-SA, 2018.

[7] Stack Overflow, MySQL Notes for Professionals, Creative Commons BY-SA, 2018.

[8] R. Manger (2014). Database, Element Zagreb

[9] Tatroe, K., & MacIntyre, P. (2020). Programming PHP: Creating dynamic web pages. O'Reilly Media.

Monitoring performance of the database management system in the health institution

M. Cobović[a], Z. Janeš[b], D., M. Bašić[c], D. Nadih[d]

[a] University of Slavonski Brod, Ivane Brlić Mažuranić 2, HR-35000 Slavonski Brod, Croatia, mcobovic@unisb.hr

[b] General Hospital "Dr. Josip Benčević" Slavonski Brod, Andrije Štampara 42, HR-35000 Slavonski Brod, Croatia, Zdravko.janes@gmail.com

[c] Croatian Health Insurance Fund, Tome Skalice 4, HR-35000 Slavonski Brod, Croatia, Marijan.baso@gmail.com

[d] Elementary School "Antun Mihanović", Mihanovićeva 35, HR-35000 Slavonski Brod, Croatia, dinko.nadih@gmail.com

Abstract

Healthcare information systems (IS) collect, analyse and process a large amount of diverse data, which enables healthcare professionals to make faster, easier and more efficient decisions related to the treatment and care of patients. Each data or part of the data collected during treatment is stored in one of the many databases that exist in one health information system. Efficient and fast data exchange has a great importance in the daily work of health professionals. Therefore, ensuring the availability and efficiency of databases is one of the main tasks of IT staff. Database administrators (DBAs) need to be aware of the causes and symptoms of reduced server performance and the database itself in order to minimize their impact on IS performance in a timely manner. IT staff monitors, analyses and optimizes the operation of individual databases on a daily basis through a database management system (DBMS). Monitoring the performance, general condition (health) and use of the database is crucial for maintaining optimal database operation and enables timely action with the aim of adjusting performance and other system parameters. By using the Windows Performance Monitor to collect specific performance counters, we can quickly learn about server performance degradation caused by insufficient hardware resources.

Keywords: performance, databases management, health institution.

1. INTRODUCTION

The rapid growth of the use of technology in the health sector, consequently generates large amount of data, which creates the need for their further structuring and comparison of information for easier and faster decision-making. To make the data always available to users, they are stored in databases. The most common definition of database is a collection of data arranged in accordance with its intended use. It is a storage of information in which logical and physical data are associated with each other.[1]

The healthcare database enables an appropriate system for storing, organizing and managing the information generated in the healthcare information system. Everything a healthcare professional collects from a patient forms a part of a database. Patients datasets and their health records, treatment and care outcomes data, laboratory data, radiological and other diagnostic tests, finance data and much

more should be confidential to the public, but at the same time easily accessible to healthcare professionals who use them during the treatment and care of patients.[2] The whole purpose of the database is to ensure that information is secure, up-to-date when needed to be easily accessible to anyone who may require it during the patient care process. The importance of efficient and timely access to database data must not be neglected because it is crucial that healthcare providers can access the necessary information quickly and without errors. All processes in healthcare, from individual to complex, depend on the accuracy, efficiency, and availability of the database. [2]

A database system includes a set of different hardware and software resources with a large number of configuration parameters that affect and control the performance of database systems.[3] It's recommended to monitor these parameters proactively in order to prevent any potential performance degradation. If the performance degradation happens, the first step towards the resolution is to determine the problem, find out the cause, and resolve the issue.[4]

Every database mechanism exists within the server operating system, so if the operating system does not work well, the database itself will have problems. It is crucial that the operating system has sufficient working memory and processing power that can be allocated to database processes. Therefore, it is important that the database administrator, in addition to the database metrics, monitors the metrics related to the system.

A performance bottleneck occurs when a component in a system is under load above its capacity which further prevents other resources from operating at their full capacity. The most common problems with database performance degradation are usually due to memory problems, I / O subsystems or CPUs. Although it is not easy to determine whether database performance problems are due to a lack of hardware resources or something else, database administrators can first look at common symptoms of database performance congestion: SQL Server hogging the processor, Longer execution times on queries, Excessive I / O, Application log showing out-of-memory messages, Extreme activity on the disks, Long wait times per I / O. [5]

During the preparation of this paper, we established a system for monitoring system performance indicators of a medium-sized hospital database (computer network with about 500 workstations) in order to try to identify potential problems regarding the degradation of its performance by monitoring and analysing the obtained data. The relational database Microsoft SQL Server 2012 installed on a virtual server Microsoft Windows Server 2012 R2 with 2 CPU Sockets with 12 logical virtual processors and 92 GB RAM was used. The SQL Server database engine manages 8 instances with a total size of 500 GB. SQL Server is a relational database server that supports the well-known Structured Query Language (SQL) database language. As a publicly known Database Management System (DBMS), SQL Server has the advantage of being streamlined installation, enhanced performance, lower cost of ownership, and better security features. However, it also has several shortcomings in terms of complex performance tuning, no native support of source control, and expensive cost for the enterprise edition.[6]

To monitor the performance of the SQL Server database, we used the Windows Performance Monitor (PerfMon) software tool built into the Microsoft Windows operating system since its old version 3.51. [7] PerfMon enables monitoring of the performance of various system components in real time, but also the creation of analytical data collections for later analysis. PerfMon utility allows selection of different counters for monitoring server performance which measure specific system activity or state, for example the amount of available physical memory. From Windows Server 2008 version PerfMon allows the creation of data collector sets, which makes

easier the exchange of performance counters sets between stakeholders. With hundreds of standard performance counter sets such as CPU and memory utilization, when SQL Server is installed, an additional collection of monitor counters is added to enable database administrators to monitor the performance and status of SQL Server instances. [8] As is already widely known, computer performance is a measure of his ability to perform the tasks assigned to it and is actually only noticed when it is found to be insufficient. By monitoring these performance counters during a test run, the database administrator can establish which hardware or software resources are causing a possible bottleneck.

2. METHODOLOGY

Database administrators most often use the methodological approach of bottom-up analysis of information obtained by collecting cumulative system indicators from all hardware and software components during database performance monitoring using administrator tools and scripts that are built into the database mechanism by default. Administrators often do not know which specific indicators should be monitored, which are the most important and where they are located. Therefore, they cannot react in a timely manner to the occurrence of database process congestion. Significant problem arises when users complain that the database is slow or even unavailable. We believe that, in order to save time and effort, a better analytical approach would be top-down, where the collected information about the performance of the base is divided into smaller parts until a possible problem is detected. By using this approach, administrators monitor the system while it is running, and the behavior of all its components and resources at different load levels and, in this way, identify critical performance degradation faster and better. Unfortunately, this approach can also be time-consuming and difficult to implement, especially when a significant degradation of the database system performance suddenly occurs during the operation of the database in the production environment. [9]

According to Schwartz, J. A. [9] database administrators would be more efficient in finding problems if they use a combination of both previously mentioned analytical approaches. Therefore, in the continuation of this work, we tried to base ourselves on the collection of the most important metric data of hardware and software resources, which are crucial for the quick identification of the cause of database performance degradation. Windows Performance Monitor has proven to be a practical tool since it enables the simultaneous analysis of several different indicators, but also the possibility of adding and removing individual indicators (metrics) in real time and as needed. It also has the ability to store the collected indicators, which enables their later analysis, as well as the creation of graphic displays that further enable various clearer visual comparisons of the collected data. Windows Performance Monitor enables local as well as remote data collection, so it is possible to monitor multiple servers and their databases from one place.

As we pointed out earlier, there are three basic points where performance degradation usually occurs, and these are memory, I/O subsystem (physical and logical disk) and CPU. In order to establish what is happening with our database, it is necessary to monitor and collect performance metrics over time in order to isolate processes that take up too many resources based on our own knowledge of the usual state of database operations.

Congestion or CPU load is most often the result of insufficient hardware resources, and it is relatively easy to identify this problem by monitoring a few counters:

- % Processor Time,
- SQLServer:General Statistics – User Connections,
- SQLServer:Memory Manager – Memory Grants Pending,

- SQLServer:SQL Statistics – Batch Requests/sec,
- SQLServer:SQL Statistics – Compilations/sec,
- SQLServer:SQL Statistics – Recompilations/sec,
- System – Processor Queue Length

Memory counter - Available Mbytes is the amount of physical memory that is available for allocation to a process or for system use. Low amount of available memory might indicate external memory pressure. SQLServer:Memory Manager - Total Server Memory (KB) and SQLServer:Memory Manager - Target Server Memory (KB) show ideal amount of memory the server is willing to consume or total amount of dynamic memory the server is currently consuming. Both counters should be approximately 1.[11]

Another counter to monitor is Memory - Pages/sec which shows the rate at which the pages are written from disk to RAM and read from RAM to disk. The values higher than 50 show intensive memory activity and possible overhead and memory pressure that can lead to SQL Server performance degradation. SQLServer:Buffer Manager - Checkpoint pages/sec and SQLServer:Buffer Manager - Lazy writes/sec indicate whether dirty pages are flushed to disk too often. Dirty pages are automatically flushed to disk at a checkpoint. If the available free space in the buffer cache between two checkpoints is low, a lazy write will occur to flush the pages from buffer to disk and free up memory. The Lazy Writes/sec value should be below 20.[4]

I/O subsystem related bottlenecks are caused by excessive reading and writing of database pages from and onto disk which is than manifested through long response time, application slowdowns and tasks time-outs. So SQL Server database engine might not get enough disk resources for its normal operation and would have to wait to be able to read and write to disk. The most important I/O subsystem counters related to database process are:

- Physical Disk: Avg. Disk Queue Length
- Physical Disk: Avg. Disk Sec/Read
- Physical Disk: Avg. Disk Sec/Write
- Physical Disk: %Disk Time
- Physical Disk: Disk Reads/Sec
- Physical Disk: Disk Writes/Sec

The PhysicalDisk Object: Avg. Disk Queue Length counter shows you the average number of read and write requests that were queued on the selected physical or logical disk. The higher the number the more disk operations are waiting. It requires attention if this value frequently exceeds a value of 2 during peak usage of SQL Server. If you have multiple drives you should take this number and divide by the number of drives in the array to see if the number is above 2.[12] Aug. Disk Sec/Read and Avg. Disk Sec/Write counters show the average time required to read data from the disk and the average time to write data to the disk. An average time of up to 8 ms is considered excellent, while anything over 20 ms indicates a major problem regarding the performance of the I/O subsystems. The values of this counter do not depend on the number of disks, known as spindles, behind the physical drive.[17] According to Newton T., the slow response time indicates that the disks trying to process the operation are too busy to respond immediately.[18] This counter should have a high priority, especially when the number of disks behind the physical disk unit is unknown, for example when using a virtual server.

Physical Disk: %Disk Time is the ratio of elapsed time when the disk drive was busy with read or write requests. This counter should be less than 50%. The counters Disk Reads/Sec and Disk Writes/Sec show the ratio between read and write operations on the disk. It is important that this ratio is less than 85% of the disk capacity, otherwise the disk access time increases exponentially.

It is important to point out that, when measuring I/O performance, attention should be paid to the fact that each production server has physical disks arranged in RAID arrays for redundancy and data security, which means that

data is simultaneously written to several disks. Therefore, when monitoring the Disk Read/Sec and Disk Write/Sec counters, this calculation should be taken into account: [13]

Raid 0: I/Os per disk = (reads + writes) / number of disks
Raid 1: I/Os per disk = [reads + (writes*2)] / 2
Raid 5: I/Os per disk = [reads + (writes*4)] / number of disks
Raid 10: I/Os per disk = [reads + (writes*2)] / number of disks
For example the disks on the database server are stacked in a RAID 10 array so the I/O calculation would be:
Disk Reads/sec = 100, Disk Writes/sec = 85
RAID-10 I/Os per disk = [reads + (writes*2)] / 2 or [100 + (85*2)] / 2 = 120 I/Os per disk.

According to Windows Performance documentation, suggested measurement interval is 15 seconds for the typical test run length between 1 and 8 hours.[7] We set the duration of the data collection process to 3 hours with a measurement interval of 15 seconds. We performed 3 test runs at different times of the day:

- during peak business activity between 7 and 12 in the morning,
- during the late afternoon when business activity is significantly lower,
- after midnight when there are almost no registered users and the database is used by various backup and analytical automated scripts.

The use of the PerfMon tool is known to every system and database administrator and is well documented, so due to the length of this paper there is no need to analyse every step during the creation of the measurement procedure. As we said earlier, 3 Data Collector Sets were created (for each individual hardware component – memory, CPU and I/O subsystem) with defined performance counters, measurement interval of 15 seconds and PerfMon log file in binary format (Figure 1). The log format of the output file can also be set as a Text File (Comma delimited), which facilitates import into Microsoft Excel for possible further detailed processing of the collected data. In this article, we chose the binary format of the Log file in order to analyse the measurement results using the Performance Analysis of Log (PAL) tool developed by Clint Huffman. PAL enables the creation of overviews that can be analysed more easily and quickly (Figure 2). [14,15] Another reason for using the PAL tool is the considerable size of the log files generated by the Performance Monitor utility, which after several hours of measurements contain a respectable amount of data. The PAL tool will read the Performance Monitor log and create a report in HTML form, applying the established counter value thresholds to determine if performance degradation exist.

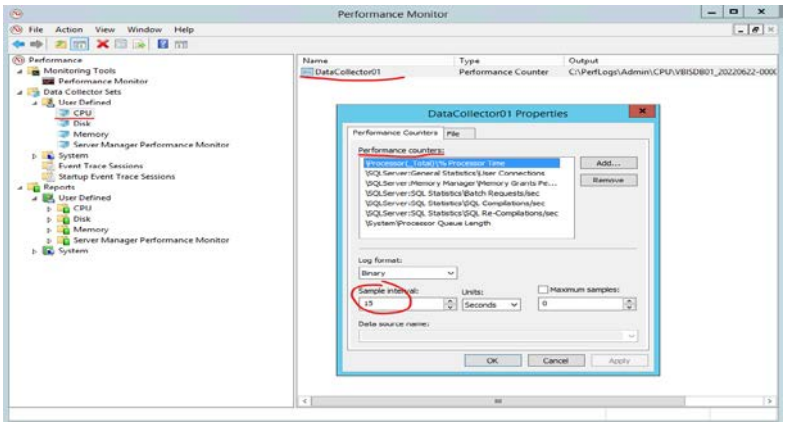


Figure 1. Screenshot of the Windows Performance Monitor Data Collector Set with Performance Counters (Source: Made by author).

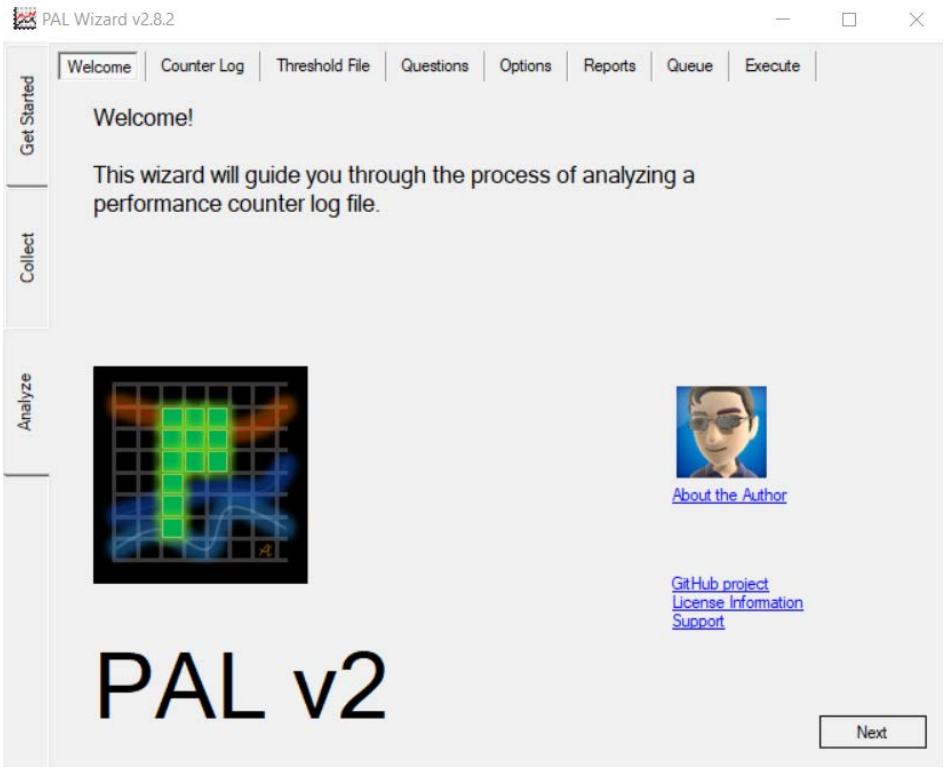


Figure 2. Screenshot of the PAL tool main page [14].

3. RESULTS

The performed measurements resulted in over 30MB of Windows Performance Monitor log data in binary .blg format. As the measurements were carried out in 3 different periods during the day, several log files were created that we needed to combine for easier analysis through the PAL tool. Relog tool which is a command line utility for manipulating PerfMon output files was used to merge several log files into one (Figure 3).

```
# relog MemDataCollector01.blg MemDataCollector02.blg MemDataCollector03.blg -f BIN -o MemData.blg

Input
----------------
File(s):
     MemDataCollector01.blg (Binary)
     MemDataCollector02.blg (Binary)
     MemDataCollector03.blg (Binary)

Begin:    23.6.2022 0:05:01
End:      23.6.2022 18:00:01
Samples:  2163

100.00%

Output
----------------
File:     MemData.blg

Begin:    23.6.2022 0:05:01
End:      23.6.2022 18:00:01
Samples:  2163

The command completed successfully.
```

Figure 3. Screenshot of the relog command line utility when merging multiple log files (Source: Made by author).

The log files created by the Performance Monitor were read with the PAL tool in order to create reports that could be more easily analysed. All threshold values configured in the PAL were lower than or equal to those mentioned earlier in this paper, which guarantees that the readings to be considered will be highlighted in the report. Figure 4 shows the execution of scripts that analyse and consolidate data obtained from Windows Performance Monitor (Figure 4).

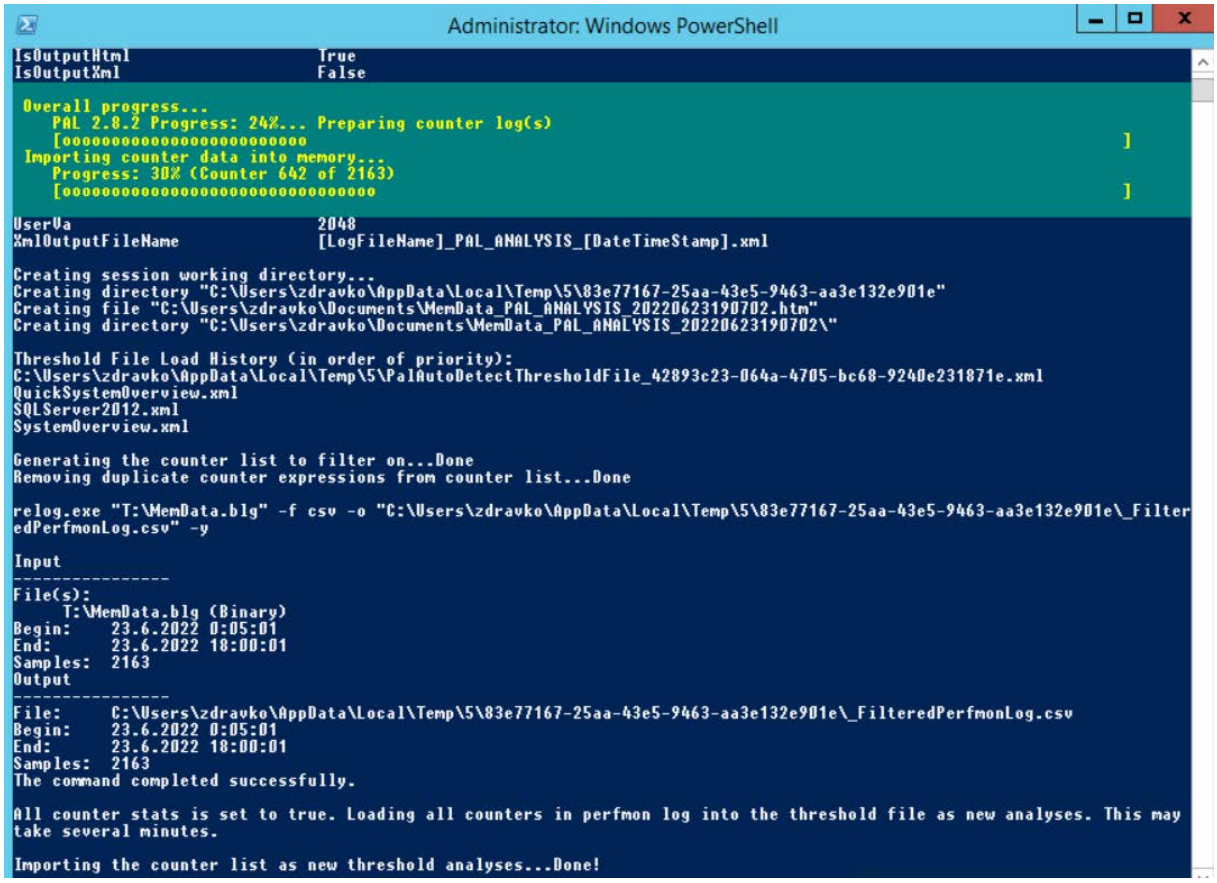


Figure 4. Screenshot of executing PAL scripts during the creation of reports.

Given that a significant amount of data was collected it is not practical to show all indicators especially as most were within normal limits. We will focus on just a few counters whose values indicate performance degradation issues.

The figure below shows the PAL reports of CPU-related performance counters where we see that despite the individual high values for the % Processor Time counter, other counters give no reason to suspect CPU performance degradation (Figure 5). It is common for SQL Server database process to reach high CPU values during data processing because random peaks of CPU activity is common in Windows, as can be seen in the figure below (Figure 6).

Condition	\Processor(*)\% Processor Time	Min	Avg	Max	Hourly Trend	Std Deviation	10% of Outliers Removed	20% of Outliers Removed	30% of Outliers Removed
More than 80% processor utilization	VBISDB01/_Total	1	14	84	0	13	10	9	7

Condition	\SQLServer:General Statistics\User Connections	Min	Avg	Max	Hourly Trend	Std Deviation	10% of Outliers Removed	20% of Outliers Removed	30% of Outliers Removed
An increasing trend of greater than 10 user connections per hour	VBISDB01	31	372	1.050	14	297	307	248	204

Condition	\SQLServer:Memory Manager\Memory Grants Pending	Min	Avg	Max	Hourly Trend	Std Deviation	10% of Outliers Removed	20% of Outliers Removed	30% of Outliers Removed
OK	VBISDB01	0	0	0	0	0	0	0	0

Condition	\SQLServer:SQL Statistics\Batch Requests/sec	Min	Avg	Max	Hourly Trend	Std Deviation	10% of Outliers Removed	20% of Outliers Removed	30% of Outliers Removed
OK	VBISDB01	2	118	685	1	105	93	79	66

Condition	\SQLServer:SQL Statistics\SQL Compilations/sec	Min	Avg	Max	Hourly Trend	Std Deviation	10% of Outliers Removed	20% of Outliers Removed	30% of Outliers Removed
OK	VBISDB01	1	56	289	1	50	44	37	30

Condition	\SQLServer:SQL Statistics\SQL Re-Compilations/sec	Min	Avg	Max	Hourly Trend	Std Deviation	10% of Outliers Removed	20% of Outliers Removed	30% of Outliers Removed
OK	VBISDB01	0	1	39	0	4	0	0	0

Figure 5. Conclusion reports for CPU performance counters

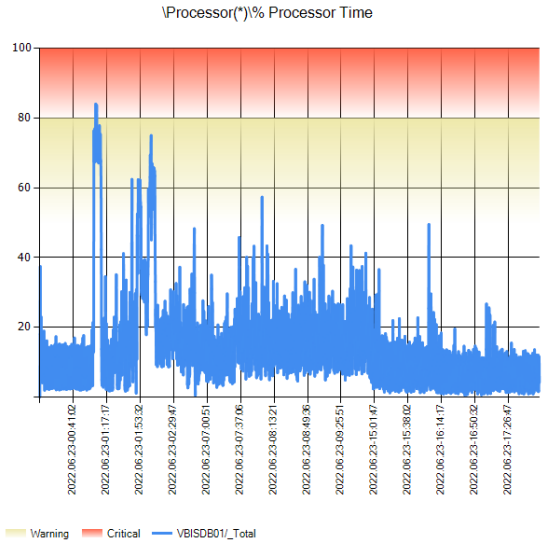


Figure 6. Graphical report of % Processor Time performance counter

The figure below shows the PAL reports of memory performance counter Available Mbytes which represent the amount of physical RAM, in megabytes, immediately available for allocation to a process or for system use (Figure 7). If this counter is low, that is an indication that the operating system may start lacking memory. Windows may be paging out your application to disk in order to keep some free space for the OS. Also memory problems can trigger disk problems. If a database process doesn't have enough memory, then disk activity may be artificially high on the page file drive. Other measurements related to memory resources showed results within normal limits, so we will not mention them separately.

Overall Counter Instance Statistics

Condition	\Memory\Available MBytes	Min	Avg	Max	Hourly Trend	Std Deviation	10% of Outliers Removed	20% of Outliers Removed	30% of Outliers Removed
Less than 5 percent of RAM is available or less than 64 MB of RAM is available	VBISDB01	742	1.170	1.823	20	225	1.126	1.089	1.051

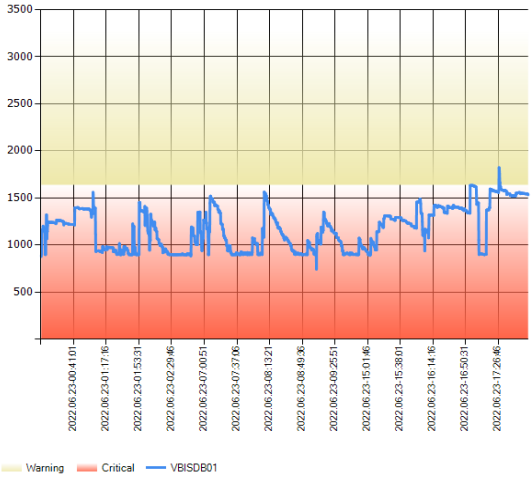


Figure 7. Report for the Memory – Available Bytes Performance Counter

Below in Figure 8, the physical drive used by the database (VBISDB01/5 G:) is either very overloaded, because the average queue length on a disk is as high as 279, or that logical drive actually consists of more than one physical disk (Figure 8). As it is a virtual server, the amount of physical disks is unknown, which makes this performance counter practically useless. However, performance counters that measure disk response time are still useful, as overloading of the physical components of the hard disk would show through increased response time, regardless of the number of physical disks within the logical disk unit.

Overall Counter Instance Statistics

Condition	\PhysicalDisk(*)\Avg. Disk Queue Length	Min	Avg	Max	Hourly Trend	Std Deviation	10% of Outliers Removed	20% of Outliers Removed	30% of Outliers Removed
More than 2 I/O's are waiting on the physical disk	VBISDB01/3 T:	0	1	357	0	12	0	0	0
More than 2 I/O's are waiting on the physical disk	VBISDB01/2 L:	0	0	46	0	2	0	0	0
More than 2 I/O's are waiting on the physical disk	VBISDB01/5 G:	0	279	61.504	-78	2.033	51	1	0
More than 2 I/O's are waiting on the physical disk	VBISDB01/0 C:	0	0	7	0	0	0	0	0

Figure 8. Report for the PhysicalDisk: Avg. Disk Queue Length counter.

Overall Counter Instance Statistics

Condition	\PhysicalDisk(*)\Avg. Disk sec/Read	Min	Avg	Max	Hourly Trend	Std Deviation	10% of Outliers Removed	20% of Outliers Removed	30% of Outliers Removed
Greater than 25 ms physical disk READ response times	VBISDB01/3 T:	0	,003	,11	0	,01	0	0	0
Greater than 25 ms physical disk READ response times	VBISDB01/2 L:	0	0	,13	0	,004	0	0	0
Greater than 25 ms physical disk READ response times	VBISDB01/5 G:	0	,097	21,14	0	,76	,019	,008	,007
Greater than 25 ms physical disk READ response times	VBISDB01/0 C:	0	,013	,798	0	,043	,002	,001	,001

Figure 9. Report for the PhysicalDisk – Avg. Disk sec/Read Performance Counter

Overall Counter Instance Statistics

Condition	\PhysicalDisk(*)\Avg. Disk sec/Write	Min	Avg	Max	Hourly Trend	Std Deviation	10% of Outliers Removed	20% of Outliers Removed	30% of Outliers Removed
Greater than 25 ms physical disk WRITE response times	VBISDB01/3 T:	0	,01	1,291	0	,061	,002	,001	,001
Greater than 25 ms physical disk WRITE response times	VBISDB01/2 L:	0	,003	,297	0	,011	,001	,001	,001
Greater than 25 ms physical disk WRITE response times	VBISDB01/5 G:	0	,114	23,267	0	,861	,021	,003	,002
Greater than 25 ms physical disk WRITE response times	VBISDB01/0 C:	0	,003	,157	0	,009	,001	,001	,001

Figure 10. Report for the PhysicalDisk – Avg. Disk sec/Write Performance Counter

Figures 9 and 10 below shows the average disk response times for read and write operations during our measurements.

As mentioned earlier, Avg. Disk sec/Read is the average time, in seconds, of reading data on disk and Avg. Disk sec/Write is the average time to write data to disk. If the response times for both counters are greater than 0.025 (25 milliseconds), then the disk subsystem is likely to be overloaded. [17,18]

Our results show that the counters for read latency are within normal limits, except for the disk where the database files are located, where a constant average value of 97 ms of response time should be a cause for alarm, as this significantly exceeds the 25 ms threshold. However, by removing the 10% outliers, we obtain an acceptable, though still elevated, value of 19 ms.

Looking at Figure 11, we see that the highest values for read latency are achieved at night when backup and data consolidation procedures are performed, as well as index adjustment procedures.

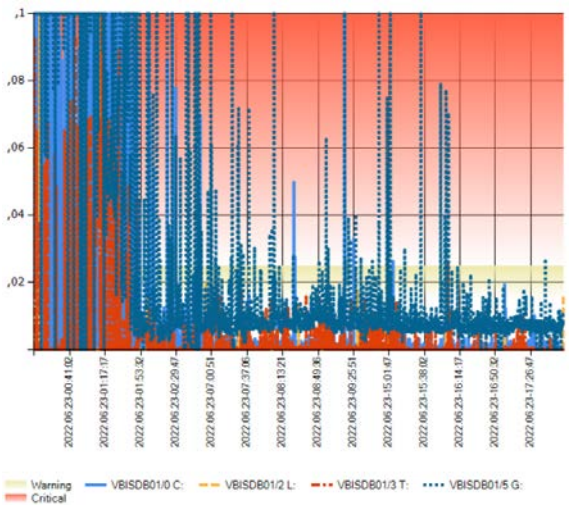


Figure 11. Graphical report of Avg. Disk sec/Read performance counter

On the other hand, the indicators for write latency for the disk (VBISDB01/5 G:) on which the database resides are slightly worse (average value of 114 ms), although even here the removal of 10% outliers gives an acceptable result (< 25 ms). Looking at Figure 12, we notice that the largest writing delays are also achieved at night when various service procedures are active, but there is also the smallest user activity.

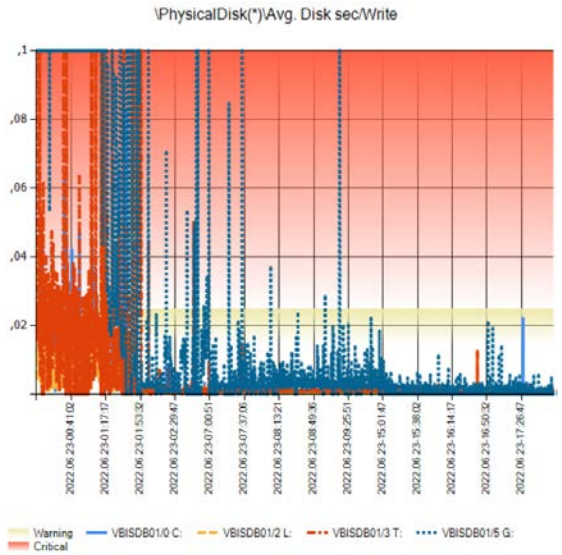


Figure 12. Graphical report of Avg. Disk sec/Write performance counter

Disk latency should be below 15 ms and disk latency above 25 ms can cause noticeable performance issues. Latency above 50 ms is indicative of extremely underperforming storage. [19] These results indicate that the disk drive used by the database (VBISDB01/5 G:) is probably a bottleneck affecting the performance degradation of the database engine.

4. CONCLUSIONS

From our collected data, we can conclude that the traffic coming from clients from application servers and workstations to the database server is very intense, meaning that most operations are condensed into peaks of heavy write operations with long periods of relative inactivity in between. Hard disk performance during these peaks is clearly a bottleneck, with a response time exceeding the 25 ms threshold. There are sequential response lag spikes during the test run that clearly indicate a considerable response lag during periods of high activity.

Finally, this paper is based on the idea of using software available to all to perform tasks related to monitoring the performance of database servers, which is due to the nature of the work under heavy load and its constant availability and functionality is extremely important. Quickly identifying problems with the performance of server hardware components can lead to significant savings in time and operation and ultimately to lower costs caused by downtime.

Regular data collection using Windows Performance Monitor can provide a relatively quick insight into the performance status of database servers and respond promptly to improve them. We have shown that, for the first time, it is sufficient to monitor a few basic performance counters through which a specific problem regarding performance degradation can be easily isolated.

5. REFERENCES

[1] J. Haggerty. Why Are Databases Important in Healthcare? Data Berry. Available from: https://www.databerry.com/news/why-are-databases-important-in-healthcare/ Accessed on 06/06/2022

[2] How Important Are Databases in the Healthcare System? Best Tools to Maintain Performance in a Database. SolarWinds Worldwide LLC. Available from: https://www.dnsstuff.com/how-important-database-healthcare. Accessed on 06/06/2022

[3] A. Khattab, A. Algergawy, A. Sarhan. MAG: A performance evaluation framework for database systems. Knowledge-Based Systems, Volume 85, (2015), Pages 245-255, https://www.sciencedirect.com/science/article/pii/S0950705115001859. Accessed on 07/06/2022.

[4] M. Petrović M, A DBA guide to SQL Server performance troubleshooting – Problems and performance metrics. Quest Software Inc. https://www.sqlshack.com/dba-guide-sql-server-performance-troubleshooting-part-1-problems-performance-metrics/. Accessed on 07/06/2022.

[5] C. Bolton, J. Langford, G. Berry, G. Payne, A. Banerjee, R. Farley, Professional SQL Server 2012 Internals and Troubleshooting. Wiley, Hoboken, New Jersey, USA, (2013)

[6] S. Varga, D. Cherry, J. D'Antoni, Introducing Microsoft SQL Server 2016: mission-critical application, deeper insights, hyperscale cloud, Microsoft Press. London, (2016)

[7] Microsoft Windows Performance Monitor [computer program]. Version 6.3.9600. Redmond, Washington, United States: Microsoft; (2003)

[8] A. Jorgensen, S. Wort, R. LoForte, B. Knight, Professional Microsoft SQL Server 2012 Administration. Wiley, Hoboken, New Jersey, USA, (2012)

[9] J. A. Schwartz, Utilizing performance monitor counters to effectively guide windows and SQL server tuning efforts. Unisys Corporation. Published in Int. CMG Conference (2006)

[10] G. Fritchey, SQL Server 2017 Query Performance Tuning. Apress, Grafton, USA, (2018)

[11] J. Gavin, Windows Performance Monitor Counters for SQL Server. Edgewood Solutions. https://www.mssqltips.com/sqlservertip/6945/windows-performance-monitor-counters-for-sql-server/. Accessed on 10/06/2022

[12] T. Nagy, How to Identify IO Bottlenecks in MS SQL Server. Edgewood Solutions. https://www.mssqltips.com/sqlservertip/2329/how-to-identify-io-bottlenecks-in-ms-sql-server/. Accessed on 10/06/2022

[13] R. L. Sawtell, J. Jorden, L. Mortensen, MCSA/MCSE/MCDBA: SQL Server 2000 Administration Study Guide: Exam 70-228. Sybex, San Francisco, USA, (2003)

[14] Performance Analysis of Logs (PAL) Tool [computer program]. Version 2.8.2. Microsoft, Redmond, Washington, United States, (2011)

[15] Huffman, C. Clint Huffman's Windows [online]. Microsoft, Redmond, Washington, United States, (2013) http://blogs.technet.com/b/clinth/. Accessed on 10/06/2022.

[16] Microsoft Windows Relog Tool [computer program]. Version 6.3.9600.17415. Microsoft, Redmond, Washington, United States, (2009) https://docs.microsoft.com/en-us/previous-versions/windows/it-pro/windows-xp/bb490958(v=technet.10)?redirectedfrom=MSDN. Accessed on 23/06/2022.

[17] C. Huffman, PerfGuide: Analyzing poor disk response times. Microsoft, Redmond, Washington, United States, 2010. http://social.technet.microsoft.com/wiki/contents/articles/perfguide-analyzingpoor-disk-response-times.aspx. Accessed on 23/06/2022

[18] T. Newton, Performance tuning Windows Server 2008 R2. Microsoft, Redmond, Washington, United States, (2010) http://blogs.technet.com/b/askperf/archive/2010/11/05/performance-tuningwindows-

server-2008-r2-p-2.aspx. Accessed on 25/06/2022

[19] M. Grande. Diagnosing Disk Performance Issues. Concurrency, Inc, Brookfield, Wisconsin, United States, (2022) https://www.concurrency.com/blog/september-2019/diagnosing-disk-performance-issues. Accessed on 25/06/2022

XBRL format for business reporting

M. Cobović[a], R. Simić[b], T. Katinić[c], I. Marušić[d]

[a] University of Slavonski Brod, Ivane Brlić Mažuranić 2, HR-35000 Slavonski Brod, Croatia, mcobovic@unisb.hr

[b] University of Slavonski Brod, Ivane Brlić Mažuranić 2, HR-35000 Slavonski Brod, Croatia, ranko.simic@gmail.com

[c] University of Slavonski Brod, Ivane Brlić Mažuranić 2, HR-35000 Slavonski Brod, Croatia, tomislav_01@yahoo.com

[d] University of Slavonski Brod, Ivane Brlić Mažuranić 2, HR-35000 Slavonski Brod, Croatia, marusic.ivan@gmail.com

Abstract

Business reporting is continuously changing – not only by means of report structure, but even more in technical characteristics in favor of standardization and better availability of business reports.

In EU, there is an ongoing introduction of unique electronic format for producing annual financial reports. This article describes participants that are either conducting changes or are referred to by changes - IT technologies, specific terminology and significance used in unique electronic format.

At this moment, changes are applied on small number of relevant business subjects, and article shows dimensions of a group for which there is a realistic expectation of same solutions with added and new taxonomies.

Keywords: financial reporting, ESMA, ESEF, XBRL

1. INTRODUCTION

Business organizations, regardless of their size or form are complex systems that consists of several subsystems. They are building blocks of superior social systems in which they operate with influence from their environment on business organization, and on the opposite side, they are mostly partners to other business organizations from which they buy goods and services, making them their creditors. Business partners can be those from same national economy, and in EU terms, business relations are simple even between partners from different EU members. Every business relation comes with certain risks, but those risks can be reduced by getting to know business partners through financial reports. Making of financial reports is in a domain of reporting subsystem that is usually referred to as accounting. In modern economic environment, the goal of financial reporting is assembly of useful information for investors and business partners [1].

Business organizations, besides influence on economy also make influence on society, environment, social and human rights as well as health of a community in which the business organization operates. Regarding that, organizations are obliged to make non-financial reports that contain data related to those society domains.

Every data is not an information. In order to convert extremely valuable data into an information, it is important, among other things, to make it available to creditors or regulators of

certain areas in some kind of defined structure and defined format which should be open and standardized, if possible.

Business organization reporting is continuously changing under the influence of new technologies and organizational solutions that ensure effectiveness.

Regarding that, in the article are listed actual changes in financial reporting domain in EU member countries, with focus on Republic of Croatia.

2. FINANCIAL REPORT DIGITALIZATION

Process of making and usage of business reports can be presented in a form of value-added chains through groups of processes that don't change for years, as shown in picture 1. Business process execution changes mostly under the influence of business process digitalization that ensure automated relation between business process and accounting function in real time, which reduces costs while at the same time enhances quality of internal and external reporting

Fig 1. Business reporting supply chain.

The influence of telematic changes is seen also in method of submitting and format of financial reports [2].

3. INSTITUTIONAL FRAME OF FINANCIAL REPORTING

Financial report consists of a series of data with time dimension. Data types about overall financial status of business subject and structure of standard financial reports in Republic of Croatia is determined by Financial reporting standards committee according to Accounting law. [3]. Other Committee obligations are also determined by an Accounting law.

Everything else connected to financial report, as submitting media, electronic format, timeframes, etc. are regulated by institution in charge that implements the obligation of reporting by specified regulations. In this way, it is possible, and it happens, that the technical characteristics of financial report are not the same, which implies increased costs of report making for those who are obliged to make reports.

3.1. ESMA

Through the Transparency directive (2013/50/EU) [4] of EU parliament, European Securities and Markets Authority (abbr. ESMA) as an independent EU body, it is in charge of making schemes for regulating technical standards that will specify electronic reporting format that will on one hand facilitate report making, and on the other hand provide availability, analysis and comparability of annual financial reports.

In 2015. to 2019. period, in determined procedure ESMA has made an expected specification called European Single Electronic Format (abbr. ESEF) which should have been implemented since 01.01.2020.

Main purpose of ESMA is to ensure stability of financial structure of European Union by strengthening of investors protection and emphasizing stable and systematic financial market in EU area so that applying of ESEF refers to annual consolidated financial reports of entrepreneurs listed on stock exchange.

4. ESEF SPECIFICATION AND IT TECHNOLOGIES

ESEF Is a technical specification that defines use:

a) EXtensible HyperText Markup Language (abbr. xHTML) reporting

format that ensures report readibility both for computer and human;

b) consolidated financial statements in the annual financial report must be tagged with unique XBRL tags.

4.1. XBRL

XBRL is a language developed for purpose of electronic reporting that is based on its character of open international standard for business reporting. It has origins in XML and uses advantages of technologies related to XML, as XML schema, XLink, XPath and Namespaces.

Development and managing of XBRL is done by XBRL International, consortium that consists of more than 600 partner organizations in more than 50 countries [5].

4.2. XBRL taxonomy

ESEF specifies formats of annual financial report, but also tags used in such reports. Taxonomy is published [6] and maintained through set of xsd and xml files.

XBRL taxonomy can be considered as hierarchical dictionary that describes certain parts of the report, as “net income”, “net profit”, etc. Taxonomy is shown in picture 2. and contains three basic elements:
XBRL specification, XBRL taxonomy and XBRL instance. XBRL specification defines guidelines for preparing XBRL taxonomy. XBRL taxonomy is “marking library” which contains marks that are specific to taxonomy. Third element of XBRL is an electronic report itself, prepared according to XBRL taxonomy and specification.

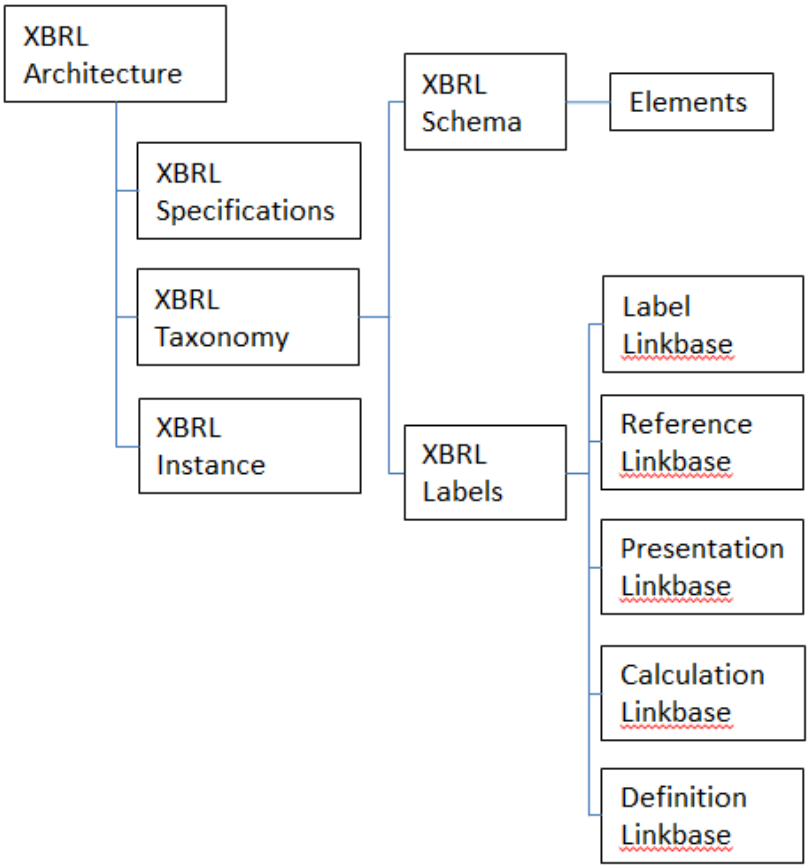


Fig 2. XBRL taxonomy relation according to XBRL specification.

However, XBRL taxonomy is not unique. According to data available on XBRL Consortium web pages [7], it can be seen that different national economies of EU countries

have their own national XBRL taxonomies maintained between XBRL Consortium on one side and governments and business associations on the other side. This taxonomy is superset of necessary elements of superior taxonomy.

4.3. Annual financial report according to ESEF specification

Annual financial report according to ESEF specification is not set of financial reports on paper, xls and/or pdf files on file system, or data entered through web form of institution that collects annual financial reports.

Annual financial report according to ESEF specification is compressed (zip) file that has defined structure of directories and files in those directiories, as shown in picture 3.

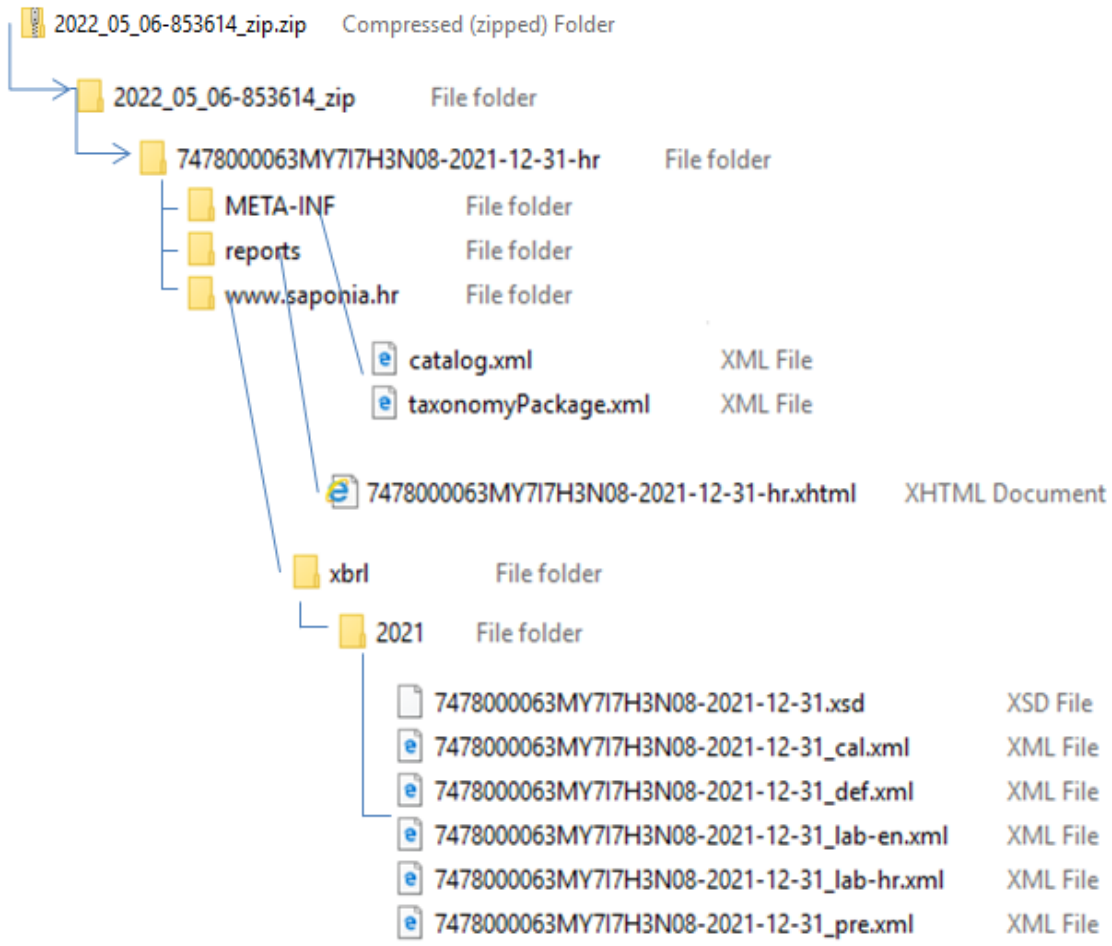


Fig 3. Annual financial report according to ESEF file structure

5. IMPLEMENTATION OF REPORTING ACCORDING TO ESEF SPECIFICATION

After the ESEF specification has been adopted, ESMA has regulated the obligation of applying the specification for all business subjects that are listed on stock exchange, starting from 01.01.2020. which means that reports for 2020. should have been available in 2021. However, considering the outbreak of COVID-19 disease, the application of ESEF specification has been postponed for the next year, so that in this year business subjects affected by this obligation have submitted reports for the first time in the Prescribed information register that is held by Croatian agency for supervision of financial institutions (abbr. HANFA).

Use of ESEF specification presents change in business organization. Most of this change goes to adapting of existing IT systems to ESEF specification. It turned out that during the implementation stage of ESEF specification, business subjects have more options listed below. For implementation of the specification both internal or external resources can be used.

5.1. Application of additional tool

This approach most often does not change existing IT system, but instead develops or gets additional tool that extracts marks and elements from existing report and forms reports according to ESEF specification.

5.2. Addition to existing IT system

In this type of solution, existing IT system is extended namely for functionality of forming annual financial reports according to ESEF specification.

5.3. Built-in support for XBRL in IT system

In this approach, existing IT system is upgraded by support for forming annual financial reports according to ESEF specification, but in this case XBRL is integrated in IT system even on other reports that don't oblige to specification and don't have to be assembled by using XBRL.

6. CONCLUSIONS

Obligatory application of XBRL in financial reports of business subjects that are listed on stock exchange is a novelty in the EU and by extent in Republic of Croatia, although that technology is nothing new for China, USA, Canada, even Spain, Denmark, etc. where XBRL is in use for some time, not only for financial reporting but for much wider purpose.

Observed through absolute numbers, ESEF specification in Republic of Croatia is applied by approx. 200 business subjects listed in stock exchange market. Annual financial reports in Republic of Croatia are disclosed for public for those 200 business subjects but also for additional 130.000 profit tax payers which are potential candidates for XBRL reporting. If we consider other uses for financial reports, like income tax or non-financial reporting, usage area of XBRL is even wider.

ESEF and XBRL specifications are technically much more complex than reporting in xlsx or txt format. Cost of implementation is inevitable and is between 6.000 and 10.000 EUR [8] in one business organization according to the model described in this article in chapter 5.1., but it is to be expected, based on the experience of countries with long tradition of XBRL usage, that the benefits are much larger.

7. REFERENCES

[1] I. Pervan: Financijsko izvješćivanje na internetu i praksa hrvatskih dioničkih društava koja kotiraju na burzama, Financijska teorija i praksa, (2005)

[2] R. Simic, D. Barisic: Financial reports using e-business model, TEAM 2010, Kecskemet, (2010)

[3] Odbor za standarde financijskog izvještavanja, https://www.osfi.hr, last access 29/06/2022

[4] Direktiva o transparentnosti, https://eur-lex.europa.eu/legal-content/HR/ALL/?uri=LEGISSUM:l22022, last access 29/06/2022

[5] XBRL specification, https://specifications.xbrl.org/work-product-index-group-base-spec-base-spec.html, last access 29/06/2022

[6] ESEF XBRL Taxonomy, https://www.esma.europa.eu/document/esef-xbrl-taxonomy-documentation, last access 29/06/2022

[7] XBRL Consortium , https://www.xbrl.org/, last access 29/0XBT6/2022

[8] Tvrtke i tržišta , https://rep.hr/vijesti/tvrtke-i-trzista/kako-je-prosla-prilagodba-dionickih-drustava-na-izvjestavanje-u-esef-formatu/8448/, last access 29/06/2022

Risk Evaluation Methods for Preliminary Risk Analysis of Li-ion Battery Tests

Z.C. Johanyák [a], A. Koncz [b], L.K. Pokorádi [c]

[a] Department of Information Technologies, John von Neumann University, Iszáki út 10, 6000 Kecskemét, Hungary, johanyak.csaba@gamf.uni-neumann.hu

[b] Doctoral School on Safety and Security Sciences, Óbuda University, Népszínház u. 8, 1081 Budapest, Hungary, koncz.annamaria@uni-obuda.hu

[c] Institute of Mechatronics and Vehicle Engineering, Óbuda University, Népszínház u. 8, 1081 Budapest, Hungary, pokoradi.laszlo@bgk.uni-obuda.hu

Abstract

Lithium-ion batteries are widely used in diverse devices, which resulted in a high demand on their testing. Battery tests are potentially hazardous and safety critical as well as technical events can easily occur. Therefore, a fast preliminary risk analysis is essential before carrying out the tests. In this paper, seven potentially applicable methods are presented and analysed.

Keywords: Lithium-ion battery, risk evaluation, battery test, FMEA, TERPN, fuzzy, STABALID, HORA.

1. INTRODUCTION

Nowadays, lithium-ion batteries are inevitable parts of our lives: laptops, handheld tools, electrical devices, and even e-mobility devices: like e-bikes, e-scooters, hybrid and electric cars are equipped with them. The number of applied cells is at least one in case of handheld tools, and it can reach even thousands in case of electric cars.

The demand for lithium-ion batteries is high as their application is widespread in the manufacturing sector. During the COVID 19 pandemic, the need for lithium-ion batteries increased as the shift to home office triggered household handicraft works, and the demand for portable electric devices, such as laptops, etc. In the following years, a shortage of lithium-ion battery supply is forecasted [1][2], due to material shortage because of the excessive time of mining, and exploitation.

The technological and market aspects have a significant impact on battery testing facilities, as the demand for their services is not balanced; there are expansive peaks in workload. This accelerates the battery testing projects that leads to the decrease of preparation times. This way, the test intervals are approaching the technological time needs. Under the given circumstances, testing safety gains more and more importance, as lithium-ion battery tests are potentially hazardous and safety critical.

As battery manufacturers are not necessarily cell manufacturers, there is a relative lack of information about the used cells (only the mandatory information is given on material data sheets and cell certificates). As even cells differ in their material and construction, their safety level is different as well. The situation is even more complicated if contract manufacturers order battery testing services, as they only have high level information about the batteries. From testing perspective, batteries must be considered as ‘black boxes’ due to their mostly unknown differences in material, structure, and

safety options (presence of battery management systems, battery thermal managements systems, etc.)

Therefore, it is essential to have procedures and policies that support the estimation of the risks associated to the tests and can be carried out in a short amount of time. In this paper, we present and analyse six methods that can be applied for this purpose.

The rest of this paper is organized as follows. The risk evaluation methods are presented in Section 2 and the conclusions as well as the analysis of the methods are presented in Section 3.

2. RISK EVALUATION METHODS

2.1. Traditional Failure Mode and Effect Analysis

Failure Mode and Effects Analysis (FMEA) was invented in the 1940's [3][4] and it was standardized by the US military (MIL-P-1629 military standard) in 1943. Later it was used and implemented by the NASA as well. Since the second half of the 20th century FMEA gained importance in design and process analysis as well, and nowadays it is an inevitable part of applied quality assurance/quality management systems.

FMEA focuses on identifying and evaluating failure chains (potential failure – potential effect – cause) and defining actions that can reduce the identified risks. It is an iterative process built up from the following steps.

1. Identification of the building blocks/items of the subject of the analysis (e.g., steps of a process or parts of a product, etc.).
2. Identification of the potential failure modes for each item.
3. Identification of the effects for each failure mode.
4. Identification of the causes of each failure mode.
5. Rating the severity (S) of each effect, the occurrence (O) of each failure mode, and detection (D) of each failure mode (how likely is the failure detected with the current control measures). The three risk factors are rated usually with values from the [0,1] interval based on ranking catalogues.
6. Risk Priority Number (RPN) calculation.

$$RPN = O \cdot S \cdot D \tag{1}$$

7. Definition of preventive and control actions that can reduce the risk. This step is done only for failure chains with *RPN* values greater than a predefined threshold. Failure chains are processed in a descending order of *RPN* values.
8. Reassessing the risks.

2.2. Ványi and Pokorádi's hierarchical FMEA method

Ványi and Pokorádi introduced a hierarchic Failure Mode and Effects Analysis (H-FMEA) approach [5] for risk assessment. Their method is based on the hierarchic structuring of FMEA with the usage of multidisciplinary elements (hardware-software-mechanical aspects). The aim of this model is to provide a general understanding of system modelling with the proposal of specific system elements. At the highest level of analysis, the system elements are taken into consideration, and they are connected to lower-level design elements. The proposed model is based on the automotive R&D approaches and uses special characteristics to define the specific factors with high importance (e.g., safety critical components). The middle-level analysis elements are connected to the hardware and mechanical analysis.

The H-FMEA consists of four different levels (EL: Effect level, SL: System Level, DL: Design Level, CL: Cause Level). When carrying out a hierarchic FMEA the main restriction is that different levels carry the same meaning and severity in the whole analysis. In this case, it means that the failure mode refereed at the hierarchy level is connected with the net

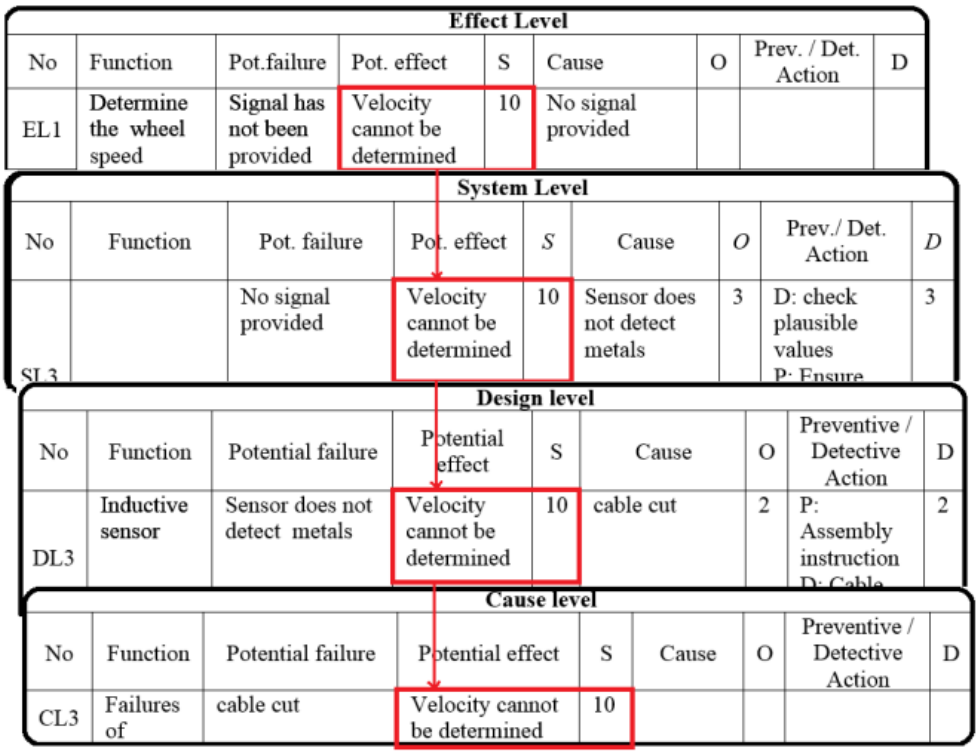


Fig. 1. Top to bottom effect linking in Ványi and Pokorádi's hierarchical FMEA approach

represented by the lower-level failures. (Failure net: failure effect-failure mode-failure cause).

The aim of Ványi and Pokorádi's H-FMEA model is to minimize the risks of a certain product. The novelty of their idea lays in the schematization and the inheritance of risk priority numbers.

The authors use a qualitative analysis method with fault-tree analysis and propose a sensitivity investigation to improve the traditional FMEA approach. For softening of the original FMEA the Action Priority (AP) categories are used during the analysis.

2.3. Di Bona et al.'s Total Risk Priority Number (TERPN) approach

The TERPN approach [6] is a combination of the Safety Improve Risk Assessment (SIRA) method, the Failure Mode, Effect and Criticality Analysis (FMECA) method, and the Association Internationale de la Sècuritè Sociale (AISS) method. Di Bona et al.'s method consists of nine steps:

1. Identification of risk areas (focusing on tasks, machines, products).
2. Identification of risks (related to safety and health of workers, management organizational aspects, product quality).
3. FMECA evaluation for each area of analysis (tasks, machines, products) by determining the probability (P), severity (S), detection (D) values with values from the interval [1,10] as well as risk priority numbers (RPN) related to each failure chain of each area:

$$RPN_{xi} = O_{xi} \cdot S_{xi} \cdot D_{xi}; \quad i = 1 \dots n_x, \qquad (2)$$

where x identifies the area of the analysis (tasks-t, machines-m, products-p), and n_x is the number of failure chains on that area.

4. Determination of an Efficient Risk Priority Number (ERPN) index for each failure chain of each area of analysis.

$$ERPN_{xi} = (RPN_{xi} \cdot P_{xi} \cdot E_{xi}) / C_{xi} \,, \quad (3)$$

where P_{xi}, E_{xi}, and C_{xi} denote the evaluation of the aspects related to the protection, effectiveness of safety strategies, and cost, respectively. Similar to the *O*, *S*, and *D* factors the P_{xi} values are determined by the expert team carrying out the analysis based on recommendations given in form of catalogue tables. For example, P_{xi}=1 if no prevention action is possible, and P_{xi}=10 when a lot of prevention actions are possible. The effectiveness of safety strategies (E_{xi}) is determined by the amount of reduction of accidents as a result of prevention and protection measures. The authors propose a checklist-based scoring technique for the *E* values. The cost factor is also determined using a rating catalogue, which assigns values between 1 and 10 based on the percentage of the total annual budget fixed by the company for safety strategies.

5. Evaluation of the global *TRPN* index $TERPN^*$.

$$TERPN_x = \sum_{i=1}^{n_x} ERPN_{xi} \,, \quad (4)$$

6. Evaluation of the Global *TRPN* index for the whole company

$$TERPN_g = TERPN_t + TERPN_m + TERPN_p \quad (5)$$

7. Identification of the new values taking into consideration the adopted corrective actions.

$$TERPN^*_g = TERPN^*_t + TERPN^*_m + TERPN^*_p \quad (6)$$

8. Calculation of the total of cost of intervention, which should be less than or equal to the actual safety budget.

$$C^*_g = (C^*_t + C^*_m + C^*_p) \leq SafetyBudget \quad (7)$$

9. Identification of the improved risk priority number ($IRPN^*$).

$$IRPN^*_g = (TERPN_g - TERPN^*_g) / TERPN_g \ [\%] \quad (8)$$

Di Bona et al.'s method is an improvement of the traditional FMEA/FMECA methods, as it uses significant number of influencing factors and it is easy to apply and provides accuracy in risk analysis.

2.4. Zlateva et al.'s fuzzy based risk assessment

Zlateva et al. introduced a hierarchical fuzzy logic based approach [7] for risk assessment. Their model was originally developed for the estimation of social risks from natural hazards in Bulgaria. The problem itself is defined as a multi-criterial task and it evaluates several input variables, such as indicators for natural hazards and social vulnerability. Their model contains a fuzzy logic based system that uses five input factors and has one output (Fig. 2).

The input linguistic variables are defined as follows: *Input1* (Extreme temperatures), *Input2* (Floods), *Input3* (Seismic hazard), *Input4* (Population density) and, *Input5* (Socio-economic status). The system uses three intermediate linguistic variables that connect the fuzzy subsystems.

In case of each linguistic variable (except the final output partition) three linguistic terms and related fuzzy membership functions are used (Low, Middle and High). All membership functions of the model are trapezoid shaped (except the final output partition), and their partitions cover the interval [0, 10].

The first level of the model includes one fuzzy logic subsystem, the second level consists of two fuzzy logic subsystems, and the third level includes only one subsystem. The outputs of the subsystems (intermediate language variables) are identified as follows: *Output1* (Climatic risk), *Output2* (Environmental risk), *Output3* (Social vulnerability), *Output4* (Social risk).

The whole system's output is considered as a complex risk value. The final output partition contains five fuzzy linguistic terms: Very low, Low, Middle, High, and Very High. Their membership functions are triangular shaped, and the output (social risk from natural disasters) is evaluated in the interval of [0,100].

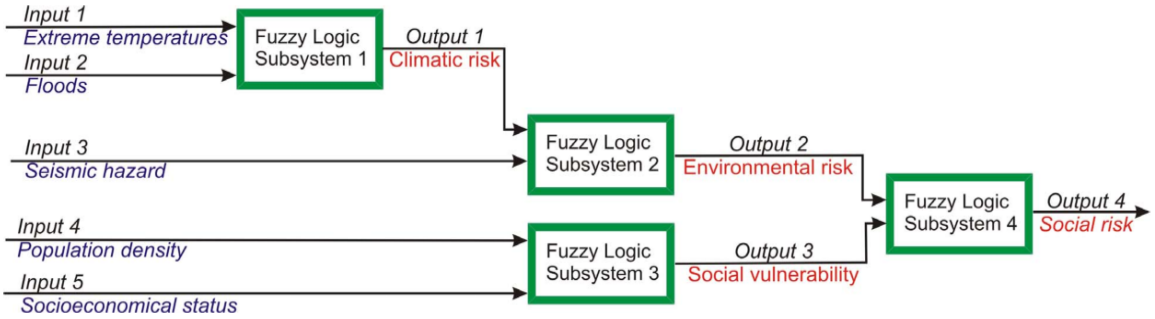


Fig. 2. Three-level hierarchical fuzzy system [7]

The system uses Mamdani type fuzzy inference which is based on only nine rules.

2.5. Multilevel fuzzy approach of risk and disaster management

Takács [8] proposed a methodology for creating a fuzzy inference based hierarchical model for risk evaluation. According to Takács, the risk management model is built up as a hierarchy of risk factors, actions and directions. The methodology is presented using a case study for travel risk-level calculation.

The suggested hierarchical multilevel risk management model follows a top-down approach. First the high-level risk factor groups are identified, like natural disasters and man-made disasters. Next, each of them is unfolded into further subgroups. For example, the man-made events can be grouped into unintended and wilful events. This process continues in a recursive manner until all those elementary factors are identified for which a quantitative evaluation can be given. They will serve as input linguistic variables of the system. For example, in case of geographical disasters the frequency of earthquakes, tsunamis, etc. is the quantitative measure.

Having all the input variables identified fuzzy partitions are defined for them. For example, their linguistic terms can be defined as 'low' (low risk), 'normal' (standard risk), and 'high' (high risk), etc.

Next, a bottom-up process starts where each subgroup-components relation is mapped into a fuzzy subsystem, where the identification of the output partition and linguistic variable is followed by the definition of fuzzy rules describing the connection between input and output. For example, in case of the above-mentioned earthquake case the output linguistic variable is called Natural disasters, the fuzzy subsystem has three inputs, i.e. hydrometeorological disasters, geographical disasters, and biological disasters. The output of this subsystem expresses the risk of the occurrence of a natural disaster. At the top level the last fuzzy subsystem determines the final risk value. All subsystems use Mamdani type fuzzy inference.

The usage of the decision-making system starts with entering crisp evaluation for each input variable. Next, the fuzzy subsystems at the lowest levels are activated and their output is passed on to the upper levels until the final risk is calculated.

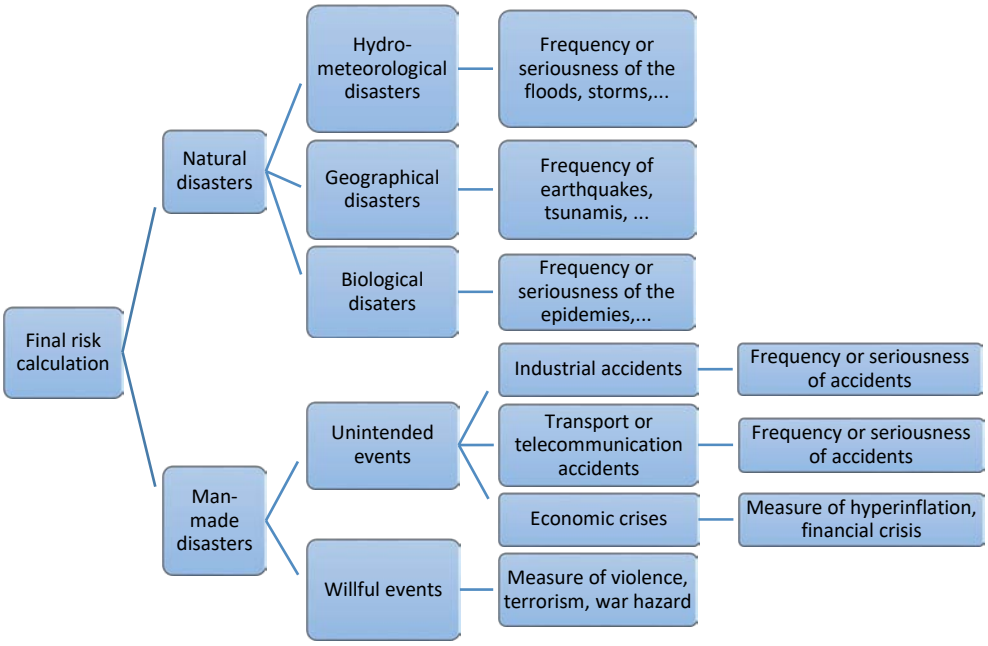


Fig. 3. Hierarchical structure of the risk components

The presented methodology has similar elements to the Fault Tree Analysis (FTA). However, here the connection between groups and their component is not described by and/or type gates like in case of FTA, as well as the probability/risk of the parent event is calculated in a different way using fuzzy rules that ensure a greater flexibility for the system.

2.6. Risk analysis of stationary Li-ion batteries for power system analysis

Soares et al [1] proposed a methodology for risk analysis of stationary Lithium-ion batteries focusing on hazards and dangerous situations. Their approach consists of five steps as follows.

1. Identification of the risks, i.e. carrying out internal problem analysis and an external peril analysis. The authors categorized the potential risks into seven categories: mechanical, chemical, electrical, thermodynamic, radiation, biological, and environmental risks. Their identification was carried out based on human expertise.
2. Identification of the stages (steps) of the analyzed process. Their investigated process was the life cycle of the batteries, which consists of six stages: production, storage, transportation, installation/ decommissioning, operation, and maintenance/inspections. The results were summarized in a table called hazard map. Each main column of the table corresponds to a stage and has two subcolumns one for the internal risks and one for the external risks. The individual risks appear as cells of the respective subcolumn. The heights of the columns (number of cells) can be different since different number of risks are associated to each stage.
3. Risk evaluation, i.e. determination of the probability of occurrence and the severity in case of each risk. The authors defined four probability categories: improbable event ($P \leq 10\text{-}9$/h), remote event ($10\text{-}9 < P \leq 10\text{-}7$/h), occasional event ($10\text{-}7 < P \leq 10\text{-}5$/h) and probable event ($P > 10\text{-}5$/h). In case of the severity four levels were defined: minor severity level (represents slight degradation of battery performance, etc.), major severity level (represents considerable degradation of battery performance, etc.), hazardous severity level (battery is out-of-service), catastrophic severity level (the battery is

out-of-service, major damage on the battery). Finally, three risk levels are defined (acceptable, tolerable, and intolerable). The actual value can be obtained from a table based on the current probability and severity levels. For example, the combination of Probability level 3 and Severity level 2 is evaluated as a tolerable risk level.

4. Definition of the recommended mitigation measures.
5. Risk re-evaluation

The key message of Soares et al.'s model is that batteries, as potential hazardous products have a strong impact on the surrounding environment, but indeed environmental conditions are strongly influencing its risk level.

2.7. Hierarchical Overall Risk Analysis (HORA) Model for the Preliminary Risk Analysis of Lithium-Ion Battery Testing Laboratories

The HORA [9] model has been developed as a preliminary risk analysis method for Lithium-ion testing facilities. It was intended to complement the generally applied fire and safety evaluations, which do not cover all risk aspects of Lithium-ion battery testing. HORA implements a hierarchical approach. It defines three connected levels, i.e. product, process, and system related risks, respectively. The lower-level risks combined with some evaluated factors contribute to the upper-level risks.

Each risk value (product, process, and system) is determined using fuzzy rules and Mamdani type inference. In case of all three fuzzy subsystems the input values are crisp ones, i.e. the output of the lower-level system is defuzzified before being fed as an input to the upper-level fuzzy system.

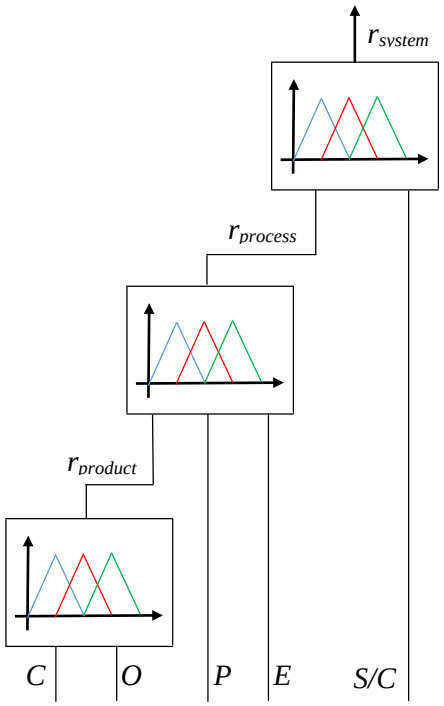


Fig. 4. Hierarchical Overall Risk Analysis (HORA) Model

HORA uses five factors for the determination of the risk level related to a battery test. The factors are Protection (*P*), Controllability (*C*), Occurrence (*O*), Effectiveness (*E*), and a combined one called System/Cost (*S*/*C*). The first factor (*C*) evaluates the controls that are built in the battery itself. The value of the *O* factor is based on the experience related number of events or assumed occurrence of events. The Protection (*P*) factor evaluate the existence of the laboratory safety solutions, while the Effectiveness (*E*) tells how effective the current safety solutions are. The last factor (*S*/*C*) combines three aspects, i.e. laboratory environment related effects due to standardized tests (severity related to laboratory), laboratory personnel related effects (severity related to personnel), and the cost of damages. All factors (*C*, *O*, *P*, *E*, *S*/*C*) are evaluated with numbers from the [1,10] interval based on predefined rating catalogues. The output of the system is a value between 1 and 10 obtained by the last defuzzification.

3. CONCLUSIONS

Although FMEA is a well-established and widely used analysis tool, it suffers from some

shortcomings [3][9] in case of risk evaluation of Lithium-ion battery tests as follows.

1. *Subjectivity* (Applicability issue): as the inputs for analysis (Design FMEA) come from different sources (partners, customers) the level of method understanding is different, even in term of evaluation (Severity, Occurrence, Detection ratings). The differences in ratings cannot be avoided even if using standardized rating catalogues.
2. *Time consuming activity* (Applicability issue): either the inputs are missing, or excessive amount of time is needed to do the linkage of non-standard Design-FMEA (battery related) and Process-FMEA (laboratory related).
3. *Information management issues* (Applicability issue): due to the fact that not all battery manufacturers are cell manufacturers as well, not all technical information is available. For battery level tests the cell level IEC 62133-2 [10] certificate is needed. Unfortunately, not all technical information is available on the certificate sheet (product definition, manufacturer, ratings, type reference, trademark, factory locations are available). Relevant information can be gained from the Material Safety Data Sheets (MSDS) provided from the cell supplier. The electrolyte, anode and cathode material can be identified, but the Bill-of-Materials (BoM) data, or detailed technical specification is not provided, and often there is no information about cell level safety options. Based on this there is high level of uncertainty in case of battery testing, as there is no information available about the battery cells themselves.
4. *Management of complex systems* (Applicability issue): as a battery is considered to be a complex system, in practice it often occurs that the mechanical, electrical and software aspects are handled in different analysis. The merging and providing of this information are insufficient in most cases.
5. *High expenses* (Applicability issue): both from manufacturer and service provider side the involved resources are outstanding, as there are no standardized methods. The time spent on analysis increases the time need of the tests, which influences the project expenses.
6. *Failure mode description* (Cause and effect issue): due to the lack of guidelines, and standardized analysis activities the borders of failure modes and effects are blurred, which results in unclear analysis.
7. *Risk measurement* (risk analysis issue): the lack of specific criteria and common quantification result in non-comparable results in analysis outcomes, although the same laboratory Process FMEA needs to be linked.
8. *Results' reliability* (risk analysis issue): the planned countermeasures for risk reduction are often inconsistent for risk evaluation, and the deadlines of measure implementation are not synchronized in time.

The above presented shortcomings could be alleviated by applying a hierarchical approach, including new factors, as well as by using fuzzy techniques.

Ványi and Pokorádi introduced the hierarchical approach. The novelty of their idea lies in the schematization and the inheritance of risk priority numbers.

Di Bona et al. have defined several new factors in their analysis (*Severity*, *Occurrence*, *Detection*, *Prevention*, *Effectiveness*, and *Cost*). For Lithium-ion battery testing purposes the usage of multiple factors is favourable, as it aids multilevel analysis.

Zlateva et al. created a three-level fuzzy approach for social risk estimation. The input parameters can be divided into ecological (climatic, environmental) and social (social

vulnerability) parameters. These factors can be considered as either system or process related, in contrast to HORA's multilevel (system, product, process level) approach.

Takács suggested the usage of fuzzy Analytical Hierarchy Process (AHP) for the pairwise comparison of objectives, criteria, constraint, and alternatives.

Soares et al. define Risk Mitigation Measures (RMM) in their paper. The implementation of these measures results in new probability (PRMM) and severity (SRMM) levels, as the method is based on continuous improvement. In case of HORA, the application purpose differs, since it is used for decision-making support in case of standardized tests with the preliminary assumption that proper laboratory environment is present (based on existing fire and explosion safety analysis).

The HORA model uses the hierarchical structure of FMEA. The difference between Ványi and Pokorádi's approach and the HORA model lies in the fact that the aim of the later is to provide a laboratory related preliminary analysis, not a product level safety analysis. The usage of Action Priority (AP) categories in Ványi and Pokorádi's approach is similar to HORA's fuzzy approach.

While Di Bona et al. uses Prevention as a related factor, HORA has replaced it with Protection, combined with Effectiveness (related to the second fuzzy subsystem). With the replacement a complex process- level analysis can be provided.

Further research will focus on supporting the risk evaluation process by different machine learning and artificial intelligence techniques [11][12][13][14][15].

4. REFERENCES

[1] Soares, F. J., Carvalho, L., Costa, I. C., Iria, J. P., Bodet, J. M., Jacinto, G., Lecocq, A., Roessner, J., Caillard, B. and Salvi, O., The STABALID project: Risk analysis of stationary Li-ion batteries for power, system applications, Reliablity Engineering and System Safety, no. 140, pp. 142-175, 2015.

[2] A. Lee, After Chip Crisis, Is Battery Shortage Next?, https://www.ttnews.com/articles/after-chip-crisis-battery-shortage-next. [Accessed 19-10-2021]

[3] Spreafico, C., Russo, D. and Rizzi, C., A state-of-the-art review of FMEA/FMECA including patents, Computer Science Review, no. 25, pp. 19-28, 2017.

[4] D. Stamatis, Failure Mode and Effect Analysis: FMEA from Theory to Execution, ASQ Quality Press, 2003.

[5] G. Ványi and L. Pokorádi, Sensitivity analysis of FMEA as possible ranking method in risk prioritization, Polytechnical University of Bucharest. Scientific Bulletin. Series D: Mechanical Engineering 80:(3) vol. 80, no. 3, pp. 165-176, 2018.

[6] Di Bona, G., Silvestri, A., Forcina, A. and Petrilla, A., Total efficient risk priority number (TERPN): a new method for risk assessment, Journal of Risk Research, vol. 21, no. 11, pp. 1384-1408, 2018.

[7] Zlateva, P. V., Pashova, L., Stoyanov, K. and Velev, D., Social Risk Assessment from Natural Hazards Using Fuzzy Logic, International Journal of Social Science and Humanity, vol. 1, no. 3, pp. 109-113, 2011.

[8] J. Takács, Multilevel fuzzy approach to the risk and disaster management, Acta Polytechnica Hungarica, vol. 7, no. 4, pp. 91-102, 2010.

[9] Koncz, A., Johanyák, Z.C., Pokorádi, L.: Hierarchical Overall Risk Analysis (HORA) Model for the Preliminary Risk Analysis of Lithium-Ion Battery Testing Laboratories, Proceedings of the Romanian Academy – Series A: Mathematics, Physics, Technical Sciences, Information Science, 23:1, pp. 89-97.

[10] IEC 62133-2:2017+AMD1:2021: Secondary cells and batteries containing

alkaline or other non acid electrolytes - Safety requirements for portable sealed secondary lithium cells, and for batteries made from them(...)Part 2, Commission Electrotechnique Internationale, 2021.

[11] I. A. Zamfirache, R.-E. Precup, R.-C. Roman, and E. M. Petriu, Reinforcement learning-based control using Q-learning and gravitational search algorithm with experimental validation on a nonlinear servo system, Information Sciences, vol. 583, pp. 99-120, Jan. 2022

[12] S. Blažič, D. Dovžan, I. Škrjanc, Cloud-based identification of an evolving system with supervisory mechanisms, 2014 IEEE International Symposium on Intelligent Control, ISIC 2014, Antibes, France, art. no. 6967642, pp. 1906-1911, 2014.

[13] J. Vascak, P. Kovacik, K. Hirota, and P. Sincak, "Performance-based adaptive fuzzy control of aircrafts," Proceedings of 10th IEEE International Conference on Fuzzy Systems, Melbourne, Victoria, Australia, 2001, pp. 761-764 vol.3

[14] Piller I., Vincze D., Kovács Sz.: Declarative Language for Behaviour Description. In Emergent Trends in Robotics and Intelligent Systems. Advances in Intelligent Systems and Computing, vol 316. Springer, 2015.

[15] M. Babič, G. Varga, D. Ghiculescu, M. Jakubowicz, S. Slavov, G. Seritan, D. Marinković, A Novel Approach for Pattern Recognition by Using Graph Theory and its Application in Mechanical Engineering Academic Journal of Manufacturing Engineering 19: 3 pp. 5-10. , 6 p. (2021)

Finite element analysis of piping supporting structure in thermal power plants

B. Damjanović [a], P. Konjatić [b], M. Katinić [b], D. Turk [b]

[a] Saacke Marine Systems – TPK Nova d.o.o., Slavonska avenija 20, 10000 Zagreb, Croatia, E-mail: b.damjanovic@saacke.hr

[b] University of Slavonski Brod, Trg Ivane Brlić Mažuranić 2, 35000 Slavonski Brod, Croatia, E-mail: dturk@unisb.hr

Abstract

Beam structures are common in engineering practice, and with the growing complexity of the structures, beam finite elements sometimes are not sufficient to achieve accurate results. This paper aims to show the possibilities of using different finite element types and to see what kind of possible impact those elements will have on similar structures. This paper analyses the stress and the displacement of a structure supporting the piping system of the boiler water supply inside a thermal power plant. While sustaining piping loads, the designed structure intends to carry piping hangers and supports. Numerical analysis of the finite element method is performed using the software Ansys Workbench. Meshing methods with different finite elements are tested, and the solutions are obtained. The tested finite elements are beam, solid, shell, and solid-shell finite elements, respectively. One of the results is the displacement convergence diagram for each type of used finite element, with the appropriate time needed for obtaining solutions for that element. With reduced time, more accurate solutions for overall analysis are achieved.

Keywords: Finite element analysis, structure, piping, supports

1. INTRODUCTION

The finite element method is used regularly in the field of structural design. With the help of the finite element method and modern computers, it is possible to calculate structures of very complex geometry which is an advantage compared to other calculation methods, especially if it's challenging to achieve an analytical solution.

For the analysis of structures, solid finite elements are most commonly used and do not require additional geometry preparation, but are not resource-effective.

When designing structures it is important to know structure loading. In the process the investigation of stability, strength and rigidity is examined.

Paper by Erke Wang, et all [1] covers a comparison of hexahedral and tetrahedral elements on the example of linear static mechanical problems. Paper describes the advantages and disadvantages of using both types of elements. Hardware limitations were also covered while using quadratic elements in large models.

Erke Wang [2] covered thin-walled structure analysis, where a comparison of solid-shell and shell elements versus solid elements was made. These types of elements were used on the same geometries with linear and nonlinear material properties.

The structure analysed by this paper will spend its life cycle inside the combined cycle thermal power plant. The structure's function is to carry the pipe supports of the boiler water supply system. The capacity of the thermal power plant is 490 MW, and the power plant itself is characterized using combined cycle technology.

To support the pipe system for the distribution of the boiler water supply, a construction was designed to carry four hangers and four clamp supports (Figure 1.).

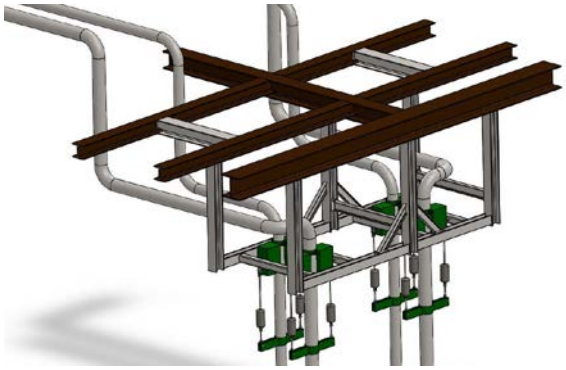


Fig. 1. Model of observed structure with the associated pipe supports

The profiles belonging to the primary structure, which is the fundamental part of the thermal power plant, are marked brown. The profiles marked grey, are parts of a subsequently added structure and its purpose is to support the pipes.

2. METHODS AND MATERIALS USED FOR RESEARCH

The structure analysis was performed within the Ansys Workbench 18.0 software package [3].

For analysis and comparison of results, beam (Beam188 and 189), three–dimensional solid (Solid185, 186, 187), shell (Shell181 and 281), and solid-shell elements (Solsh190) were used. Elements were compared according to [1, 2].

2.1. Material

Structural steel S355J2 is used in the primary structure of the power plant, while S235 is used in the secondary structure to which supports are attached. The properties of these materials must be entered into the Ansys Workbench material database according to appropriate material standards, EN10025-2:2019, EN1991-1-1:2002, and EN 1993-1-1:2005/A1:2014.

Table 1. S235 Material properties [4,5,6]

Material property	Value
Young's modulus of elasticity (E)	200 000 MPa
Yield strength (R_e)	235 MPa
Ultimate strength (R_m)	360 MPa

Table 2. S335 Material properties [4,5,6]

Material property	Value
Young's modulus of elasticity (E)	200 000 MPa
Yield strength (R_e)	335 MPa
Ultimate strength (R_m)	470 MPa

The area of interest in this paper is the structure designed with material S235, for which the allowable stress is equal to 157 MPa using the safety factor of 1,5. For ductile materials where the yield strength is exhibited, the allowable stress is calculated by dividing the value of the yield strength (R_e) by the safety factor. Safety factor of 1,5 is used when structure is made of reliable material and where loading and environmental conditions are not critical [7].

The allowable deflection of the beam or cantilever according to EN1993-1-1, suggests, that inside UK National Annex for Eurocode 3 is equal to Length/200 [8].

2.2. Geometry

The analysis should include the part of the primary structure to which the secondary structure with supports is attached. The area of interest in this analysis is only the load-bearing structure.

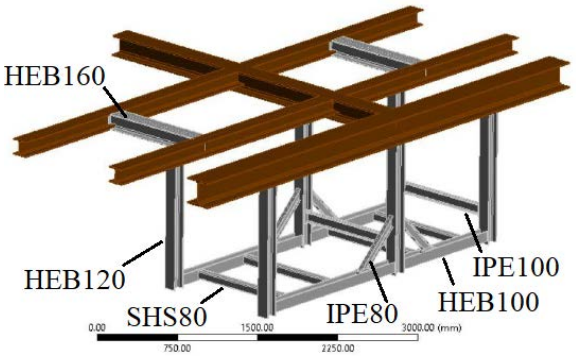


Fig. 2. Geometry for analysis

Structure is made of HEB100, HEB120 and HEB160 profiles type along with the supporting IPE80, IPE100 and SHS80 profiles.

2.3. Boundary conditions

Profiles of secondary structure, as the profiles of the primary structure, are connected by welding technology in the same way as the rest of the power plant. For this reason, on the marked locations of the free ends of the beams, marked in Figure 3, fixed support is set as a boundary condition, and the contact between each profile is defined as "Bonded", which indicates an inseparable connection. Bonded contact is used because this location is not a place of interest for this paper, and does not affect the main solutions, but makes simulation faster as it is linear contact.

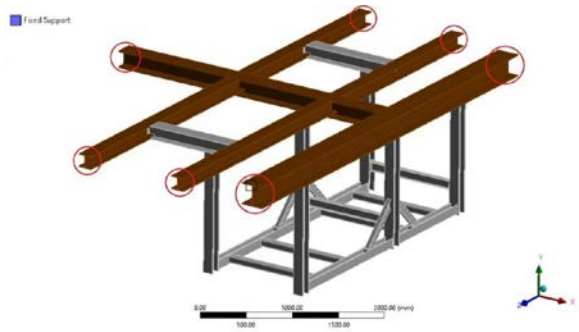


Fig. 3. Marked locations of fixed support

The support loads have been obtained from pipe stress analysis. In pipe stress analysis the supports from the observed structure are set as boundary conditions, and the pressure and temperature of the pipeline are set as loads. As a result, pipe stress and displacement, as well as support reactions are obtained. Supports reaction loads are also action loads on the construction of the same value but in the opposite direction. The forces in Figure 4. marked with the letters B, D, F, and H refer to the movable supports, and the forces marked C, E, G, and I to the spring hangers, which are suspended on square profiles between which the pipeline extends.

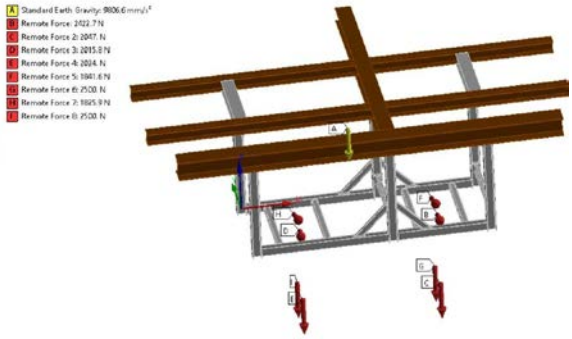


Fig. 4. Support loads acting on the structure

Table 3. Support loads

Support	Force components		
	F_x [N]	F_y [N]	F_z [N]
B	-162	-2311	709
C	0	-1	-2047
D	-213	-1912	602
E	0	-1	-2024
F	-4	-1764	529
G	0	-3	-2500
H	20	-1749	524
I	0	-3	-2500

3. RESULTS OF THE ANALYSIS

In this chapter, the displacements, and equivalent stress solution of the observed structure will be presented. Since more analyses have been performed with different finite elements, only the analysis with solid elements will be visually shown. The results of the other finite elements, used in this comparison, will be shown only in the diagram.

3.1. Stress and deformations

Figure 5. shows the field of equivalent von-Mises stress. The maximum amount of equivalent stress is 289,26 MPa. In the detail shown in Figure 5, occurred singularity at the point can be observed. With each further refinement of the mesh, the stress value would be higher and closer to infinity. This phenomenon occurs due to the sudden discontinuity of the geometry at the joint

location. The profiles are rarely joined in this way, but if welds were modelled, a smoother transition would be achieved between the contact surfaces of the joined profiles. For more accurate results at the joint, an additional analysis of the weld is required, which will not be performed in this paper but may be considered as a continuation of the investigation. In the rest of the structure, where there are no singularities, the stresses do not exceed the allowable values.

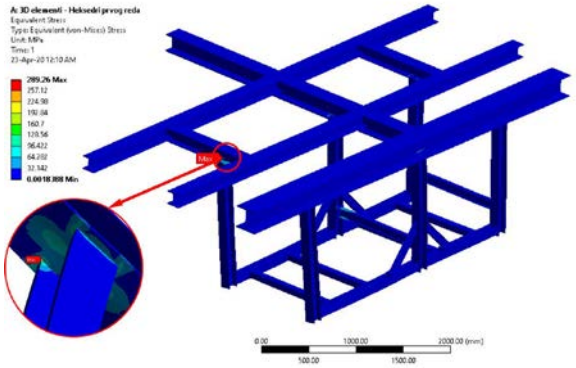


Fig. 5. Field of equivalent von-Mises stress for SOLID186 element

Figure 6. shows the field of total displacements. The maximum value of total displacement is equal to 3,72 mm.

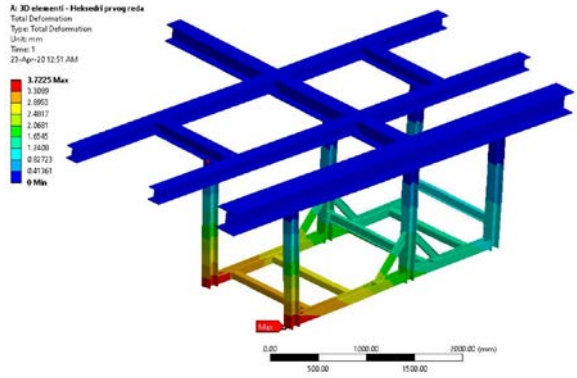


Fig. 6. Field of total displacement for SOLID186 element

The allowable deflection for profile with maximum deflection is equal to [8]:

$$w_{allow} = \frac{L}{200} = \frac{1310}{200} = 6{,}55 \text{ mm} \qquad (1)$$

$$w_{max} = 3{,}72 \text{ mm} < w_{allow}$$

where w_{max} stands for maximum deflection, w_{allow} stands for allowable deflection and L stands for profile length.

From equation 1 we can conclude that maximum deflection has lower value than allowable deflection.

3.2. Comparison of finite elements

The performed analysis showed that the results varied using different finite elements but without significant deviation. The total values, elements size, and duration of the analysis were used as reference values.

From the diagram in Figure 7. it can be seen that second-order finite elements, already at the element size of 15 mm, will create a mesh which reaches the displacement value, almost as accurate as those independent of the mesh density. It's concluded that a mesh consisting of second-order finite elements will need a lesser amount of finite elements than a mesh consisting of first-order finite elements. The degenerated Solid185 does not reach the values for the displacement independent of the mesh density with available used resources. Beam finite elements show the fastest convergence of results, whether they are first or higher-order elements.

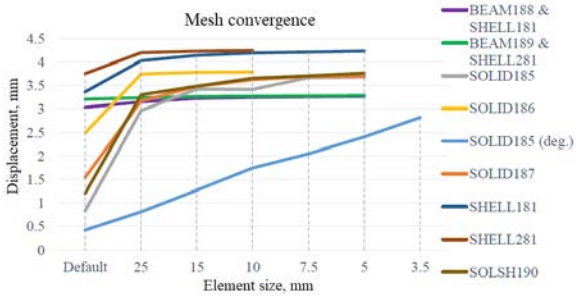


Fig. 7. Comparison of the different finite element convergence

Table 4. shows mesh statistics for each type of element in the convergence state as an addition to the diagram in figure 7.

Table 4. Mesh statistics for each type of finite elements

Element type	Element size	Number of nodes	Number of elements
BEAM188	5 mm	26455	16595
BEAM189	5 mm	51045	16595
SOLID185	5 mm	1596891	1056563
SOLID186	10 mm	1468843	227357
SOLID187	5 mm	1716677	825108
SHELL181	5 mm	756459	748823
SHELL281	10 mm	577469	189990
SOLSH190	5 mm	1403479	567981

The individual groups of finite elements show very similar displacement results. The diagram in Figure 8. shows displacements for different finite elements compared in this paper. The beam elements showed the stiffest behaviour in combination with the shell elements. Three-dimensional finite elements, except for the degenerate Solid185 finite elements (first-order tetrahedral elements), achieved very similar results. Solid185 even with very dense mesh settings could not achieve the independence of the mesh density. Acquiring accurate results with SOLID185 finite element may be possible, but will need a lot more computational resources, and thus is not relevant for further testing.

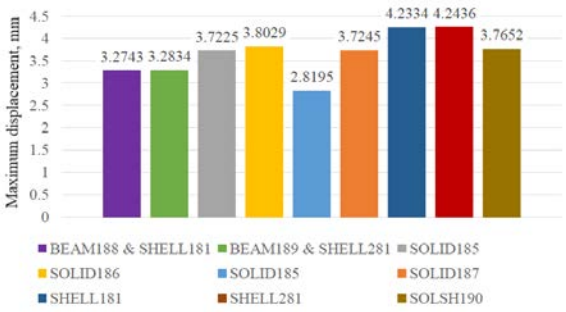


Fig. 8. Comparison of maximum displacement for different types of finite elements

The diagram in Figure 9. shows a comparison of the time required to solve each analysis (elapsed time). Three-dimensional finite elements need the most time to solve, while analysis with beam elements has the shortest duration needed for solving the analysis. The comparison was created by solving the analysis with mesh settings using the elements size of 15 mm. This finite element size is selected so not all computational resources are utilized, and relevant comparison is possible.

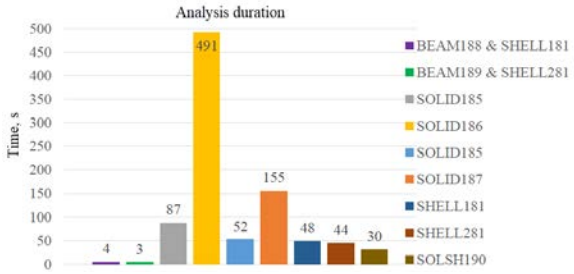


Fig. 9. Comparison of time duration for each analysis

Table 5. shows the number of elements, nodes, elapsed, and CPU times for each analysis as an addition to the diagram in figure 7.

Table 5. Mesh data for each analysis in respect to time duration

Element type	Number of nodes	Number of elements	Elapsed time (s)	CPU time (s)
BEAM188	7533	4221	3	2.453
BEAM189	13097	4221	4	3.109
SOLID185	192078	104468	87	40.32
SOLID186	670563	103232	491	67.20
SOLID187	469182	211108	155	57.28
SHELL181	89647	87291	48	20.35
SHELL281	265034	87303	44	40.08
SOLSH190	214793	86095	30.234	30

4. CONCLUSIONS

Often in engineering practice, a compromise between the duration of the analysis and the accuracy of the results has to be achieved.

The displacement solutions do not deviate significantly from each other, but some elements show more flexible behaviour, while others have stiffer behaviour. The stiffest behaviour was observed from Beam188 combined with

Shell181 finite element and Beam 189 combined with Shell 281 finite element. Most flexible behaviours were observed from Shell 181 and Shell 281 finite elements.

Degenerate Solid185 finite element, which is a first-order tetrahedral finite element, do not reach an accurate result for this kind of problem, and by applying those finite elements, it was not possible to achieve a displacement value independent of the mesh density. It's concluded that the use of Solid185 finite element in similar calculations is not recommended.

With the respect to duration, convergence and the obtained solutions of the analysis, it's concluded that the use of Solsh190 (solid-shell) finite elements for calculating similar steel structures may be promising and also beneficial for those kinds of analysis. Solsh190 is used for shell structures with a wide range of thickness. Element has solid element topology with eight nodes and three degrees of freedom at each node, translation in x, y and z direction. The element has stress stiffening, creep, plasticity large deflection, hyperelasticity and large strain capabilities. Connecting Solsh190 to other elements doesn’t requires additional effort [9]. The flaw Solsh190 elements have is that they require geometry preparation to make meshing possible, which sometimes can be a very time-consuming task that also needs to be taken into consideration while choosing the right type of finite element for the analysis.

5. REFERENCES

[1] Wang, Erke; Nelson, Thomas, and Rainer Rauch. Back to elements - tetrahedra vs. hexahedra, Proceedings of the international ANSYS conference, 24. – 26. May 2004., 3. – 16.

[2] Wang, Erke, Thin-wall structure simulation, Proceedings of the international ANSYS conference, 2. – 4. May 2006., 12. – 27.

[3] ANSYS Workbench 18.0, Ansys, Inc., 2018.

[4] EN10025-2:2019 Hot rolled products of structural steels - Part 2: Technical delivery conditions for non-alloy structural steels

[5] EN1991-1-1:2002 Eurocode 1: Actions on structures - Part 1-1: General actions - Densities, self-weight and imposed loads for buildings

[6] EN 1993-1-1:2005/A1:2014 Eurocode 3: Design of steel structures - Part 1-1: General rules and rules for buildings

[7] Dzulfiqar, Muhammad Faiz, et al. "Assessment on the Designed Structural Frame of the Automatic Thickness Checking Machine–Numerical Validation in FE method." Procedia Structural Integrity 33 (2021): 59-66.

[8] BS NA EN 1993-1-11: UK National Annex to Eurocode 3: Design of steel structures. Design of structures with tension components

[9] Analysis System, Ansys Workbench Help, Release 18.0, Ansys, Inc. 2018.: SOLSH190 Element Description

Goodness of Fit in LabVIEW

Tibor Dobján [a], Éva Osztényiné Krauczi [b]

[a] John von Neumann University GAMF Faculty of Engineering and Computer Science, Izsáki street 10, 6000, Kecskemét, Hungary dobjan.tibor@gamf.uni-neumann.hu

[b] John von Neumann University GAMF Faculty of Engineering and Computer Science, Izsáki street 10, 6000, Kecskemét, Hungary osztenyine.eva@gamf.uni-neumann.hu

Abstract

Scientists pursuing applied sciences use NI LabVIEW for scientific measurements, but usually they have to use some other software to analyze data. Goodness of Fit is a data analyzing tool for found the distribution type and the parameters of the distribution of a given random variable. The aim of this paper is present a Goodness of Fit LabVIEW implementation. We have used an Object-Oriented Programing approach and the latest LabVIEW features to implement D'Agostinos normality test, Kolmogorov-Smirnov test for Student distribution test and also Kolmogorov-Smirnov test for tricontaminated normal distribution. We prove that the Object-Oriented Programing design and the new LabVIEW features like multiple inheritance and map datatype handling allows us to create a flexible and scalable implementation. With proper design it is easy to expand the implementation with new test types or with new distributions. With this Goodness of Fit software package it is possible to do some data analysis in the measurement software. Then the result can be applied directly in controlling systems. More sophisticated control systems can be made with the help of this software package. There are some design conceptions and an accelerating trick are also presented.

Keywords: LabVIEW, Object Oriented Programing, Goodness of Fit, D'Agostino test, Kolmogorov-Smirnov test

1. INTRODUCTION

LabVIEW is a graphical programing environment which helps to develop G codes. Object Oriented Programing (OOP) is a programing design methodology which helps to make flexible, reusable codes in a multi programmer environment [1, 2]. Research about real-time control algorithms includes several steps, like data acquisition, data analyse, decision making, and act [3, 4, 5, 6]. Scientists pursuing applied sciences use custom software solutions of various development teams to build up a testing environment for their scientific experiments [7, 8]. The different communication interfaces between multiple platforms can increase the complexity of the code in a greater extent than is required by the control algorithm.

We have made a Goodness-of-Fit (GoF) implementation in LabVIEW respect to OOP design for that reason, to make it possible to create effective codes in one platform where data analyse tasks are exist. The GoF implementation allows us to make a decision on the distribution of observations at a given significance level, i.e. to perform a goodness-of-fit analysis.

Our research hypothesis is that, the new LabVIEW features after LabVIEW 2021 makes possible to create a flexible and scalable GoF programing package for our selected distributions. We have selected the classic normal distribution, the Student distribution what is extended by a ρ parameter and the tricontaminated (TriCo) normal distribution to implement. We used D'Agostinos test for testing the normality. We used the Kolmogorov-Smirnov (KS) test for the other two tests.

The second section gives a theoretical overview of KS and the D'Agostino GoF techniques and describes the used distributions. The third section contains the description of the implementation. The fourth section shows the testing

cases and the experimental result s. The fifth section is about the conclusions of this research.

2. THEORETICAL OVERVIEW

2.1. GoF techniques

One important task of statistical tests is to identify the distribution of observations. Of course, a claim about the distribution can be made only at a given level of significance. Thus, the aim of GoF testing procedures is to decide, for a given significance level α, on the null hypothesis that the sample comes from a given distribution or family of distributions. In this subsection, there are two GoF techniques introduced.

Let $x_1, x_2, \dots, x_n$ denote the sample, i.e. a set of independent, identically distributed random variables X. The sample average is

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i \tag{1}$$

the sample standard deviation is given by

$$\sigma_n = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(x_i - \bar{x})^2} \tag{2}$$

Also let $x_{1,n}, x_{2,n}, \dots, x_{n,n}$ be the ordered sample, what is needed for calculating test statistics.

2.2. KS-test

The KS-test belongs to the Empirical Distribution Function (EDF) class of GoF tests.[9] The basic idea of these tests is to measure the discrepancy between the hypothetical distribution function $F_0(.)$ and the empirical distribution function $F_n(.)$ calculated from the sample, and to decide whether the distribution function is identical or different on the basis of the magnitude of this difference. The KS-test uses the functional distance from the supremum norm.

The null hypothesis H_0 is that the distribution function of random variable X is $F_0(.)$. The alternative hypothesis H_1 is that this is not true.

KS test have been used for Student and TriCo distributions detailed in section 2.4 and section 2.5.

The GoF tests procedure consist of three steps, specialised for the case of the KS-test, these are:

1) The value of the test statistic can be determined from the sample. The first step in this test is to order the sample. The next step is to compute the distance of the distributions:

$$D_n = sup_{x\in\mathbb{R}}|F_n(x) - F_0(x)| = max(D^+, D^-), \tag{3}$$

where

$$D^+ = max_l\left\{\frac{l}{n} - F_0(x_{l,n})\right\},$$
$$D^- = max_l\left\{F_0(x_{l,n}) - \frac{l-1}{n}\right\}. \tag{4}$$

In calculating D^+ and D^-, the fact have been used for that the transformation $F(X)$ results in a random variable with uniform distribution on the interval [0,1], if the random variable X is a distribution function F(.).

2) For a given significance level α, the critical value D_α have been specified and hence the nonrejection region of the test, i.e., the values of the test statistic at which the null hypothesis is accepted. The critical value is calculated from the distribution of test statistics under the null hypothesis:

$$\alpha = P(D_n > D_\alpha | H_0). \tag{5}$$

3) The null hypothesis have been decided. If $0 \le D_n \le D_\alpha$, then the null hypothesis at significance level α cannot be rejected. Otherwise, it is rejected, i.e. the alternative hypothesis is satisfied.

The decision can also be made by calculating the p-value. The p-value is the significance level at which the null hypothesis just accepted. If it is greater than the predefined significance level, the null hypothesis cannot be rejected, if it is less than α, it has rejected.

The implementation of KS-test can be shown in section 3.3 under KS engine title. KS hyperengine contains the exact implementation of formula 4.

2.3. Normality test using the D'Agostino-test

This test belongs to the class of regression and correlation tests and is a modified version of the much used Wilk-Shapiro test (used between 3 and 50 sample sizes). The modification is necessary because of the large sample size (more than 50 observations). While the KS-test checks whether the sample is from a given distribution, this test checks whether the sample belongs to a given family of distributions, namely the normal family [9].

If the sample is from the normal family, that means that it comes from a random variable X with any expected value $\mu \in \mathbb{R}$, any standard deviation $\sigma > 0$ and the density function

$$f_{\mu,\sigma}(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{\frac{(x-\mu)^2}{2\sigma^2}}, x \in \mathbb{R}. \quad (6)$$

Again, the first step in this procedure is to order the sample. Next comes D'Agostino-test statistic:

$$D_A = \frac{\sum_{l=1}^{n} x_{l,n} * \left(l - \frac{n+1}{2}\right)}{\sigma_n * n^2}, \quad (7)$$

for which the critical values are denoted by $D^1_{\alpha/2}$, $D^2_{1-\alpha/2}$. The nonrejection region of the test is

$$D^1_{\alpha/2} \leq D_A \leq D^2_{1-\alpha/2}. \quad (8)$$

The implementation of D'Agostino-test can be sown in section 3.3 under D'Agostino engine title.

2.4. Student distribution checked by KS-test

When it is decided from the sample whether it has a student distribution, the hypothetical distribution function F_0 in the KS-test is the Student distribution with parameter ρ, degree of freedom k and the density function

$$f(x) = \frac{1}{\sqrt{k\pi\rho^2}} \frac{\Gamma\left(\frac{k+1}{2}\right)}{\Gamma\left(\frac{k}{2}\right)} \left(1 + \frac{x^2}{k\rho^2}\right)^{-\frac{k+1}{2}} \quad (9)$$

$k \in \mathbb{N}, \rho > 0$ és $x \in \mathbb{R}$,

where the Gamma function is

$$\Gamma(y) = \int_0^\infty t^{y-1} e^{-t} dt, y \geq 0.$$

The hypothesis testing procedure described in subsection 0 is applied with this pre-fixed parameter distribution function F_0.

2.5. Verification of TriCo normal distribution by KS-test

For proving that the sample is TriCo normal, the KS-test with the hypothetical distribution function F_0 with the parameters

$$(\omega_1, \mu_1, \sigma_1, \omega_2, \mu_2, \sigma_2, \omega_3, \mu_3, \sigma_3);$$
$$\mu_1, \mu_2, \mu_3 \in \mathbb{R},\ \sigma_1,\ \sigma_2,\ \sigma_3 \in \mathbb{R}^+,$$

and the density distribution

$$\begin{aligned} f(x) &= \omega_1 f_{\mu_1,\sigma_1}(x) \\ &+ \omega_2 f_{\mu_2,\sigma_2}(x) \\ &+ \omega_3 f_{\mu_3,\sigma_3}(x), \end{aligned} \quad (10)$$

where

$$\omega_1 + \omega_2 + \omega_3 = 1, 0 \leq \omega_1, \omega_2, \omega_3 \leq 1$$

and normal density functions $f_{\mu_1,\sigma_1}, f_{\mu_2,\sigma_2}$ and f_{μ_3,σ_3} have to be used. Then the KS-test described in subsection 0 with this distribution has performed.

2.6. Generation of simulated signals

In LabVIEW, there exists a vi for the generation of a normal distribution sample with an arbitrary expected value $\mu \in \mathbb{R}$ and an arbitrary standard deviation $\sigma \in \mathbb{R}^+$. The other two samples of distribution are programmable.

For a Student distribution with parameter $\rho \in \mathbb{R}^+$ and degree of freedom $k \in \mathbb{N}$ the sample

$$F^{-1}(u_1), F^{-1}(u_2), \dots, F^{-1}(u_n) \quad (11)$$

can be obtained by applying the quantile function $F^{-1}(.)$ of the Student distribution built into LabVIEW to each member of the sample $u_1, u_2, \dots, u_n$ with uniform distribution on the interval [0,1].

The i-th order of the TriCo distribution of a sample with parameter

$$(\omega_1, \mu_1, \sigma_1, \omega_2, \mu_2, \sigma_2, \omega_3, \mu_3, \sigma_3)$$

$$I_{\{0\le U\le\omega_1\}} * X_{\mu_1,\sigma_1} + I_{\{\omega_1<U\le\omega_2\}} * X_{\mu_2,\sigma_2} + I_{\{1-\omega_3<U\le 1\}} * X_{\mu_3,\sigma_3} \quad (12)$$

requires the generation of four independent random variables: a uniformly distributed U on the interval[0,1], a normally distributed X_{μ_1,σ_1}, with parameter μ_1, σ_1, a normally distributed X_{μ_2,σ_2}, with parameter μ_2, σ_2, and a normally distributed X_{μ_3,σ_3}, with parameter μ_3, σ_3, where

$$I_{\{A\}} = \begin{cases} 1, & \text{if A event occurs} \\ 0, & \text{if A does not occur} \end{cases} \quad (13)$$

denotes the indicator function of event A.

3. IMPLEMENTATION

3.1. LabVIEW OOP

LabVIEW is an object-oriented programming environment, that uses concepts from other object-oriented programming languages such as Java and C++, including class structure, encapsulation, and inheritance [3]. The most modern features have been used to design and implement the GoF functionality for scientific purpose.

3.2. Design

FIT class handles the parameters of fitting and result data of the goodness of fit tests. SIGNAL class handles the time series generation with a given distribution. DISTRIB class is a parent class of the distribution classes. STUD, GAUSS, TRICO classes are handling Student distribution, Normal distribution and TriCo distribution, respectively. Their behaviour depend on the parental class and also the parental interface. TESTS is the parent interface of the test interfaces. KS interface handles the KS-test specific functions. DAGOST interface handles some functions of normality test. Multiple inheritance available on LabVIEW since 2020. The hierarchy of the above classes and interfaces can be seen on figure 1.

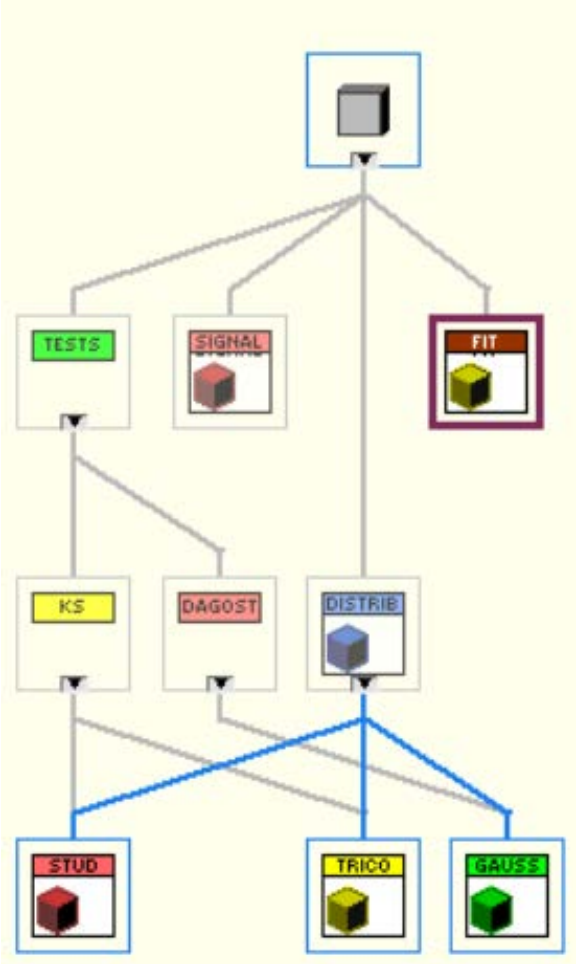


Figure 1. Hierarcy of classes and interfaces

Each statistical test has the same structure in all cases, can be seen in figure 2. Dynamic dispatch used to make test, because all kind of distribution are inherited from DISTRIB parent class.

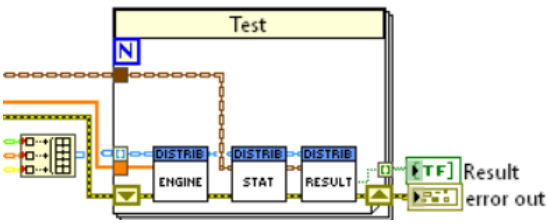


Figure 2. Universal distribution testing code

Once the statistic value have to be calculated with the given distribution engine.vi. Then the distribution of test statistic should have been calculated by the stat.vi. This has the same code

for every distribution. After that the result of GoF test can be calculated in different way of each test method. So result calculation has implemented once in each test type.

3.3. Engines

Each test type has an own engine.vi, what contains a sort function and a parallelized loop for calculating the statistical value. Engines are inherited from Tests.class. The ordered signal is connected to the parallelized loop in each case. The implementation ask the number of logical processors from the operation system, and set the number of maximum parallel loops to it. So this code use the maximum computation resources in all kind of computers where it runs.

D'AGOSTINO ENGINE

This implements formula 7, it can be seen on figure 3-4. This method can be used only for normal distribution testing.

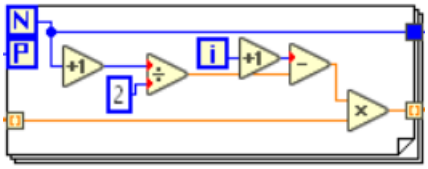


Figure 3. First part of D'Agostino-test engine

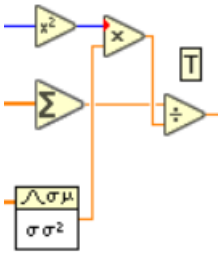


Figure 4. Second part of D'Agostino-test engine

The standard deviation have been computed from the same sample, what have been connected to incoming tunnel of the loop.

KS ENGINE

KS Engine should work with a different distributions, that's way it is more complex. It has two subVI-s. Figure 5 shows the usage of the subVI-s in a parallelized loop.

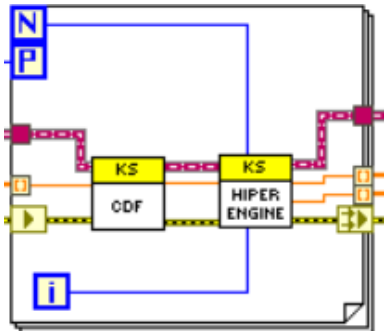


Figure 5. KS engine parallelized loop

Of course KS test has also a non-parallelized part, what can be seen of figure 6.

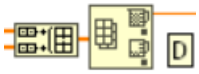


Figure 6. Implementation of formula 3.

Custom Cummulative Distribution Function (CDF) subvi-s have been used, because our implemented distributions are unique and LabVIEW not contains the CDF functions for them basically.

CDF of Student distribution extend the internal Student t CDF function with ρ parameter, it can be seen on figure 7.

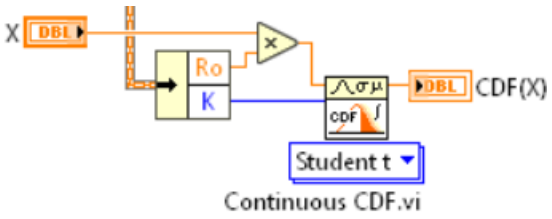


Figure 7. CDF of Student distribution

Trico CDF generation uses three normally distributed CDFs and a pooling algorithm, can be seen on figure 8.

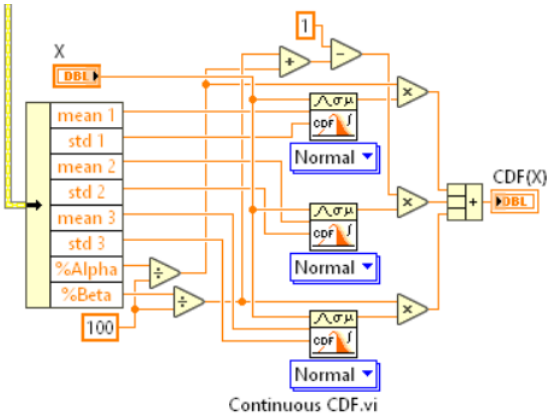


Figure 8. CDF of TriCo distribution

KS hyper engine contains the part implementation of formula 4. what is common in all KS test methods. It can be seen on figure 9.

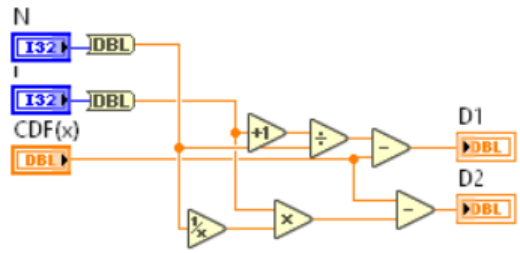


Figure 9. KS hyper engine

3.4. Stat

Generating the distribution of test statistics has the most computing demand. Time Series generation VI-s are generating vectors with Length element. This means N times Length pieces of random number generation respect to the given distribution. Increasing the N value will improve the precision of the test. Engine VI-s calculates only one StatValue, what is stored in the outgoing indexing tunnel. As it can be seen on figure 10.

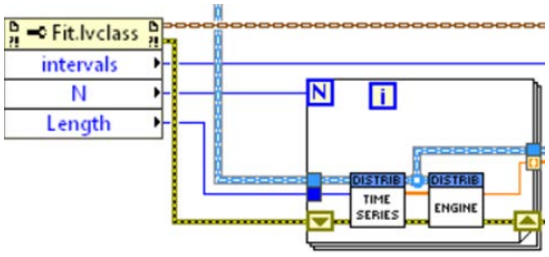


Figure 10. StatValue calculation by engines

GENERATING TIME SERIES

Each distribution has an own time series generator method. Time series with normal distribution can be generated, by LabVIEW inbuilt Gaussian White Noise.vi function. It can be seen on figure 11.

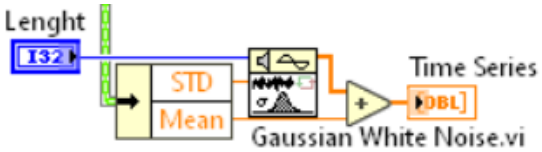


Figure 11.
Generating time series with normal distribution

There is not exist built-in time series generator vi for Student distribution, so a custom vi had to be implemented. Uniform White Noise VI generates values between – 0,499 and +0,499. 0,5 had been added to set 0-1 range excluding 0, because Continuous Invers CDF gives a NaN value for 0 input. The implementation can be seen on figure 12.

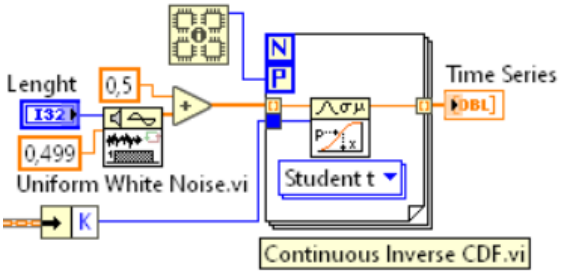


Figure 12.
Generate time series with Student distribution

TriCo distribution is mixture of three separated normal distribution. Its parameters are the parameters of the three normal distribution, and two probability parameters, alpha and beta. Generating time series with TriCo distribution can be seen on figure 13.

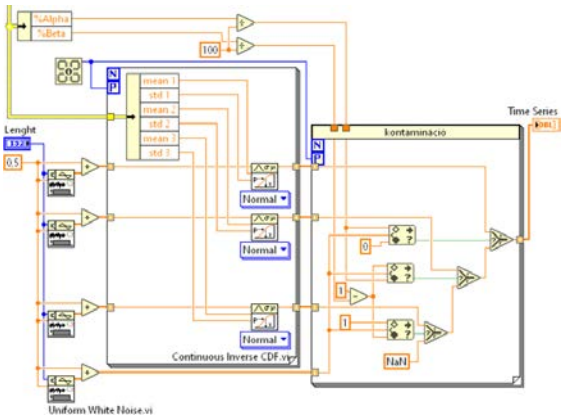


Figure 13.
Generate time series with TriCo distribution

DISTRIBUTION OF TEST STATISTICS

Distribution of test statics means that the calculated StatValues are collected from the parallelized loop and a histogram has been created from that. Creating cumulative normalized histogram from the calculated data. It can be seen on figure 14.

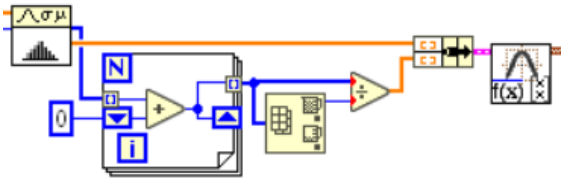


Figure 14. Distribution of test statistics

The last icon is a subVI that converts histogram data points for proper evaluations in result vi-s. It can be seen on figure 15.

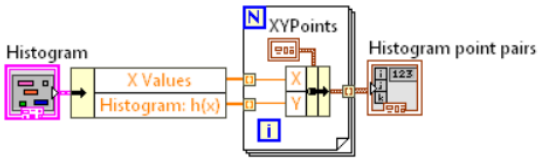


Figure 15. Converting histogram points

STORE OF HISTOGRAM POINTS

Distribution of test statistic generation has a very high computation demand as it has been mentioned above, but it is totally independent, from the signal and the signal parameters. It depend only from fit parameters and containing distribution parameters. Significance parameter is needed to generate result of GoF. Histogram points are stored instead of p values or critical values, because recalculation of test statistic is not needed for different significance levels in this way.

Test statistic store in map structure, it can be seen on figure 16. Map data structure is available from LabVIEW 2019.

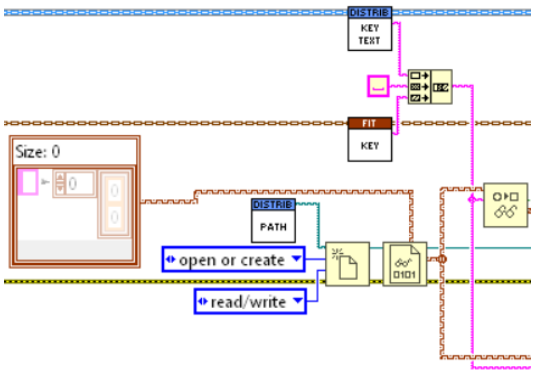


Figure 16. Loading map

The given distribution parameter key is concatenated with the fit parameter key. The key structure of distributions are different so all parameter sets are unique.

Store the calculated new histogram points can be seen on figure 17. The first icon insert the new histogram point vector and the concatenated parameter key to the map. The second icon set the file pointer to beginning of the file to overwrite the old map. The third icon makes the file writing. The fourth icon closes the file reference.

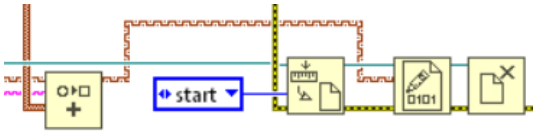


Figure 17. Store map

Key calculation of Fit parameters can be seen on figure 18.

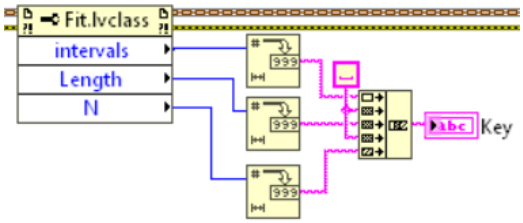


Figure 18. Fit key

Key calculation of Normal Distribution can be seen on figure 19.

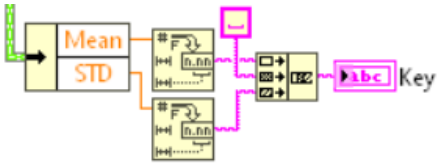


Figure 19. Normal distribution key

Key calculation of Student Distribution can be seen on figure 20. The datatype of the first parameter is differs from normal distributions first parameter.

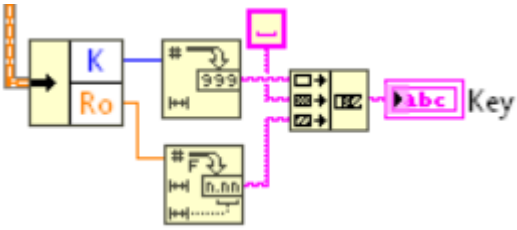


Figure 20. Student distribution key

Key calculation of TriCo Distribution can be seen on figure 21.

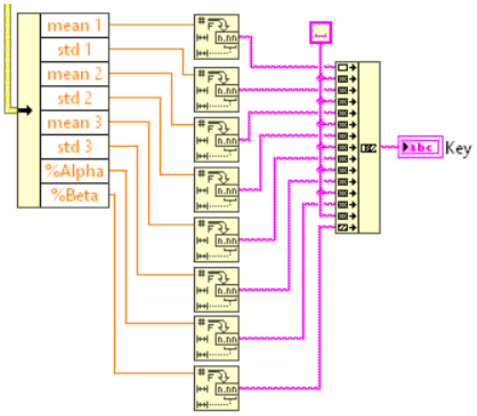


Figure 21. TriCo distribution key

3.5. Result

Each test type has a unique result calculation. Both result.vi gets the calculate statistic value, the calculated and converted histogram points and the needed significance level in percentage. It calculates the decision limits, the P value and makes the decision.

In the case of Normal distribution the result code implemented to the DAGOST interface for that reason to be similar to the other distribution codes. It can be seen on figure 23.

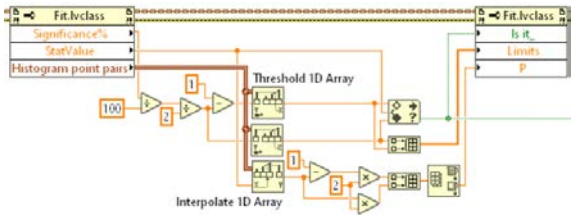


Figure 23. D'Agostino result calculation

Student and TriCo distribution uses the same result calculation inherited from KS interface, what can be seen on figure n. It makes the second and third steps of KS-tests. It can be seen on figure 22.

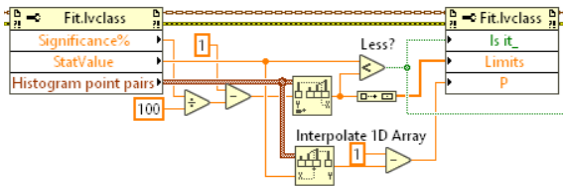


Figure 22. KS Result calculation

3.6. Distribution classes

Each distribution has unique parameters and unique wire colour, what can be seen on figure 23, 24, 25. Their methods CDF, Engine, Result, Key, Time Series are described in above sections.

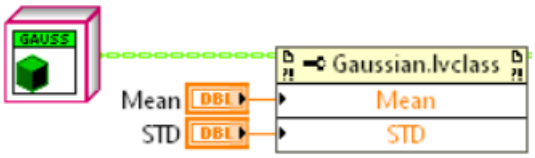


Figure 23. Attributes of Gaussian.lvclass

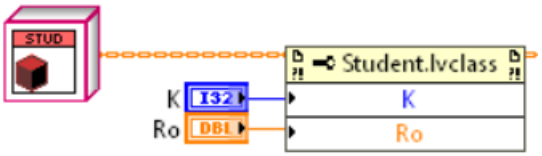


Figure 23. Attributes of Student.lvclass

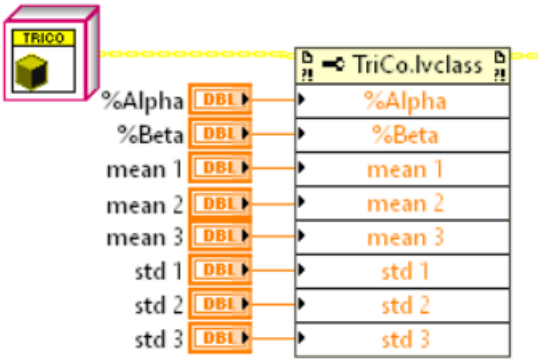


Figure 23. Attributes of TriCo.lvclass

4. TESTING RESULTS

In the implemented program, that can be checked whether the sample $x_1, x_2, \dots, x_n$ belongs to the normal distribution family, using the D'Agostino test; whether it is Student distributed, using the KS-test; or whether it is TriCo distributed, also using the KS-test. Simulated signals were used to check the performance of the program.

4.1. A Testing the operation of the D'Agostino-test

To be able to decide on the null hypothesis at the end of a hypothesis testing procedure, the distribution function of the test statistic is needed. Simulated distribution functions has been used, where the sample size of the test statistic was determined by the fact that the critical

value calculated from the empirical distribution function does not change to 4 decimal places when a new sample is taken. Thus, a sample of $N = 10000$ items was used to generate the empirical distribution function of the test statistic. The cumulative histogram was given broken down into 25 intervals.

The program also gives the critical values for a given significance level and the test statistic for a given sample, as well as the p-values, since the decision can be made based on these.

The performance of the D'Agostino test was checked for normal, Student and TriCo samples with different parameters and a significance level of 1% in each case. In all cases the sample size was 10000 items. Tables 1 and 2 show the related results.

Table 1. Decision of the D'Agostino test for normal and Student samples with different parameters.

Distribution	The first parameter	The second parameter	Decision
Normal	0	1	√
Normal	0	1000	√
Normal	0	0.0001	√
Normal	1000	1	√
Normal	-1000	1	√
Normal	0.0001	1	√
Student	1	3	×
Student	1	4	×
Student	1	10	×
Student	1	30	√
Student	1	35	√
Student	1	100	√

The results obtained are in agreement with the theory. Since the D'Agostino test can test for membership in a normal distribution family, it classifies a normal distribution sample with any parameter as normal with a first-order error of 0.01. Since the asymptotic distribution of Student's distribution is the normal distribution, while the degrees of freedom goes to infinity, that has been expected the null hypothesis to be accepted for "large" degrees of freedom. Furthermore, there is an example of a TriCo normal distribution becoming a normal distribution for certain parameter values.

Table 2 Decision of the D'Agostino test for TriCo distribution samples with different parameters.

Description	Parameters			Decision
	ω_1	μ_1	σ_1	
	ω_2	μ_2	σ_2	
	ω_3	μ_3	σ_3	
Classic TriCo	0.33	-4	1	×
	0.33	0	1	
	0.33	4	1	
Configured to be Normal	0.33	0	1	√
	0.33	0	1	
	0.33	0	1	
Configured to be Student	0.12	-0.6	2.5	×
	0.76	0	0.9	
	0.12	0.6	2.5	

4.2. Testing the KS-test for the Student distribution

The KS-test was tested for the Student distribution with 1 parameter and 3 degrees of freedom at 1% significance level. The empirical distribution function of the test statistic was calculated on a sample of 1000 items, with the range of interpretation divided into 10 intervals. Furthermore, the sample size and the distribution of the alternatives were not changed, so checking the distribution of samples has been continued with 10,000 items, i.e., whether they were Student distributed with 1 parameter and 3 degrees of freedom. The results are presented in Tables 3 and 4.

The null hypothesis was accepted for three alternatives in the test. When the sample was from the Student distribution with parameter 1 and 3 degrees of freedom, this had a 99% chance of being true; when the alternative was the Student distribution with parameter 1 and 4 degrees of freedom, as it was similar to the null hypothesis distribution; and for a TriCO sample, when the parameters of the distribution were chosen to give a distribution similar to the null hypothesis.

Table 3 Decision of the KS-test to check the Student distribution for normal and Student samples with different parameters.

Distribution	The first parameter	The second parameter	Decision
Normal	0	1	×
Normal	0	1000	×
Normal	0	0.0001	×
Normal	1000	1	×
Normal	-1000	1	×
Normal	0.0001	1	×
Student	1	3	√
Student	1	4	√
Student	1	10	×
Student	1	30	×
Student	1	35	×
Student	1	100	×

Table 4 Decision of the KS-test for the Student distribution for TriCo samples with different parameters.

Description	Parameters			Decision
	ω_1	μ_1	σ_1	
	ω_2	μ_2	σ_2	
	ω_3	μ_3	σ_3	
Classic TriCo	0.33	-4	1	×
	0.33	0	1	
	0.33	4	1	
Configured to be Normal	0.33	0	1	×
	0.33	0	1	
	0.33	0	1	
Configured to be Student	0.12	-0.6	2.5	√
	0.76	0	0.9	
	0.12	0.6	2.5	

4.3. Testing the performance of the KS-test for the TriCo distribution

The performance of the KS-test was tested for the TriCo distribution with parameter (0.33;-4;1;0.33;0;1;0.33;-4;1) at 1% significance level. The simulated distribution function of the test statistic was calculated with the same precision as in the Student case. Furthermore, the sample size or the distribution of alternatives has been not changed, so testing the distribution of samples with 10000 elements could be continued. The results are presented in Tables 5 and 6.

Table 5 Decision of the KS-test to check the TriCo distribution for normal and Student samples with different parameters.

Distribution	The first parameter	The second parameter	Decision
Normal	0	1	×
Normal	0	1000	×
Normal	0	0.0001	×
Normal	1000	1	×
Normal	-1000	1	×
Normal	0.0001	1	×
Student	1	3	×
Student	1	4	×
Student	1	10	×
Student	1	30	×
Student	1	35	×
Student	1	100	×

Table 6 Decision of the KS-test for TriCO distribution for TriCO samples with different parameters.

Description	Parameters			Decision
	ω_1	μ_1	σ_1	
	ω_2	μ_2	σ_2	
	ω_3	μ_3	σ_3	
Classic TriCo	0.33	-4	1	√
	0.33	0	1	
	0.33	4	1	
Configured to be Normal	0.33	0	1	×
	0.33	0	1	
	0.33	0	1	
Configured to be Student	0.12	-0.6	2.5	×
	0.76	0	0.9	
	0.12	0.6	2.5	

The null hypothesis is accepted only for samples with the null hypothesis. The other alternatives differ significantly from the null hypothesis distribution.

5. CONCLUSIONS

The development of the LabVIEW OOP GoF software package was successful, so our research hypothesis is accepted. We have presented all parts of the source code in this paper and some test cases for validation. We have made implementation for D'Agostino normality test, KS-test for Student distribution and KS-

test for TriCo distribution. We have checked that the implemented functions are working correctly.

With this solution it is possible to make real world measurements and data analysis in one programing environment, LabVIEW. More sophisticated control algorithms can be implemented in this way.

OOP is not needed for scientific programing, but can be a good strategy to develop a modular software. For further work we would like to extend the engines with χ^2 test method and the list of distributions with Gamma and Weibull distribution with the help of multiple inheritance, what is a new feature of LabVIEW 2020.

Now, we are able to test signals from real world measurements with this LabVIEW GoF program package.

6. ACKNOWLEDGEMENTS

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7. REFERENCES

[1] Jamal, Rahman., Graphical object-oriented programming with LabVIEW. Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment 352.1-2 (1994): 438-441.

[2] Manduchi, G., E. De Marchi, and A. Mandelli., A new LabVIEW interface for MDSplus. Fusion Engineering and Design 88.6-8 (2013): 1196-1199

[3] Beck, D., et al., Control System Design Using LabVIEW Object Oriented Programming. Proceedings of ICALEPCS07, Knoxville, Tennessee, USA (2007)

[4] Chen, Michael., Object oriented programming in labview for acquisition and control systems at the aerodynamics laboratory of the national research council of canada. 2007 22nd International Congress on Instrumentation in Aerospace Simulation Facilities. IEEE, (2007)

[5] Waldron, Conor, et al. An autonomous microreactor platform for the rapid identification of kinetic models. Reaction Chemistry & Engineering 4.9 (2019): 1623-1636

[6] Szopos, Erwin, and Horia Hedesiu. LabVIEW FPGA based noise cancelling using the LMS adaptive algorithm. ACTA TECHNICA NAPOCENSIS Electronics and Telecommunications 50.4 (2009): 5-8

[7] Buele, Jorge, et al., Interactive system for monitoring and control of a flow station using LabVIEW. International Conference on Information Technology & Systems. Springer, Cham, (2018)

[8] Mitra, Anirban C., and Nilotpal Banerjee., A LabVIEW-based data acquisition system in a quarter car test rig to optimize vehicle suspension system. Intelligent Computing and Applications. Springer, New Delhi, (2015) 593-601

[9] R. D'Agostino, Goodness-of-fit-techniques. Routledge., (2017)

Friction in production the coefficient of friction μ $\sigma_n = k_f$ the factor of friction m

$$\mu\sigma_n \geq k$$

G. Grizelj, A. Stoic, M. Stoic , A. Sarac , M. Sarac , V. Starcevic , I. Opacak(A), I. Opacak

[a] University of Slavonski Brod, Faculty of Mechanical Engineering in Slavonski Brod, Trg I. B. Mazuranic 2, 35000 Slavonski Brod, Croatia, bgrizelj@unisb. hr

Abstract

Is given in the paper mathematical representation of friction. Bowden-Tabor Theory for cold forming and Bowden-Tabor Theory for hot forming Friction is sometimes helpful. For example, high friction on the punch surface helps increase reductions in deep drawing and ironing. In a few instances it has to have at least some small value, as in rolling where it assures entry of the workpiece into the roll gap and helps maintain rolling without skidding of the workpiece. However, in most instances friction is preferably reduced to zero by the introduction of a lubricant.
In the vast majority of metalworking processes the workpiece is deformed by means of a contacting die. The pressure required for deformation generates a normal stress to the die surface, and movement of the workpiece relative to the die surface generates a shear stress at the interface. Thus a classical tribological situation arises, with friction at the die-workpiece interface, and with potential for wear of both die and workpiece materials. Mitigation of these effects then calls for the introduction of a lubricant. In contrast to nonmetalworking situations, deformation of theworkpiece results in a sometimes very substantial enlargement of surface areas. Thus new, fresh metal surfaces are exposed, and the lubricant must protect not only the old but also the new surfaces. The success or failure of such lubrication has important consequences on the quality of the issuing product, and also on pressures, forces, energy requirements, and often the very possibility of plastic deformation itself. For these reasons, the field of friction, lubrication, and wear (tribology) in metalworking has been the subject of many investigations.

Keywords: friction, the coefficient of friction, the factor of friction

1. INTRODUCTION

Factors entering the tribology of space needed numerous, and their interactions are exceedingly complex.
Friction is the resistance to motion encountered when one body slides over another. In metalworking processes it arises from sliding of the workpiece against the die. The die-workpiece interface Fig. 1 (on the macro scale) [1] to [12].

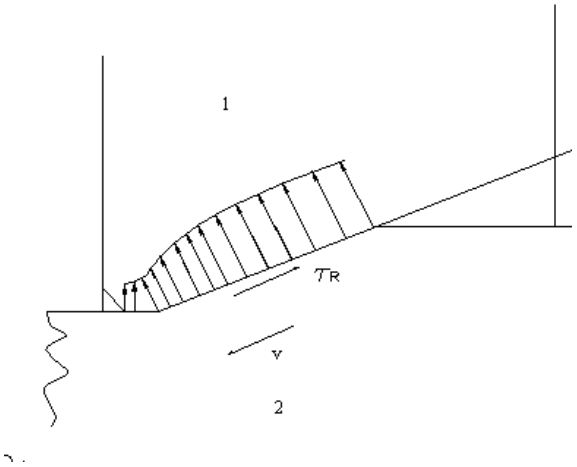


Fig.1. Die (1)-workpiece (2) interface – on the macro scale

The die-workpiece interface Fig.2 (on the micro scale).

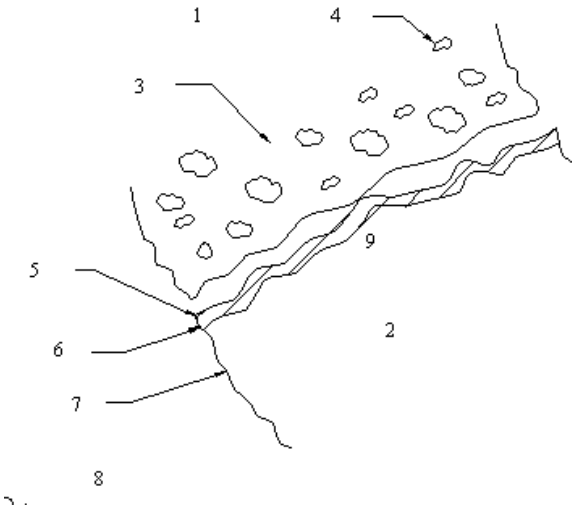


Fig. 2. Die (1)-workpiece (2) interface – on the micro scale, 3-matrix, 4-hard phase, 5-adsorbed film, 6-reaction (oxide) film, 7-surface layer, 8-disturbed enriched/depleted, 9-bulk

2. YIELD CRITERIA AND STRESS-STRAIN RELATIONS

In the one-dimensional tension-compression test, yielding (flow) takes place when the stress $\sigma = F/S$ reaches the value σ_f. This condition can be considered to be a yield criterion,

$$\left|k_f\right| = \frac{F}{S}. \qquad (1)$$

For multiaxial stress states, the onset of yielding is not dependent on a single stress (for example, the largest tensile or compressive stress), but on a combination of all stresses. From the many yield criteria which have been proposed, two have shown good agreement with experimental results. These are:

1. Maximum shear stress criterion (Tresca, Mohr) [1-12]
2. Distortion energy criterion (von Mises, Hencky) [1-12]

They have served as the basis for most of the work in the field of plasticity. Both contain the one- dimensional criterion, Eq. 1, as a special case.

The maximum shear-stress criterion states that the material at a point in the workpiece receives permanent deformation when the largest of the shear stresses at this point reaches a critical value. It can be expressed as

$$\left|\tau_{\max}\right| = k \qquad (2)$$

Here k is the material-dependent shear yield strength which, for example, can be determined from a torsion test. It is to be recalled that the stress state like the deformation state possesses principal axes. These axes, which are mutually perpendicular, represent the directions of the principal stresses σ_1, σ_2 and σ_3.

A planar state of stress with principal stresses σ_1 (the largest) and σ_3 (the smallest) can be represented by Mohr's circle, as shown in Fig. 3.

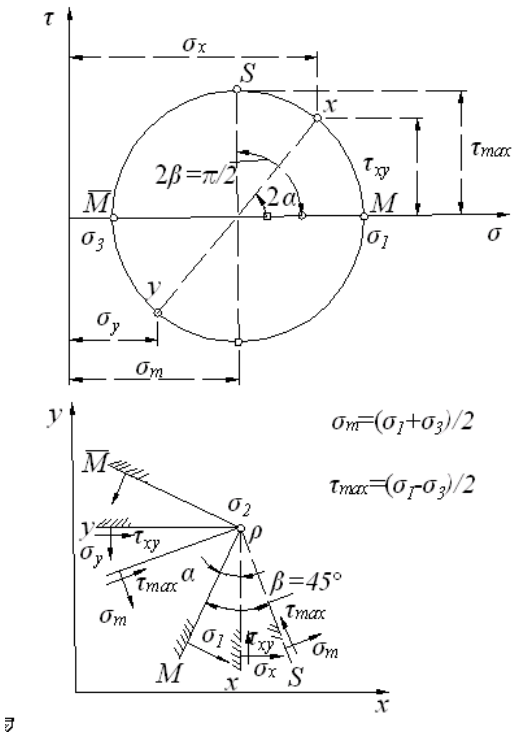


Fig. 3. Representation of plane state of stress by Mohr's circle

This circle, which represents the stress states at a point in the material for any rotation of the axes, has for its radius the maximum shear stress $\tau_{\max}$. The latter can be expressed as

$$\tau_{\max} = \frac{\sigma_1 - \sigma_3}{2} \tag{3}$$

$$\sigma_1 - \sigma_3 = 2k \tag{4}$$

Stress states which induce permanent deformation in the material are thus represented by Mohr's circle of radius *k*.

In the uniaxial tension test $\sigma_2 = \sigma_3 = 0$), one has, at the moment of yielding Fig. 4.

$$\sigma_1 = 2k \tag{5}$$

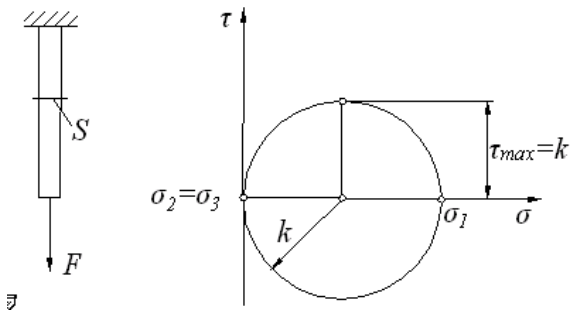


Fig. 4. Mohr's circle for uniaxial tension

$$\sigma_1 = \frac{F}{S} = k_f = 2k \tag{1}$$

$$2k = k_f \tag{6}$$

This yields

$$k = \frac{k_f}{2} \tag{7}$$

(4) and (6) $\Rightarrow \sigma_1 - \sigma_3 = k_f$.

The maximum shear-stress criterion, as a result, can be written as

$$\sigma_1 - \sigma_3 = k_f \tag{8}$$

An examination of Fig. 3. furthermore indicates that the position of the circle, or rather that of its center, in σ-τ space has no influence on the onset of yielding. The mean normal stress

$$\sigma_m = \frac{\sigma_1 + \sigma_2 + \sigma_3}{3} \tag{9}$$

whose negative value

$$p = \sigma_m \tag{10}$$

is known as the hydrostatic pressure, therefore, does not influence yielding. This agrees with the experimental observation that when a workpiece is subjected to a uniform pressure, creating a hydrostatic stress state everywhere

$$\sigma_1 = \sigma_2 = \sigma_3 = -p$$

then no permanent deformation results Fig. 5.

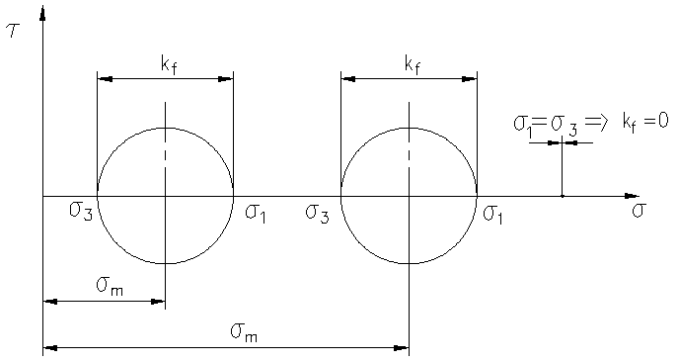


Fig .5. $\tau = f(\sigma_m)$

In determining whether or not a particular stress state has caused flow to occur, the maximum shear-stress criterion takes into account only a part of the stress state (for example, the largest and smallest principal stresses).

In comparison, the criterion of von Mises, which involves the energy of distortion, considers the entire stress state. It can be stated in the following way. The onset of flow must depend on a combination of normal and shear stresses whose magnitude does not change with a change in coordinate system. The latter is so because a coordinate system, and thereby the orientation of a material element, should have no influence on the yielding process.

Hubert 1904., von Mises 1913., und Hencky 1924.

$$W = W_v + W_o \tag{11}$$

$$W_1 = \frac{s_1 \cdot e_1}{2}$$
$$W_2 = \frac{s_1 \cdot e_1}{2} + \frac{s_2 \cdot e_2}{2}$$
$$W_3 = \frac{s_1 \cdot e_1}{2} + \frac{s_2 \cdot e_2}{2} + \frac{s_3 \cdot e_3}{2} \tag{12}$$

Hooke's law

$$e_1 = \frac{1}{E}[s_1 - n(s_2 + s_3)]$$
$$e_2 = \frac{1}{E}[s_2 - n(s_3 + s_1)] \tag{13}$$
$$e_3 = \frac{1}{E}[s_3 - n(s_1 + s_2)]$$

(12) and (13) $\Rightarrow$

$$W = \frac{1}{2E}\left[s_1^2 + s_2^2 + s_3^2 - 2n(s_1 s_2 + s_2 s_3 + s_3 \sigma_1)\right] \tag{14}$$

$$W_v = \frac{s_m \cdot e_v}{2} = \frac{1}{2}\frac{s_1 + s_2 + s_3}{3}(e_1 + e_2 + e_3)$$
$$e_v = e_1 + e_2 + e_3 = \frac{1}{E}\{[s_1 - n(s_2 + s_3)] + [s_2 - n(s_3 + s_1)] + [s_3 - n(s_1 + s_2)]\}$$

$$e_v = \frac{1-2n}{E}(s_1 + s_2 + s_3) \tag{15}$$

(14) and (15) $\Rightarrow$

$$W_v = \frac{1}{2}\frac{s_1 + s_2 + s_3}{3} \cdot \frac{1-2n}{E}(s_1 + s_2 + s_3) = \frac{1-2n}{6E}(s_1 + s_2 + s_3)^2 \tag{16}$$

$$W_v = \frac{1-2n}{6E}\left(s_1^2 + s_1^2 + s_3^2 + 2s_1 s_2 + 2s_2 s_3 + 2s_3 s_1\right) \tag{17}$$

(11) $\Rightarrow$

$$W_o = W - W_v \tag{18}$$

(15), (16) and (18) $\Rightarrow$

$$W_o = \frac{1}{2E}\left[\left(s_1^2 + s_2^2 + s_3^2\right) - 2n(s_1 s_2 + s_2 s_3 + s_3 s_1)\right] - \frac{1-2n}{6E}\left(s_1^2 + s_2^2 + s_3^2 + 2\sigma_1\sigma_2 + 2s_2 s_3 + 2s_3 s_1\right)$$

$$W_o = \frac{1+n}{6E}\left[(s_1 - s_2)^2 + (s_2 - s_3)^2 + (\sigma_3 - \sigma_1)^2\right] \tag{19}$$

$\sigma_2 = \sigma_3 = 0 \Rightarrow$

$$W_{o1} = \frac{1+n}{6E} 2s_1^2 \tag{20}$$

$$W_{o1} = W_o$$

$$2s_1^2 = (s_1 - s_2)^2 + (s_2 - s_3)^2 + (s_3 - s_1)^2$$

$$\sigma_1 = k_f$$

$$2k_f^2 = (s_1 - s_2)^2 + (s_2 - s_3)^2 + (s_3 - s_1)^2$$

$$k_f = \sqrt{\frac{1}{2}\left[(s_1 - s_2)^2 + (s_2 - s_3)^2 + (s_3 - s_1)^2\right]} \tag{21}$$

$$s_m = \frac{s_1 + s_2 + s_3}{3}$$
$$k_f = \sqrt{\frac{3}{2}\left[(s_1 - s_m)^2 + (s_2 - s_m)^2 + (s_3 - s_m)^2\right]} \tag{22}$$

$$j_1 = I(s_1 - s_m)$$
$$j_2 = I(s_2 - s_m)$$
$$j_3 = I(s_3 - s_m)$$

$$k_f = \sqrt{\frac{3}{2}\left[\left(\frac{j_1}{l}\right)^2 + \left(\frac{j_2}{l}\right)^2 + \left(\frac{j_3}{l}\right)^2\right]} \tag{23}$$

This criterion also contains as a special case the yield criterion for one-dimensional tension or compression Fig. 4.8. For with

$$\sigma_1 = \frac{F}{S}$$
$$\sigma_2 = \sigma_3 = 0$$

Then von Mises criterion becomes

$$\sqrt{\frac{1}{2}\cdot\sigma_1} = k_f$$

Both criteria also yield the same expression for the maximum shear stress at the onset of yielding,

$$\tau_{max} = \frac{1}{2}\sigma_1 = 0{,}5k_f$$

For other states of stress, the distortion energy criterion produces larger maximum shear stresses than the Tresca criterion. The largest difference between them occurs for the case of pure shear Fig.6.

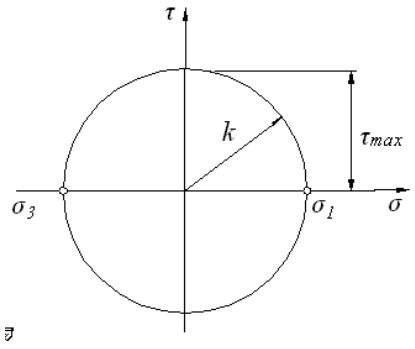


Fig. 6.Mohr's circle for pure shear

Here

$$\sigma_3 = -\sigma_1$$
$$\sigma_2 = 0$$

According to the shear-stress criterion, one obtains

$$s_1 - s_3 = k_f$$
$$s_3 = -s_1$$
$$s_1 - (-s_1) = k_f$$
$$2s_1 = k_f$$
$$s_1 = 0{,}5\,k_f$$
$$t_{max} = s_1 = 0{,}5\,k_f \tag{24}$$

while the von Mises criterion yields

$$(s_1 - s_2)^2 + (s_2 - s_3)^2 + (s_3 - s_1)^2 = 2k_f^2$$
$$\sigma_3 = -\sigma_1 \text{ and } \sigma_2 = 0 \Rightarrow$$
$$(s_1 - 0)^2 + (0 - s_1)^2 + [s_1 - (-s_1)]^2 = 2k_f^2$$
$$6s_1^2 = 2k_f^2$$
$$s_1 = \frac{k_f}{\sqrt{3}} = 0{,}577\,k_f$$
$$\tau_{max} = \sigma_1 = 0{,}577\,k_f \tag{25}$$

The differences in the maximum shear-stress prediction are thus seen to lie between 0 and 15%.

Experiments [12] Fig. 7.

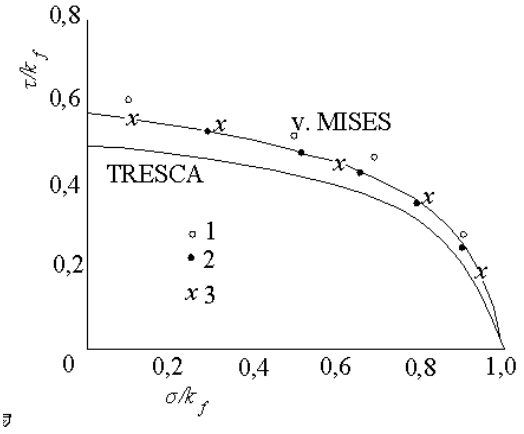


Fig. 7. Experiments [12] (1-St37, 2-Cu, 3-Al)

Special cases

a) $s_1 = s_2 \neq s_3$

$$2k_f^2 = (s_1 - s_2)^2 + (s_2 - s_3)^2 + (s_3 - s_1)^2$$
$$2k_f^2 = (s_1 - s_1)^2 + (s_1 - s_3)^2 + (s_1 - s_3)^2$$
$$k_f = s_1 - s_3$$

b) $s_1 > s_2 = s_3$

$$2k_f^2 = (s_1 - s_3)^2 + (s_3 - s_3)^2 + (s_1 - s_3)^2$$
$$k_f = s_1 - s_3$$

c) $s_1 > s_2 = \frac{s_1}{2} + \frac{s_3}{2} > s_3$

$$2k_f^2 = \left(s_1 - \frac{s_1}{2} - \frac{s_3}{2}\right)^2 + \left(\frac{s_1}{2} + \frac{s_3}{2} - s_3\right)^2 + (s_1 - s_3)^2$$

$$2k_f^2 = \left(\frac{\sigma_1}{2} - \frac{\sigma_3}{2}\right)^2 + \left(\frac{\sigma_1}{2} - \frac{\sigma_3}{2}\right)^2 + (\sigma_1 - \sigma_3)^2$$

$$2k_f^2 = \frac{6}{4}(s_1 - s_3)^2$$

$$\frac{2}{\sqrt{3}} k_f = (\sigma_1 - \sigma_3)$$

d) $\sigma_3 = 0$

$s_1 - s_2 = k_f$.

After the yield strength is reached, the material starts to flow under the influence of the stress state. In the plastic regime there exists no one-to-one correspondence between stress and strain as there is for elastic behavior. Rather, the same deformation can result from different stress states and vice versa. The following, however, is true in all cases:

1. If the material starts to flow at a particular point of the workpiece, then the stress state there must have reached the yield strength.
2. The manner of flow is dependent on the character of the stress state.
3. Normal strains cannot be directly related to the stresses.

The relation between the strain rates and the stress state is known as the flow rule. Expressed in terms of principal directions and incorporating the von Mises yield criterion, it can be written as

$$\dot{\varphi}_1 = \lambda(\sigma_1 - \sigma_m) \quad (26a)$$

$$\dot{\varphi}_2 = \lambda(\sigma_2 - \sigma_m) \quad (26b)$$

$$\dot{\varphi}_3 = \lambda(\sigma_3 - \sigma_m)\,. \quad (26c)$$

Flow rule general

$$\dot{\varepsilon}_x = \dot{\lambda} \cdot s_x = \dot{\lambda}(\sigma_x - \sigma_m)$$
$$\dot{\varepsilon}_y = \dot{\lambda} \cdot s_y = \dot{\lambda}(\sigma_y - \sigma_m)$$
$$\dot{\varepsilon}_z = \dot{\lambda} \cdot s_z = \dot{\lambda}(\sigma_z - \sigma_m)$$
$$\dot{\varepsilon}_{xy} = \frac{1}{2}\dot{\gamma}_{xy} = \dot{\lambda}\,\tau_{xy}$$
$$\dot{\varepsilon}_{xz} = \frac{1}{2}\dot{\gamma}_{xz} = \dot{\lambda}\,\tau_{xz}$$
$$\dot{\varepsilon}_{yz} = \frac{1}{2}\dot{\gamma}_{yz} = \dot{\lambda}\,\tau_{yz}$$
$$\dot{\lambda} = \frac{1}{k_f}\sqrt{\frac{3}{2}\left(\dot{\varepsilon}_x^2 + \dot{\varepsilon}_y^2 + \dot{\varepsilon}_z^2\right) + \frac{3}{4}\left(\dot{\gamma}_{xy}^2 + \dot{\gamma}_{yz}^2 + \dot{\gamma}_{xz}^2\right)}\,.$$

These relations express the fact that the principal strain rates are proportional to the difference between the corresponding principal stress and the mean stress σ_m. The right-hand side of these equations (26) incorporates the fact that under hydrostatic pressure no deformation takes place. The quantity λ is isotropic and can be assumed to depend on the material, temperature, strain, and strain rate.

3. MATHEMATICAL REPRESENTATION OF FRICTION

For purposes of predicting interface pressures, deforming forces, and energy requirements, the magnitude of τ_{fr} must be known. However, analysis is usually made simpler if the effect of friction is expressed by some non-dimensional parameter. To date, two such parameters have found wide acceptance.

Following Coulomb's classical definition, the coefficient of friction μ is simply the ratio of frictional force to normal force, or of frictional stress to normal stress (die pressure), Fig 8.

$$\mu = \frac{F_R}{F_n} = \frac{\tau_R}{p} = \frac{\tau_R}{\sigma_n}\,. \quad (27)$$

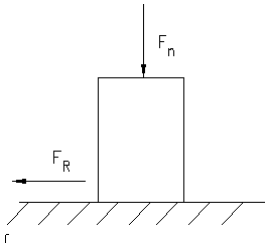


Fig.8. Variation F_R from F_n

It is possible that τ_R increases linearly with σ_n, and then μ may reach any constant value Fig. 9.

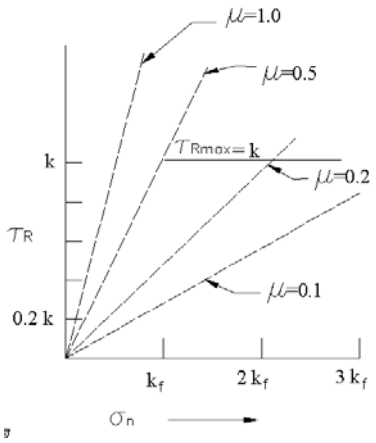


Fig. 9. Variation τ_R from σ_n for different μ

This is the case, for example, in the blankholder zone of a deep-drawing operation. However, μ cannot rise indefinitely because sticking friction sets in when $\mu \cdot \sigma_n \geq k$. In many bulk deformation processes $\sigma_n \succ\succ k$, and because k remains constant, the calculated μ actually drops, Fig. 10.

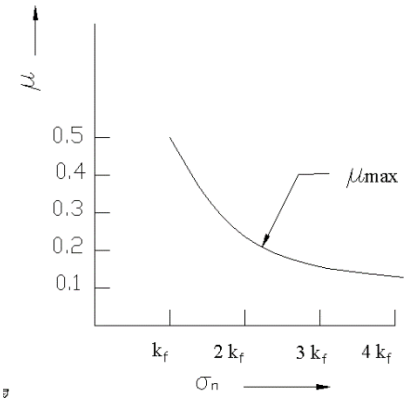


Fig.10. Variation μ from σ_n

The maximum value μ_{max} is obtained from yield criteria of pure shear, Fig.11.

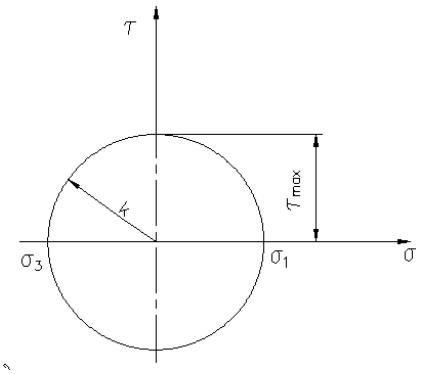


Fig. 11. Mohr's circle for pure shear

Here

$$\sigma_3 = -\sigma_1$$
$$\sigma_2 = 0$$

According to the shear-stress criterion, one obtains

$$s_1 - s_3 = k_f$$
$$s_3 = -s_1$$
$$s_1 - (-s_1) = k_f$$
$$2s_1 = k_f$$
$$s_1 = 0{,}5\, k_f$$
$$t_{max} = s_1 = 0{,}5\, k_f$$

$$\mu_{max} = \frac{\tau_{max}}{k_f} = \frac{0.5 k_f}{k_f} = 0{,}5 \qquad (28)$$

while the von Mises criterion yields

$$(s_1 - s_2)^2 + (s_2 - s_3)^2 + (s_3 - s_1)^2 = 2k_f^2$$
$$\sigma_3 = -\sigma_1 \text{ and } \sigma_2 = 0 \Rightarrow$$
$$(s_1 - 0)^2 + (0 - s_1)^2 + [s_1 - (-s_1)]^2 = 2k_f^2$$
$$6s_1^2 = 2k_f^2$$
$$s_1 = \frac{k_f}{\sqrt{3}} = 0{,}577\, k_f$$
$$\tau_{max} = \sigma_1 = 0{,}577\, k_f$$

$$\mu_{max} = \frac{\tau_{max}}{k_f} = \frac{0.577 k_f}{k_f} = 0{,}577 \qquad (29)$$

Lighter is the shift in Fig. 12. then in Fig.13.

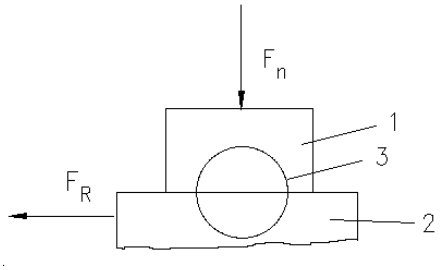


Fig. 12. Friction, 1-die, 2-workpiece, 3-increased

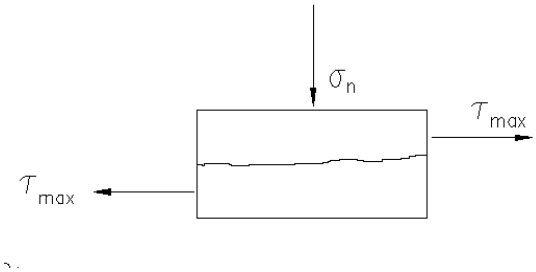


Fig. 13. Pure shear

Since $k \cong 0{,}5k_f$ (or $0{,}577k_f$ according to von Mises), it is sometimes said that μ_{max} = 0.5, but this is true only when $\sigma_n = k_f$. It is much more accurate to say that the coefficient of friction becomes meaningless when $\mu\sigma_n \geq k$, since there is no relative sliding at the interface. The possible misinterpretation of μ has led to the introduction of the frictional shear factor *m* defined as

$$\tau_i = \tau_R = mk \tag{30}$$

$$0 \leq m \geq 1 \tag{31}$$

Since τ_R is now linked to a workpiece material property *k*, which is a priori known (rather than to σ_n which must be calculated), the use of *m* greatly simplifies calculations, especially those based on upper-bound theory or numerical techniques.

4. BOWDEN –TABOR THEORY

Fig. 14 shows a friction pair.

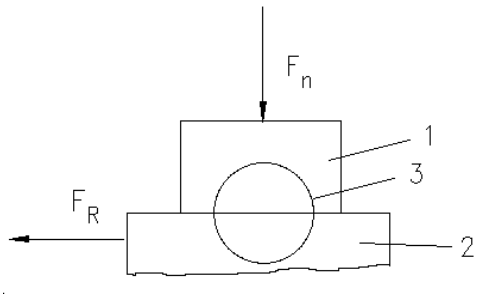


Fig.14. Friction pair, 1-die, 2-workpiece, 3-increased

Bowden – Tabor theory differs:

1. Cold forming and
2. Hot forming.

4.1 Bowden–Tabor Theory for cold forming

In selected image, Fig.9 (3) it increases; it gets the friction model cold forming, which is shown in Fig. 15.

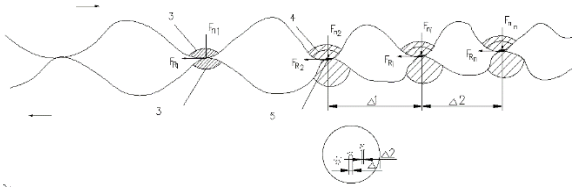


Fig.15. Friction model for cold forming [23]

$\Delta 1 = \Delta 2 \Rightarrow \mu = \text{const.}$

$\Delta 1 \neq \Delta 2 \Rightarrow \mu = \text{not const.}$

It is important in this model shown in Fig. 10, that the two bodies are in contact only at certain locations where the tool touches the projection with the projection of the workpiece. The encountered in forming forces are 2000 to 3000 MPa distributed to some stochastic present contacts bulges. This creates the local pressures at these points very large with overlays clean metal surfaces in places like contact, and there is a local cold welding parts tools and the workpiece. In order to make the material flow between the two bodies (tool and workpiece), there must be a relative movement, which means that it must be the local change of the cold welding Disconnect.

Breakthrough will inevitably happen on tool wear and workpiece. If the frictional contact

between the pair declined, thereby reducing the frictional force, is necessary to lubricate Fig. 16.

Fig. 16. Lubrication of the friction pair, 1- lubraction

Number of local cold welds depends on the lubrication and friction μ in the cold metal forming, when good lubrication is 0,05-0,1.

Lubricants:

MoS_2
graphite
emulsion
PbS
fats
soap.

4.2 Bowden – Tabor Theory for hot forming

In selected image, Fig.14. (3), it increases; it gets the friction model hot forming, which is shown in Fig. 17.

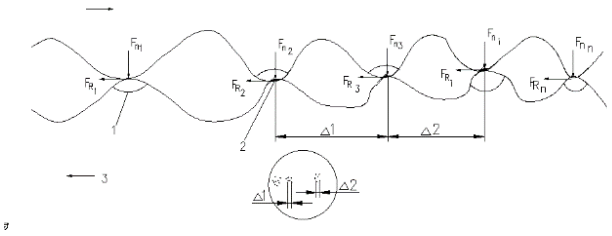


Fig. 17. Friction model for hot forming [12]

$\Delta 1 = \Delta 2 \Rightarrow \mu = \text{const.}$

$\Delta 1 \neq \Delta 2 \Rightarrow \mu = \text{not const.}$

It is important in this model shown in Fig. 17, that the two bodies are in contact only at certain locations where the tool touches the projection with the projection of the workpiece, and distributed to some stochastic present contacts bulges. This creates the local pressures at these points very large with overlays clean metal surfaces in places like contact, and there is a local hot welding parts tools and the workpiece. In order to make the material flow between the two bodies (tool and workpiece), there must be a relative movement, which means that it must be the local change of the hot welding Disconnect.

Number of local hot welds depends on the lubrication and friction μ in the hot metal forming, when good lubrication is 0,1 1-0,3.
Lubricants:
MoS_2
Graphite.
Fig. 18. shows the lamellar structure of the graphite and Fig. 19. presents the dependence of the friction μ from stress.

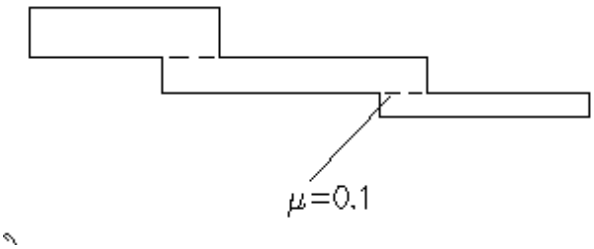
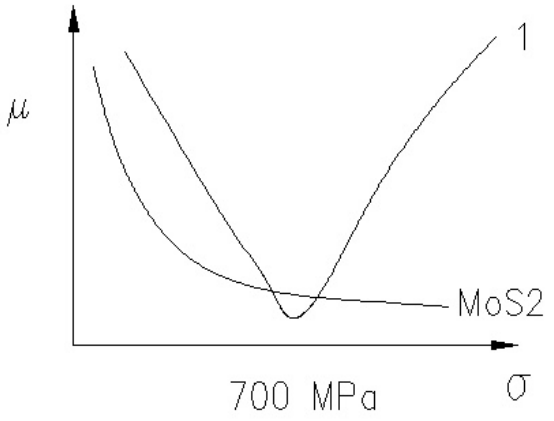


Fig. 18. Lamellar structure of the graphite

Since the graphite is composed of a lamellar structure, wherein said start with low force to a lubrication with the graphite is μ =0.



1. Graphite

Fig. 19. Depending friction of the stress

5. WEAR

Layer structure of metallic surfaces by Schmaltz, Fig. 20.

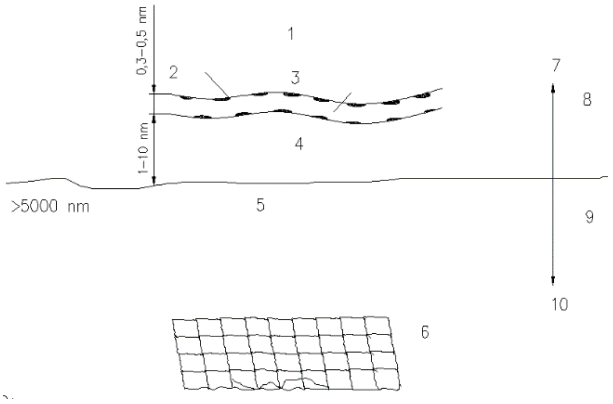


Fig. 20. Layer structure of metallic surfaces, Schmaltz Schema (1), 2-hard phase, 3- adsorbed film, 4-oxide film, 5-distortion field, 6-bulk, 7-outer boundary layer, 8-reaction layer of the inner boundary layer surrounding atmosphere, as well as with surface-active substance, 9-inhomogeneity in hardness, strength, deformation, texture, 10-intriol boundary layer [12]

Wear in general causes change in the size, shape, weight or state of the surface. It is an undesirable loss of metal particles for mechanical reasons, but also duet to chemical effects. Friction and wear in metal forming are occurring on the contact surfaces of friction, i.e. between a tool and a workpiece.

6. CONCLUSIONS

For multiaxial stress states, the onset of yielding is not dependent on a single stress (for example, the largest tensile or compressive stress), but on a combination of all stresses. From the many yield criteria which have been proposed, two have shown good agreement with experimental results (Tresca and von Mises).
Friction is sometimes helpful. For example, high friction on the punch surface helps increase reductions in deep drawing and ironing. In a few instances it has to have at least some small value, as in rolling where it assures entry of the workpiece into the roll gap and helps maintain rolling without skidding of the workpiece. However, in most instances friction is preferably reduced to zero by the introduction of a lubricant. The paper presentans the difference between:

The coefficient of friction $\mu(\sigma_n = k_f)$

and the factor of friction $m(\mu\sigma_n \geq k)$.

7. REFERENCES

[1] K. Lange, Lehrebuch der Umformtechnik Bd 1-3 Berlin /Heidelberg/New York: Spring-Verlag, (1972-1975).
[2] K. Lange, Handbook of metal forming McGraw-Hill, (1985).
[3] K. Lange, Lehrebuch der Umformtechnik Bd 1-4 Berlin /Heidelberg/New York: Spring-Verlag, (1988-1993).
[4] B. Grizelj, Oblikovanje metala deformiranjem Slavonski Brod Strojarski fakultet, (2002) (sveučilišni udžbenik).
[5] B. Grizelj, Alati i naprave Slavonski Brod Strojarski fakultet, (2002) (sveučilišni udžbenik).
[6] B. Grizelj, Seuček, I.: Rezni alati noževi glodala Slavonski Brod Strojarski fakultet, (2007) (sveučilišni udžbenik).
[7] B. Grizelj, Strojevi za oblikovanje metala deformiranjem Slavonski Brod Strojarski fakultet, (2007) (sveučilišni udžbenik).
[8] B. Grizelj, Oblikovanje lima deformiranjem Slavonski Brod Strojarski fakultet, (2009) (sveučilišni udžbenik).
[9] B. Grizelj, Volumensko oblikovanje deformiranjem Slavonski Brod Strojarski fakultet, (2012) (sveučilišni udžbenik).
[10] B. Grizelj, Prilog istraživanju elastičnog vraćanja čeličnih dvostruk zakrivljenih ploča nakon izrade hladnom plastičnom deformacijom, Magistarski rad, Zagreb, (1982).
[11] Grizelj, B.: Doprinos analizi aksijalno simetričnog savijanja lima, disertacija, FSB, Zagreb, (1994).
[12] B. Grizelj, Oblikovanje metala deformiranjem Umformtechnik Metal forming Slavonski Brod Strojarski fakultet, (2018) (sveučilišni udžbenik)

Application of metal coatings on additive produced polymeric parts

J.Groš [a], P.Raos [b], J. Stojšić [b]

[a] University of applied science Karlovac, I.Meštrovića 10, 47000 Karlovac, Croatia, josip.gros@vuka.hr

[b] Faculty of Mechanical Engineering in Slavonski Brod, Trg Ivane Brlić-Mažuranić 2, 35000 Slavonski Brod, Croatia, praos@usnib.hr, jstojsic@unisb.hr

Abstract

During many years, injection molding of the polymer molds has been proven as a quick way to make products for medium to high series production. In order to produce a quality product, all stages of the process must be controlled (ex. tool, material, injection molding machine, etc.). During the last two decades additive technology regarding prototype production and, more recently, regarding finished products has been developing intensively. The biggest disadvantage of additive technology is a limited choice of polymeric materials and different mechanical properties when compared to products manufactured by injection molding technology. Creating the mold for the injection molding process is time-consuming and expensive process, also unprofitable for smaller series. By making injection molds using additive technology, we accelerate the process of production of finished products. One of the disadvantages of making molds using the mentioned technology is the durability of the molds. In order to increase the durability of the mold, the area regarding application of the coating to the mold will be examined.

Keywords: additive technology, application of protective coatings, polymer mold

1. INTRODUCTION

Additive manufacturing (English Additive Manufacturing) is a part of production engineering that deals with the production of objects by applying particles in thin layers. The production process begins with the construction of a three-dimensional model with computer CAD modeling programs, or with the digitization of the spatial form of an already existing object with three-dimensional scanners.

The model is then transformed into a series of horizontal cross-sections that are printed layer by layer with a machine until the final product is finished. With this process, prototypes, molds and tools of high precision can be made just as successfully as ready-to-use functional parts. However, the speed of production, the choice of materials and the dimensions of the model are currently limited. [1]

Through research and through practical work on devices for additive technology, shortcomings were recognized and they will continue to be an obstacle for the full implementation of additive technology in the production process. One of the major disadvantages of additive manufacturing is that the material that is limited to a certain type of polymer developed exclusively for additive technology.

Since manufacturers continuously change the material for additive technology, scientists often have no motivation to examine the properties of the material. Another problem of technology is dimensional accuracy when manufacturing a large number of similar products (dimensional traceability). Figure 1. shows the optimal area for the use of additive technology.

Mostly, the field of application of additive technology is limited to individual production with greater geometric complexity.

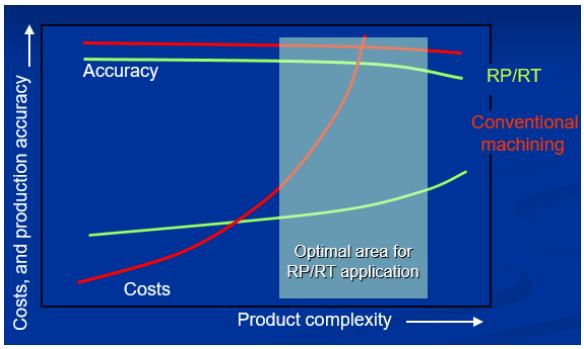


Fig. 1. Diagram of application of additive technology [2]

Very little research has been conducted on the topic of making molds from polymer materials using additive technology. New markets demand faster delivery of the finished product as well as personalization according to the client's wishes. The Croatian market usually has small-scale or serial production. Thanks to that, the costs of making metal molds represent a rather expensive and time-consuming process.

Previous studies of molds made of polymer materials using additive technology go in the direction of very small series of some 100 to 300 cuttings. [3] [4] There is no emphasis on making hundreds of products in such a way. In the following text, the research in the field of application of protective coatings, which was carried out as part of the preliminary research for the doctoral dissertation, will be presented.

2. RESEARCH EQUIPMENT AND MATERIALS

2.1. Additive devices used in the research

Two types of technologies were used for the production of the test bodies: depositional joining - FDM (Figure 2) and Hybrid process of 3D printing and stereolithography (Figure 3.). Additive device Makerbot's has two heads, i.e. nozzles, and can simultaneously make parts from two different materials or from the same material only in different color. It can also be completely closed, which prevents heat loss, which favors the 3D creation of objects, and is therefore extremely suitable for the polymer material ABS. It can also work with PLA, PS-HI and TPE materials.

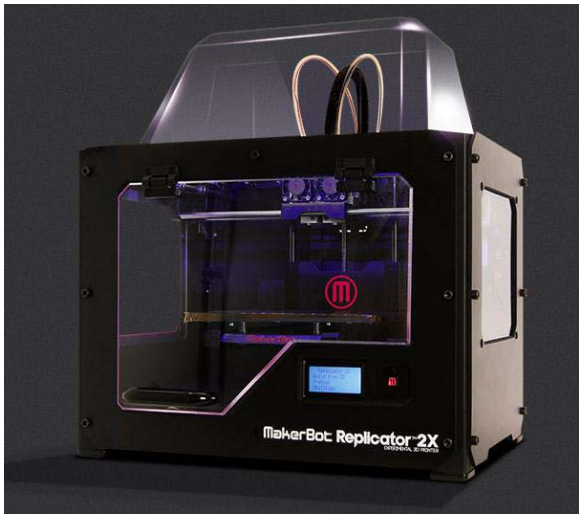


Fig. 2. Maker Bot Replicator 2x [5]

Another device that was used to create the test bodies was the Objet350 Connex. Device enables simultaneous printing of several different types of materials, thus removing the need for subsequent joining of individual parts.

Fig. 3. Objet Connex 350 on Faculty on engineering and naval technology in Zagreb

2.2. Types of materials used for making test bodies

The additive device Maker Bot Replicator 2x uses the polymer material ABS (Acrylonitrile Butadiene Styrene). ABS is the most common material in FDM additive devices. Some of the significant characteristics of the material are: its price, suitability for various purposes, as well as simple finishing by sanding, in order to achieve smooth surfaces and remove jagged edges, as well as painting. [6]

Figure 4. shows the test bodies made from ABS polymer using the Maker Bot Replicator 2x. In the first phase, the test bodies were made according to the ISO EN ISO 527:2012 standard.

Fig. 4. Test bodies made on FDM device

The additive device Objet Connex 350 offers a wide range of materials. Three types of materials were chosen: Digital ABS, Tango Black Plus and Vero Clear. Figure 5. Shows the test bodies after production on the additive device Objet Connex 350. Since in the first phase different types of spreads or protective coatings are being examined, it was decided to change the dimensions of the test bodies from the ISO EN ISO 527:2012 standard to 24x80x7 dimensions.

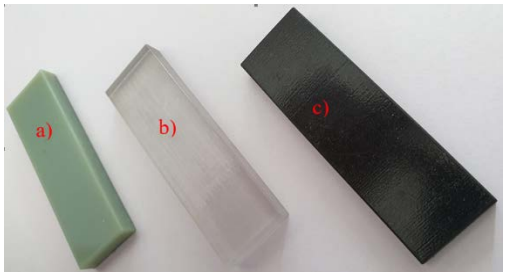


Fig. 5. Test bodies a) Digital ABS b) Vero Clear c) Tango Black Plus

3. EXAMINATION OF COATING APPLICATION

The Nova Chem company provided us with two temperature coatings based on metal coatings. The first was based on zinc and temperature resistant up to 400 °C (novasil zinc 400), while the second was based on aluminum with temperature resistance up to 600 °C (novasil al 600).

Figure 6. shows the coating applied to the test body according to ISO EN ISO 527:2012, made of ABS material using FDM additive technology. Before applying the coating, both test bodies were coated with an acrylic coating for the purpose of better adhesion of both coatings (novasil zinc 400 and novasil al 600).

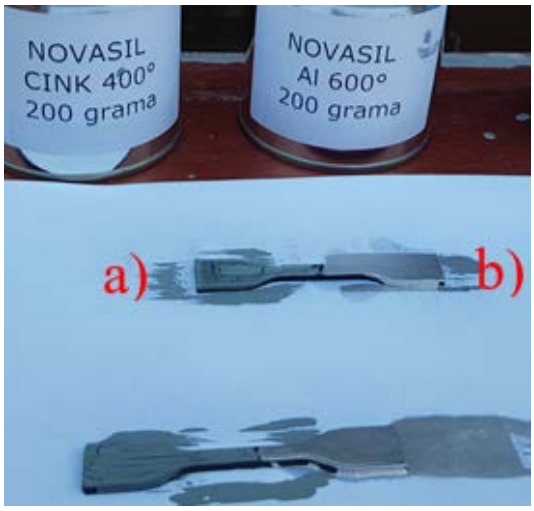


Fig. 6. Application of a) novasil cink 400 i b) novasil al 600

Figure 7. shows the absorption of Novasil zinc 400 (left side) which was not well absorbed into the surface. Novasil al 600 was well absorbed into the surface and the research was continued with it.

Fig. 7. Absorption of Novasil cink 400 i Novasil al 600 coatings

Another method of applying the metal coating was vacuum metallization in the

KOOGLE workshop by vaporizing aluminum on the test body, which is done for decorative purposes (Figure 8.). Aluminum metallization was performed on test bodies made on the additive device Objet Connex 350, and the material of the test body was Digital ABS.

At the top of test bodies one hole were made for easier acceptance of the test bodies. Since the polymer is metallized using aluminum for the purpose of a decorative nature, after each metallization process the application of a colorless varnish is necessary.

Fig. 8. Aluminum metallization

In the company Tiplon d.o.o. copper electroplating was carried out on all three test body materials. The company has three electroplating systems: CHEMCUT, ATOTECH and LANTRONIC.

Since the scope of the company is the production of printed electronic boards, all systems are intended exclusively for this purpose. Figure 9 shows copper plating, i.e. electroplating of test bodies made of a) Digital ABS b) Vero Clear c) Tango Black Plus.

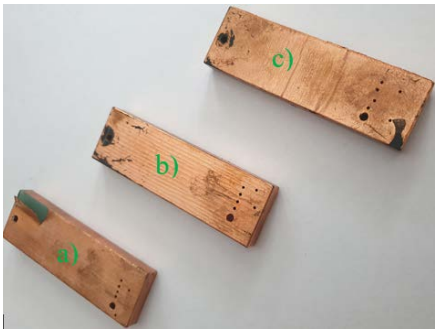


Fig. 9. Copper plating on a) Digital ABS b) Vero Clear c) Tango Black Plus.

The copper coating was not well absorbed into the surface on any of the three test bodies. A copper sheath was made. However it was not sufficient to apply any other material using electroplating. In order to achieve that, it was decided to apply an electrically conductive primer that is usually applied during electrostatic painting in the automotive industry.

AD Plastik came to meet us and applied a layer of electrically conductive primer to the three test bodies. In the company Tiplon, the copper layer was applied once again using electroplating.

Figure 10 shows three test bodies. Two stages of applying the copper coating were made: The first stage was the installation of an electrically conductive primer for the electrostatic application of paint. The second stage was the application of copper. Figure 10. b) shows the test body after it was directly connected to the electrode.

Due to the need for high current, electroplating did not occur. Figure 10. c) shows the subsequent application of paste for electrical conductivity, after which a labile copper layer was obtained.

Fig. 10. Copper electroplating – electrically conductive primer

4. RESULTS AND ACHIEVEMENTS

After the research of the application of different types of coatings on the test bodies was conducted, the conclusion is that with FDM technology and ABS material, Novasil al 600 has better adhesion. (Table 1.)

Table 1. Results FDM.

Method of creating the test body	FDM	
Type of test body material	ABS	
Type of coating	Novasil zinc 400	Novasil al 600
Results of adhesion	Not well absorbed	Well absorbed

Table 2. shows the application of coatings on test bodies made by the Polyet process. The ABS tube that was aluminum metallized has the best adhesion. Other coatings have very poor adhesion.

Table 2. Results Polyet.

Način izrade ispitnog tijela	Polyet				
Type of test body material	Digital ABS	Digital ABS	Digital ABS	Vero Clear	Tango Black Plus
Type of coating	Aluminum metallization	Copper plating	Copper electroplating – electrically conductive primer	Copper plating	Copper plating
Results of adhesion	Well absorbed	Not well absorbed	Not well absorbed	Not well absorbed	Not well absorbed

5. CONCLUSION

Research conducted on the application of coatings on polymer products made with additive technology laid the foundations for further research development.

It is recognized that the adhesion of the polymer surface has a significant influence on the adhesion of the protective coating. Better surface activation is needed. It is also necessary to pay attention to the amount of energy that enters the electrolysis process, because it can cause the polymer meltdown.

Making molds using additive technology lays the foundation for the production of individualized products that have high-quality mechanical properties equal to those of molds made of metal. Making polymer molds using additive technology is an economically acceptable and significantly faster process. In further research, the goal is to achieve good adhesion of the surface and the copper coating, which will enable the application of different types of metal coatings.

6. REFERENCES

[1] https://www.additivemanufacturing.media (8/2020)
[2] https://www.javelin-tech.com/ (8/2020)
[3] https://www.3dhubs.com/ (8/2020)
[4] Godec D., Šercer M.; Aditivna proizvodnja tvorevina (e. Rapid Protoyping – RP, Rapid Tooling – RT, Rapid Manufacturing – RM) , 2012
[5] https://www.makerbot.com/ (8/2020)
[6] http://3dprintingforbeginners.com/(8/2020)

Dynamic load of the knee joint and gait analysis

H. Ilijazović [a], D. Kozak [a], M. Kasović [b], L. Štefan [b]

[a] Mechanical Engineering Faculty in Slavonski Brod, Trg Ivane Brlić Mažuranić 2, 35000 Slavonski Brod, Croatia, E-mail: {hilijazovic, dkozak}@unisb.hr

[b] Faculty of Kinesiology Zagreb, Horvaćanski zavoj 15, 10110 Zagreb, Croatia,

E-mail: {mario.kasovic, lovro.stefan}@kif.unizg.hr

Abstract

Maintaining stability in the knee joint is important because of the maintenance of body balance in the space and walking. One of the areas that biomechanics deals with is the understanding of the influence of forces on some changes occurring in joints, including in the knee. The topic of this paper is the biomechanical of the knee joint and analysis of walking and how the analysis of walking can help us prevent and detect injuries and irregularities in the knee joint. The biomechanical analysis of the knee joint is described in the paper, which can further explain the knee movements while walking and sports activities. The pedobarography procedure analysed walking parameters in static and dynamic measurements on subjects with multiple foot deformations and Varus leg deformations. This paper describes the relationship between biomechanical and walking analyses and their interdependence. The measurement for work purposes was conducted at the Biomechanical Laboratory at the Faculty of kinesiology in Zagreb.

Keywords: biomechanics, knee joint, gait analysis, pedobarography

1. INTRODUCTION

The knee joint is the most complex and largest joint in the human body. Maintaining stability in the knee joint is of great importance because of the maintenance of body balance in the space and walking. One of the areas that biomechanics deals with is understanding the influence of forces on changes occurring in joints and knees. One of the main signs of knee joint disorder is motion disorder.

Within the framework of this paper, there was an analysis of walking in the laboratory at the Institute of Biomechanical Engineering at the Faculty of kinesiology in Zagreb using a procedure called pedobarography. After the analysis of the walk, it is analysed how the changes in the knee joint affected the test results. Unlike the papers describing some external influence affecting the walk and the knee joint [2], this paper describes the internal influences (deformations) that affect the walking disorder. The mentioned problems and the aim of the research imposed the title of the paper: “Dynamic load of the knee joint and gait analysis”.

2. KNEE BIOMECHANICS

The joint must ensure a strong link between bone oocytes and this link should provide maximum mobility. The main mechanical properties of joints are therefore strength and

mobility. The strength of the joint implies that the joint has the capacity to resist the forces that affect it during motion. On the anatomical side, joint strength is maintained by stabilisers, and the most important stabilisers are muscles [1].

The knee joint consists of an angular and rotational joint and is one of the two axial movable joints. We distinguish between two rotation axes, both longitudinal and transverse. The knee joint can be called a modified ball joint because it can also perform mild internal rotation in addition to flexion and extension. On the transverse axis there is a flexion and extension (spring) of the upper leg, and around the longitudinal axis there is a rotation of the upper leg (out and inside). In the end, one should not forget the simplest "movement" in which the knee participates, namely the standing. When standing there is only the gravity force G whose amount is equally distributed on both knees, and its direction is vertical.

Knee flexion is possible only up to 120 or 130 degrees, depending on joint mobility. If the upper leg is affected by some external forces, then the flexion is possible up to 160 degrees.

Extension of the knee joint is possible only when the upper leg and upper leg make up an angle of 180 degrees and is called zero position. However, as with flexural behaviour, some external influences (forces) may occur and hyperarexenia occurs; knee position occurs when it crosses the zero position in the positive direction.

Apart from flexural and torsion, we differentiate between the rotation of the knee joint. Rotation cannot occur while the knee is in zero position; however, when the knee joint is in a semi-bent position, the upper leg is rotated around the longitudinal axis in or out. The most important form of knee rotation is the final knee rotation; it is the knee protection mechanism for passive and active joint extension [2].

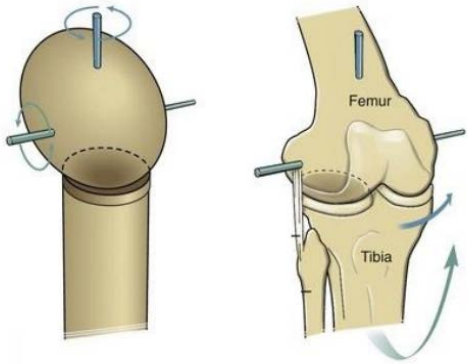


Fig. 1. Knee movements [2]

3. GAIT ANALYSIS

Each individual has its own distinctive way of walking, because the way of walking depends on many individual factors such as: gender, age, constitution, development, walking rhythm or footwear selection. Walking is a movement process in which the body moves forward, and first it relies on one leg and then on the other. The walk at each individual is different and you will never see two persons walking the same way.

3.1. Gait Cycle

The gait cycle is defined as the period between two established fifth (two-step) contact with the base of the same leg. The walking cycle consists of two phases; the stance and swing phase.

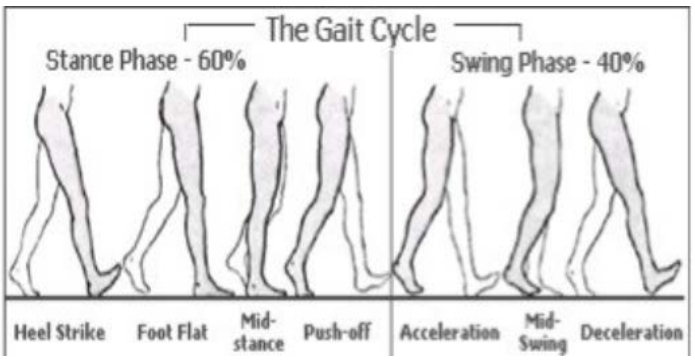


Fig. 2. The gait Cycle [3]

The stance phase is a supporting phase where the foot achieves contact with the base and makes 60% of the walking cycle. The phase consists of several substages: the fifth impact phase, the flat foot phase, the middle footing phase, the fifth lifting phase and the finger lifting phase. The swing phase consists of three substages: upstream (accelerating phase), intermediate and downward (deceleration phase). Another important term for walking is the length of step that we define as distance during the step, measured from the initial contact between one leg to the initial contact between the other leg.

3.2. Pedobarography

Pedobarography or analysis of pressure distribution is a biomechanical method that provides a detailed insight into the anatomical and functional structure of the foot while it interacts with the base in dynamic or static conditions. In addition to diagnosis of conditions, pedobarography enables monitoring and evaluation of medical treatment procedures (selection of surgery, rehabilitation) [3].

We distinguish between two types of pedobarography: static and dynamic. Static studies the pressure field during static activities (standing, body movement, but without feet lifting). Dynamic pedobarography deals with the study of pressure fields in dynamic activities such as walking, running. The base forces operating on the platform consist of one vertical and two horizontal components, antero-posterior and medio-lateral. The antero-posterior component acts in the direction of the foot, that is, in the direction of the fifth-finger, and the Medio-lateral transverse, perpendicular to it [4].

During walking along forces, moments appear that move joints and muscles. Forces and moments occur when contact with the base is made and can be presented as one resultant force and one resultant moment operating at the point of the catch. This point is called the Centre of pressure (COP) and its position is constantly changing, which will be seen later in the analysis of the gait report.

3.2.1 Measurement procedure

The measurements were performed on a Zebris platform with dimensions of 158 × 60.5 × 2.1 cm with 11264 sensors on it and a reading speed of 100 Hz. Unlike platforms that operate on the principles of force converters, zebris platforms for pedobarography is used by sensors. The platforms are rectangular in shape and can be of different dimensions. The network of measuring sensors is set up throughout the platform so that pressure can be measured on the sensor at all times because no one has the same walking pattern.After the pressure measured, each sensor analyses the data and provides an image of the pressure distribution across the surface of the foot in the gait report.

The measurement shall be performed so that the examinee passes eight times by default 9.5 m long track and turns 180 degrees after the run and repeats this action 2 minutes. In the middle of the trail there is a platform with sensors through which the examinee passes as much as possible by natural walk, normal speed.

Respondents can walk at different speeds, but the most accurate results are obtained when walking at normal speed, i.e. at natural speed at which the respondent usually walks. If the measurement failed or the results are invalid, the test shall be repeated. The measurement in the static shall be performed so that the examinee stands on the platform for a few seconds until the results are readable. Measurement may be made on one or two legs depending on the need of the test. The result of dynamic and static measurements is a gait report that provides all necessary data for further analysis. The method is completely non-invasive and can be implemented several times.

Fig. 3. Preparation for measuring

4. ANALYSIS OF GAIT REPORT

As mentioned above, the gait report is a product of walking measurements and it provides all necessary data on the subject's feet, and through walking and foot disorders it can further analyse problems caused by feet in the knee.

The dynamic gait report consists of a 3D graph of pressure that affects the feet, the display of pressure on each foot, walking parameters on each foot that are analysed in detail (geometry, phase and time), the analysis of the foot line and the analysis of force and pressure that affect each foot.

The static gait report consists of an analysis of the pressure applied while the examinee stands, a chart of forces per foot and the calculation of the average force per foot, but also per foot zones (front and back) [6].

4.4.1. Dynamic gait report

In this paper, the following parts of the walking report will be described for static analysis; showcase of foot pressure distribution and parameters , COP analysis and analysis of three foot zones.

At the beginning of the report, a 3D display of pressure distribution for each foot is presented. It is marked with colours so that we can easily and quickly recognize where the greatest is, and where the least pressure is and in what intensity. In the Zebris system, pressure can be measured from 0 to 60 N/cm^2. Smaller amounts of pressure are shown in blue and green shades, and by increasing its amount it reaches red colour. Feet in the 2D representation are further presented and we can see an overview of the average amount of pressure during the test and the maximum amount of pressure on the parts of the feet that it achieves during the measurement. On this example we can observe that the average amount is within the limits of normal amounts (in this part we cannot see exact amounts) and that on the right foot there is greater pressure than on the left and in the area of the fifth. The maximum pressure representation gives us a different view. It can be seen that the pressure is increased on the fingers (red colour) on both legs and on the heels (yellow colour).

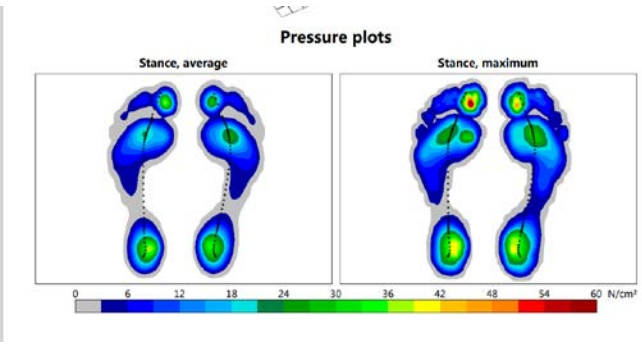


Fig. 4. Pressure plots

The second part of the report contains walking parameters. Walking parameters are divided into three tables as shown in Figure 5. The tables describe the walking geometry, walking phase in percentages and time calculated based on measurement time. All the data in the tables were compared with the maximum amounts that can be achieved and deviation was given along with the amounts measured.

The walking geometry data table consists of rotating the feet, the length of the steps and the total length of the steps (the whole step from the fifth hind leg to the thumb of the swing leg is summed up) and the width of the foot measured

at the moment the examinee stopped at the full foot on the platform.

The rotation of the foot shows how much the foot rotates when the foot is removed from the base, the rotation angle can be negative and means the foot rotates towards the inside, and the positive angle means the foot rotates outward. In the report, the maximum rotation of the foot is 15 degrees and it is measured for each foot, in the example for the left foot it was measured in a negative amount of -0.1 degrees, and for the right foot 11.3 ± 1.2 degrees, which shows that the examinee relied on the right foot during measuring on the platform and that the left foot goes more outward.

The second table refers to the walking stages and how much each leg participates in a particular phase. The table presents the footing stage, first contact, intermediate phase (centre part of the walk), before momentum, swallowing and double-support phase and phasis expressed as a percentage with permitted deviation for each leg.

In the support phase it can be seen that the left leg is more active than the right leg, but not for too large an amount, so we can say that they participate in the support equally. 62% was observed for the left leg and 60.7 ± 0.4% for the right leg. The second part is the first contact of the fingers with the background, there is a slightly greater deviation between the results, 10.2% was recorded for the left leg, and 13% for the right, and here it can be concluded that the respondent relies on the left foot. In the middle phase it stops with a full leg on the platform and there is a very small difference here, so it can be concluded that both sides participate equally in it. The left leg was 38.9% and the right leg was 38%. In the near-momentum, 13% was recorded for the left leg, and 10.3 ± 0.1% for the right leg, and here we have another confirmation that the left leg respondents are stronger than the right leg. The last component is the phase of double backbone and it is not measured for each foot but the total amount and, in this example, the amount 23.1% of all walks.

Fig. 5. Gait parameters

The following part of the report analysis consists of an overview of the change in the position of the pressure centre during walking and a comparison between the left and right feet forming the shape of a butterfly, which is also referred to in the report as butterfly (Butterfly), as shown in Figure 5 and a table of parameters describing the change in the amount of the pressure centre. Figure 5 in letter A indicates the length of one line of change to the pressure centre during walking (full foot phase), letter B indicates the length of one line during the step and letter C indicates the front/rear position representing the distance from the line connecting the heels of both footsteps to the intermediate point where the COP line is cut. In this example it can be seen that the length of the pressure centre line during walking is more uniform on the left foot than on the right foot. This part of the report walks often when making orthopaedic cartridges because it requires a detailed analysis of each foot to determine the width, length and thickness of the cartridge.

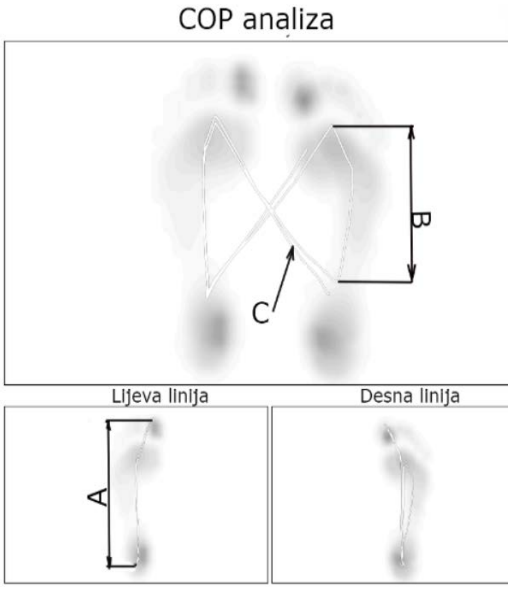


Fig. 6. COP analysis of both feet

The last part of this part of the report is the analysis of three foot zones (fifth, middle leg and front leg), as the first part shows the whole foot and the distribution of pressure for the whole foot, the force and part by part of the foot are shown here and the amounts of force in colours are presented separately for each foot. On the example shown in fig .6., we can see that the greatest force is on the front of the left foot (painted red) and on the fifth right foot. Each foot zone also has the time of action of forces, $F_{max}\,t_1$ denotes the time of action of maximum force on the heel, $F_{max}\,t_2$ the time of action of maximum force on the front leg and $(t_1 + t_2)$/t denotes the time of force distribution between two times.

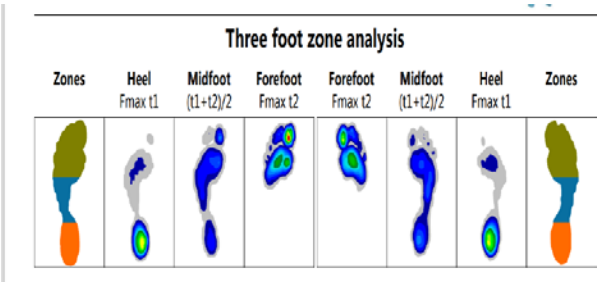


Fig. 7. Three foot zone analysis

4.4.2 Static gait report

The static walking analysis report consists of two works; the first part is the graphical representation of the feet, and the second is the analytical representation of the amount and parameters of the static measurement. In this example, the greatest amount of force is on the fifth left foot. However, unlike the static analysis, this representation has additional components as shown in Figure 8.

In letter A, the lines of the pressure centre (COP) are marked for the right and left, while in letter B 95% of the measurement areas of the pressure centre are marked. Each point of the pressure centre has its coordinates which are readable from the centre of the ellipse, and all points together when they connect form a COP line. Point B can mathematically be characterized as an ellipse with 95% accuracy level.

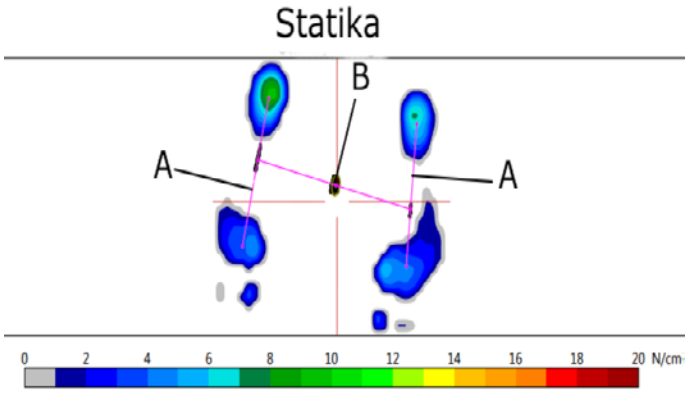


Fig. 8. Static pressure plots

The second part of the first part of the report are tables containing all geometric and time parameters relevant for this measurement. The time parameters given in the tables given in Figure 9 are the time of procedure (analysis) measured in seconds and the average rate of COP line formation measured in mm/s. The time of analysis is the time needed by platform sensors to perform measurement, the maximum time for valid results is 19 seconds, and the measurement for these data lasted 15.4 seconds. Other parameters are geometric characteristics that are important for the measurement of pressure centre and defining geometrical

characteristics of the centre of measurement areas (95% of ellipses). Geometric parameters are: length of pressure centre, length of main and secondary axis, angle between axis, deviation in amounts of main and secondary axis and surface of ellipse.

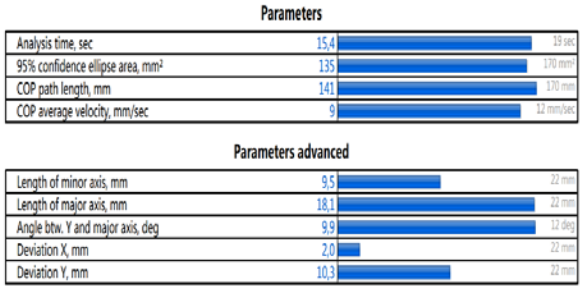


Fig . 9. Static gait report parameters

5. CONCLUSIONS

This paper presents basic knowledge of knee biomechanics which serve as a tool in new knowledge in walking analysis and generally in detection of joint and muscle deformations in man. The results obtained by measuring show the feet and walk of the examinee with multiple feet deformations, best seen in the COP analysis and graphical presentation of the pressure distribution on the feet where uneven results can be seen, while on the other hand it can be seen in the static report that the right leg is stronger than the left. This study is easy to conduct and has found its wider application in medicine and kinesiotherapy in the last twenty years.

6. ACKNOWLEDGEMENTS

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7. REFERENCES

[1] Jurčević Lulić, T: Biomehanika; Portal hrvatske tehničke baštine, (7.travanj 2021.) https://tehnika.lzmk.hr/biomehanika/

[2] Sobotta; Marušić, A: Atlas anatomije čovjeka I, Zagerb, (2000).

[3] Prof. dr. sc. Dodig, M: Biokinetika čovječjeg tijela (osnove kineziologije III.), 2019.

[4] Kasović,M: Kinetika I,II; Kineziološki fakultet u Zagrebu, (2012).

[5] Nikolić,V, Hudec M i suradnici:

Principi biomehanike, Zagreb, (2011).

[6] Zebris Software User manual, (2015).

[7] Wilson, C: Knee range of motion; KPE Medical rewiev bord, (2020).

URL:https://www.knee-painexplained.com/knee-range-of-motion.html

[8] Klenerman, L, Wood, B.: The Human Foot, Springer, London, (2006).

[9] Billing, D: Prediction of Ground Reaction Forces in Running from Wearable Instrumentation and Algorithmic Models, (2006).

[10] Richard,J;Erande,R:Biomechanics, (2012), 15 chapter.

Prediction of weld geometry of AlMg3 sheets using artificial neural networks with different input data sets

Z. Jurisic [a], N. Krnic [b]

[a] Croatian Military Academy, Zrinsko-Frankopanska 207a, Split, Croatia, zivko.jurisic2015@gmail.com

[b] FESB, University of Split, 21000, Rudjera Boskovica 32, Split, Croatia, niksa.krnic@fesb.hr

Abstract

Predicting the geometry of welded joints, mechanical properties and welding process parameter using scientific methods and mathematical models is an integral part of a comprehensive research in welding practice. In this paper, besides the experiments of robotic metal inert gas welding of 1 mm thick aluminium alloy (AlMg3) sheet, the method of artificial neural networks was used to predict the weld geometry. In the application of neural networks, the approach with four different input data for network structure was used: 1. nominal values of welding current, arc voltage and instantaneous arc power; 2. measured values of above mentioned process parameters; 3. measured values with standard deviation values and 4. root mean squared values of above mentioned measured parameters. The selected models, based on the calculation of mean relative error, showed that the neural network method can be applied with high reliability in predicting the geometric characteristics of welded joints of selected material. Also, for practical reasons, it can be used nominal values for predicting weld geometry, but application of measured data in combination with standard deviation or root mean squared values gives significantly more accurate results of weld geometry prediction.

Keywords: weld geometry prediction, artificial neural networks, robotic GMAW process, aluminium alloys

1. INTRODUCTION

The application of scientific methods for predicting the observed characteristics of welds today is an unavoidable tool in studying the effects of welding processes, whether it is the study of process parameters, mechanical and other weld properties or weld geometry.

There are different scientific approaches in structuring and optimizing weld geometry prediction models and accepting the achieved outputs. The majority of methods acceptable in practical applications of neural network modelling use different network structures (number of layers, number of neurons, inputs and outputs), different algorithms, network parameters and acceptance criteria of output results. Training, validation and testing procedures are performed for a particular model, according to the selected proportion of the available data set.

Numerous statistical methods already exist for the evaluation of models, also applicable for neural networks, based on the application of one of the criteria - minimum error (RMSE, MAE, MAPE, MRE, etc.) or maximum Pearson correlation coefficient (R), efficiency factor (EF) [1]. However, beside the selected optimal model with the best result according to the selected criterion, there are a number of other models that are almost as good as the selected optimal model and can be applied in practice.

The Artificial neural network (ANN) is an interconnected assembly of simple processing elements, units or nodes, whose functionality is based on the biological neuron [2]. The processing ability of the network is stored in the

interunit connection strengths, or weights, obtained by a process of adaptation to, or learning from, a set of training patterns.

Among all types of neural networks, the application of which depends on the individual problem, neural networks can be divided into two basic classes: feedforward networks (which implement nonlinear functions of their inputs) and recurrent (or feedback) networks (which are governed by nonlinear discrete-time recurrent equations) [3].

Feedforward networks are very often applied in technical practice, which can be considered as a fundamental structure for the development of network models. The backpropagation algorithm is the most commonly used algorithm in modelling of feedforward multilayer neural networks. The algorithm calculates the minimum error function in the weight range using the method of the steepest gradient of error. The obtained combination of weight coefficients that minimizes the error function is considered as a solution to the problem of learning (training) [4].

There are two basic backpropagation algorithms – conjugate gradient (CGBP) and Levenberg-Marquardt algorithm (LMBP) [5]. The Levenberg-Marquardt algorithm is a variation of Newton's method that was designed for minimizing functions that are sums of squares of other nonlinear functions, i.e., it is a method tailored for functions of the type sum of squared error. This is very well suited to neural network training where the performance index is the mean squared error. That makes it to be very fast when training neural networks measured on that kind of errors. When determining the topology of a neural network using the selected algorithm, it is important to select the optimal number of neurons in hidden layers (n_h). The number of neurons in hidden layers is most often optimized by choosing the weight coefficients at which the smallest error function is obtained.

In the article [6], an overview of methods for determining the number of neurons in the hidden layer of the Elman neural network is given, and an analysis of different approaches to existing methods for calculating the number of neurons in hidden layer, based on minimum mean squared error. The authors performed a statistical analysis of 101 different criteria for selecting the number of hidden neurons by calculating the statistical errors of MSE, MRE and MAE. The selected criterion for the number of hidden neurons, ($n_h=(4n^2+3)/(n^2-8)$, n-number of inputs), had lower error values compared to others. The number of neurons in hidden layer has also been studied, as one of the most important questions in defining artificial neural networks in general [7]. In this research, a special algorithm was developed, based on algorithm with the curve fitter module, from which the optimum number of nodes is predicted. Its accuracy and repeatability are tested by comparing its output over 10 runs to the actual data from a full scan. The average training error over 30 networks for each topology between 1 and 256 hidden nodes, overlaid on one such fitter output. The root mean square error (RMSE) between the fitter output and the actual data as well as the correlation coefficient between the two is counted. There is a remarkably good correlation between the fitter and actual data.

Until recently, scientific researches were not significantly directed to the application of artificial neural networks with aluminium alloys, especially when it comes to thin sheets. Therefore, in the following description, an overview of the application of ANN on aluminium alloys, which is interesting for this research, is given.

A comprehensive approach and comparison of two models of neural networks with feedforward backpropagation neural network (FFBPNN), Elman backpropagation neural network (EBPNN), and the response surface method (RSM) based design of experiments, were performed by authors in [8]. Using TIG process, welding experiments were performed on aluminium alloy 5083, 5 mm thick. 5, 10, 15, 20 and 25 neurons were used in hidden layer.

The learning algorithms applied were '*trainlm*' and '*traingdm*'. The transfer function '*tansig*' applied for FFBPNN and '*logsig*' and '*purelin*' applied for EBPNN. The results showed high accuracy, and the FFBPNN model had the smallest error.

The development of neural network model for weld geometry prediction was also carried out in article [9]. The base material was 2 mm thick aluminium alloy 6061 and the applied welding process was CMT. Two hidden layers with different numbers of neurons were used and the transfer function was 'logsig' (inputs and outputs are normalized to range [0, 1]). The selection criteria were the correlation coefficient (R) and the mean relative error, which indicated high prediction accuracy.

Aluminium alloy 6063, 3 mm thick, was used in TIG welding experiments [10]. Average absolute error and standard deviation were used as prediction quality criteria for selecting of ANN model. Modelling was performed on data set with and without normalization. The results with normalization were better.

The criteria of Pearson's coefficient of correlation (R) and mean relative error (MRE) were used for selecting the ANN model, applied for prediction of mechanical properties of welds, obtained using of GMAW process for welding 7075 aluminium alloy plate with thickness of 5 mm [11]. ANN models with two hidden layers were developed. According to the obtained results, it is observed that, predicted values obtained by ANN model and the experimental values are in excellent agreement.

Based on available literature, applied neural network models in prediction of weld geometry, and in order to developing models based on four data sets each separately applied on input layer, neural network modelling was performed in this research, with data obtained using MIG welding process on aluminium alloy 5754. This approach was used for selecting the optimal neural network model using the calculation of the minimum estimation error for whole data set, in this case the mean relative error (MRE). This approach is described in detail in the next chapter.

2. METHODS AND MATERIALS USED FOR RESEARCH

2.1. Experimental work

The aim of this research was to perform welding experiments on selected aluminium alloy using selected process parameters, to measure welding current and arc voltage signals, calculate standard deviation and RMS values and to use four different sets of input parameters for developing optimal model for prediction weld geometry applying artificial neural networks. The experiments were performed through two phases: pre-experiments and main experiments. The limit values of main welding parameters were investigated through pre-experiments based on factorial plan of experiments – applying three factors (welding current, arc voltage and welding speed) on three levels. During these experiments it was found that the process is very sensitive regard to selected material thickness of 1 mm. Therefore, further experiments were carried out by trial and error method based on previous knowledge and experience.

The experiments were performed in the Welding Laboratory of the Department of Mechanical Technology, FESB, University of Split, by using a robotized system for GMAW welding. A detailed description of MIG welding process, experimental procedure and research is presented in the master's thesis [12].

The equipment used for MIG welding as follows, Figure 1:

- robotic manipulator, KUKA ROBOTER GMBH, type KR 16,
- device for GMAW welding, MERKLE, type HighPULSE 450 RS,
- wire feeder, MERKLE ROB DV 31,

The base material was aluminium alloy sheet AlMg3 (EN AW 5754) 1 mm thick, plates of

dimensions 300x100x1mm. The surface of the base metal plate was prepared mechanically with a brush made of SS steel and chemically with alcohol. Additional material for GMAW welding was AlMg5 wire (according to DIN 1732: SG-AlMg5 and AWS A5.10, ER 5356), diameter Φ1.2 mm. As a shielding gas, argon 4.8 Special (O2 2.9 vpm, H2O 2.9 vpm) used.

Fig. 1 Robotic welding cell in welding laboratory

In order to achieve the objectives of this research, 39 experiments in the short-circuit mode were performed. The experiments were performed using the pushing technique (angle = 15°), and the working angle of the gun was 0 °.

The selected welding parameters were: welding current in the range from 40 A to 88 A, arc voltage in the range from 12 V to 17.9 V, with constant contact tip to work distance (CTWD) of 23 mm. Welding speed was adjusted for three values: 0.85; 1.1 and 2 m/min.

2.2. Development of models for weld geometry prediction using ANN

The application of methods for prediction the observed welding characteristics are regularly used in study of process parameters, mechanical and other weld properties or weld geometry. This chapter presents the procedure of developing a model for prediction the weld geometry using artificial neural networks. For neural network modelling, 39 experiments performed in short - circuit mode. Most researchers used nominal current and voltage values to determine the optimal model, while some used measured values. It has been shown that the measured values of process parameters achieve more accurate prediction results. For example, the measured parameter values were used in article [13], i.e., mean value of current and root mean squared values of current (RMS). It was concluded that both forms of current representation (mean and RMS values) must be used if a more precise model of bead geometry is required, at least for GTAW process with no material feeding. Also, taking into account electric arc power in welding process, applying different methods of calculating, the differences in values can reach up to 30 % [14]. The group of authors measured and then applied calculated mean and RMS values of current and voltage in modelling weld strength using multiple quadratic regression and ANN and the obtained results are very precise [15].

In this research, six process parameters were used for the input layer of the neural network: Imean - mean welding current, U_{mean} - mean welding voltage, P_{mean} - mean instantaneous electric arc power, ws - welding speed, Kind - inductance correction, and WJ-W factor (1 or 0 depending whether it is a welded joint or a weld). CTWD in the short-circuit process was kept constant. In output layer, the weld geometry was used - face width, face height, root width, root height and penetration per weld length.

The mean values of current and voltage, the mean instantaneous arc power and statistical features were calculated using the processed signal segments, according to the following expressions:

$$I_{mean} = \frac{1}{n}\sum_{i=1}^{n} I_i \quad (1)$$

$$U_{mean} = \frac{1}{n}\sum_{i=1}^{n} U_i \quad (2)$$

$$P_{mean} = \frac{1}{n}\sum_{i=1}^{n} (U_i \cdot I_i) \quad (3)$$

$$\sigma = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n} (x_i - \bar{x})^2} \quad (4)$$

where are: I_{mean} – mean welding current, U_{mean} – mean arc voltage, P_{mean} – mean instantaneous arc power, σ – standard

deviation of observed parameter, x – observed data set, $\bar{x}$ – mean value of observed data set.

$$I_{rms} = \sqrt{\frac{1}{n}\sum_{i=1}^{n} I_i^2} \quad (5)$$

$$U_{rms} = \sqrt{\frac{1}{n}\sum_{i=1}^{n} U_i^2} \quad (6)$$

$$P_{rms} = \sqrt{\frac{1}{n}\sum_{i=1}^{n} (U_i \cdot I_i)^2} \quad (7)$$

The measured welding parameters and weld geometry defined in this way are shown in paper [12]. By comparing the selected and measured values of welding process parameters using correlation coefficients and corresponding mean deviations, information was obtained on how the actual values of welding process parameters coincide with the selected ones, which is explained in Chapter 3.

According to the above mentioned articles, and for the purpose of this research, four options were used in the procedure of selecting the optimal model. First option, nominal values of welding current and arc voltage from welding source were used in input layer of neural network. Second option, average measured values of welding current and arc voltage were used in input layer of neural network structure. Third option, standard deviation values of welding current, arc voltage and mean instantaneous arc power are added to input layer of the second option. In fourth option, RMS values of welding current, arc voltage and mean instantaneous arc power are added to input layer.

The modelling approach to this problem was changing the number of neurons in one hidden layer from 1 to 35, during which training was performed for each number of neurons with 178 repetitions to reduce the stochasticity of model selection, that is, to choose the structure of neural network containing the number of neurons with the least mean relative error of overall data set. As a transfer function between the layers, the function "tansig" (tangent hyperbolic) was applied, since the normalized input and output data are used in algorithm (data are normalized to be within the range [-1, 1]).

The neural network parameters were selected as follows:

- ratio "*training: validation: testing*" = 70: 15: 15,
- network type: *newff* (feedforward neural network),
- transfer function: tansig (tangent hyperbolic),
- learning algorithm: *trainlm* (Levenberg-Marquardt),
- *net.trainParam.epochs*: 1000, maximum number of epochs to train,
- *net.trainParam.goal*: 1e-8, performance goal,
- *net.trainParam.mu_max*: 1e+10, maximum value for *mu*,
- *mu_step*: 0.001, Marquardt adjustment parameter,
- *net.trainParam.mu_dec*: 0.9, decrease factor for *mu*,
- *net.trainParam.mu_inc*: 5, increase factor for *mu*,
- *net.trainParam.min_grad*: 1e-10, minimum performance gradient
- *net.trainParam.max_fail*: 50.

In order to determine the maximum number of iterations, training with 1000, 2000 and 10000 iterations was performed. Because training with 2000 and 10000 iterations did not improve the results, the maximum number of iterations was limited to 1000. In order to avoid the possibility of overtraining of the selected model from the point of view of network parameters (overfitting), the method of *'early stopping*' was used. The method is based on the validation being performed during model training, in such a way that the training stops when the validation error increases by the set number of iterations, i.e. 50 iterations (*net.trainParam.max_fail*=50). The weight coefficients at which the smallest validation error was achieved are taken into account. After training, the normalized data is converted back to the real value range. Selection criterion was the minimum mean relative error (MRE).

3. RESULTS AND DISCUSSION

In accordance with the selected parameters, robotized GMAW welding of aluminium sheets were performed in short-circuit mode. An example of a welded joint obtained by MIG welding in short-circuit mode is shown on Figure 2.

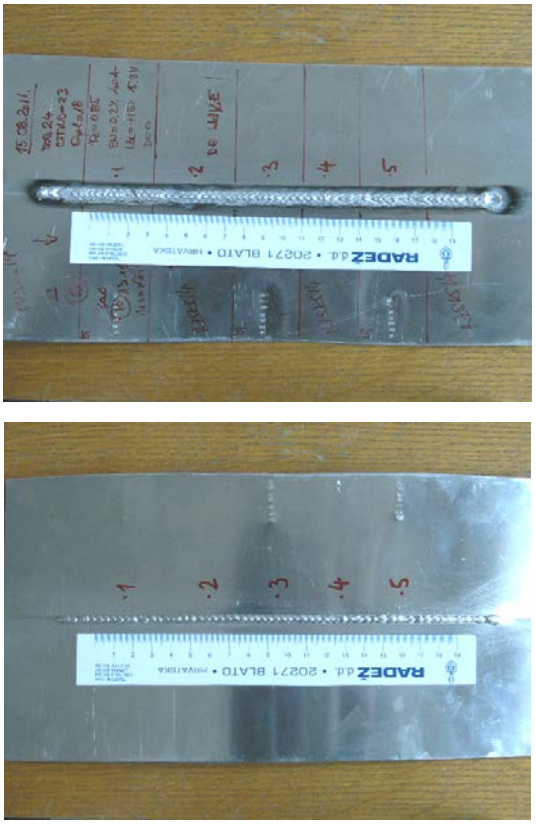

Fig. 2. Example of a welded joint by MIG welding in short - circuit mode, experiment 5

The measured arc voltage and welding current signals are stored in a computer with the help of MATLAB. Due to the existence of noise, the input signals were first filtered using the "wavelet" scaling function "db5-level 7" (Daubechy wavelet 5 with 7 coefficients) from the MATLAB software package. Filtering was performed on the "stationary" part of the signal in such a way that the initial and final part of the signal for approx. 0.5 seconds did not consider. The relation of selected and measured main parameters of the short-circuit process are graphically displayed on Figures 3. to 5. The data are shown together for three welding speeds (0.85; 1.1 and 2 m/min). The dependence is approximated by appropriate curve, linearly for welding current and arc power, and the second order polynomial is selected for the welding voltage. The deviation of welding parameters, when the stability of welding process is achieved, depends primarily on internal regulation of process defined by manufacturer of welding device. If the process is unstable, it certainly affects both, arc voltage and welding current. The mean deviation of measured from selected welding current is 8.5 A, i.e. 13.1 %, and values of mean measured current are higher than the selected ones, Figure 3.

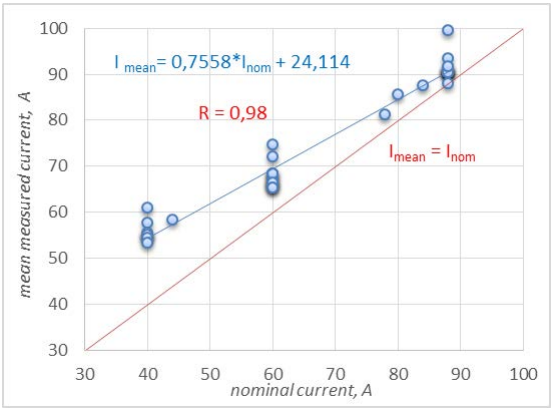

Fig. 3. Dependence of mean measured and nominal welding current in short-circuit GMAW of AlMg3 (welding speed, ws=0.85; 1.1 and 2 m/min)

The mean deviation measured from the selected arc voltage is 1.2 V (7.9 %). The values of measured mean arc voltage are higher than the values of selected arc voltage up to amount of 14.5 V, after which the values of measured mean arc voltage are lower, Figure 4.

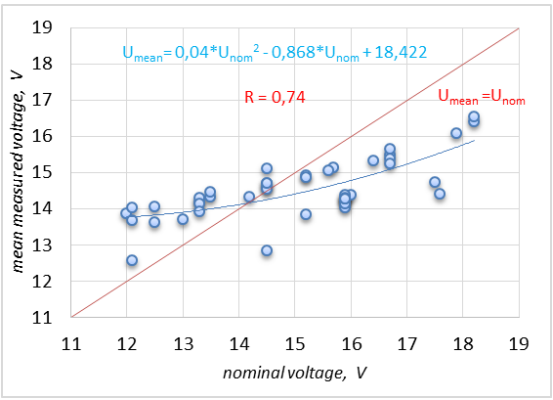

Fig. 4. Dependence of mean measured and nominal arc voltage in short-circuit GMAW of AlMg3 (welding speed, ws = 0.85; 1.1 and 2 m/min)

The deviation of mean instantaneous arc power from the selected one is 120.3 W (11.3%), Figure 5.

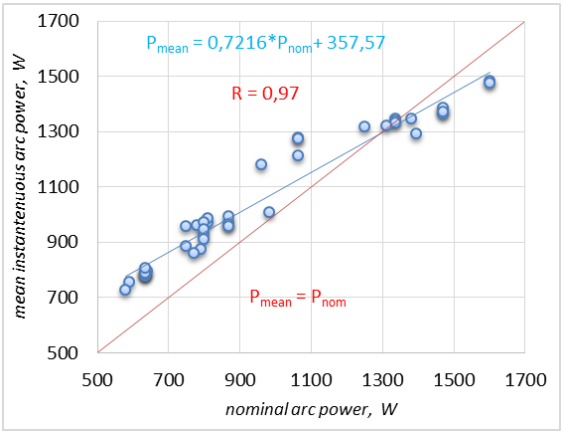

Fig. 5. Dependence of mean instantaneous and nominal arc power in short-circuit GMAW of AlMg3 (welding speed, ws= 0.85; 1.1 and 2 m/min)

The presentation of the results obtained by neural network method is described as follows. After finishing the learning process, the selected optimal weld geometry models by using ANN with four different input data sets are shown in Table 1.

Analyzing the achieved results and the optimal models with the lowest MRE, it is noticed that if 4 or 5 features at the output are considered, better results are obtained with the nominal process parameters in the input layer. If individual weld geometry features are observed at the output, then significantly better results are obtained compared to 4 or 5 outputs. Within the results of predicting one weld geometry feature, for such defined network parameters it is not recommended to use nominal data in input layer because the measured values in combination with the standard deviation values or root mean squared values give better results. Analyzing the achieved results and the optimal models with the lowest MRE, it is noticed that if 4 or 5 features at the output are considered, better results are obtained with the nominal process parameters in the input layer. If individual weld geometry features are observed at the output, then significantly better results are obtained compared to 4 or 5 outputs.

Table 1. Selected models for different input data sets

Number of outputs	*Number/type of inputs*	*MRE %*	*R*	*MRE_{test} %*	*Number of neurons in hidden layer*
5 (*FW,FH,RW,RH,PEN*)	6/nominal data	3,835	0,896	12,728	30
4 (*FW,FH,RW,RH*)	6/nominal data	4,52	0,944	15,187	28
1 (*FW*)	9/measured+std	1,892	0,966	6,645	19
1 (*FH*)	6/measured data	4,331	0,936	18,218	18
1 (*RW*)	9/measured+std	1,709	0,985	6,007	35
1 (*RH*)	6/rms data	3,584	0,966	10,717	18
1 (*PEN*)	6/rms data	0,00024	0,999	0,0005	2

FW- face width, FH-face height, RW-root width, RH-root height, PEN-penetration per weld length

Within the results of predicting one weld geometry feature, for such defined network parameters it is not recommended to use nominal data in input layer because the measured values in combination with the standard deviation values or root mean squared values give better results. Figures 6. to 10. show the results of predicting weld geometry according to the applied minimum MRE criterion.

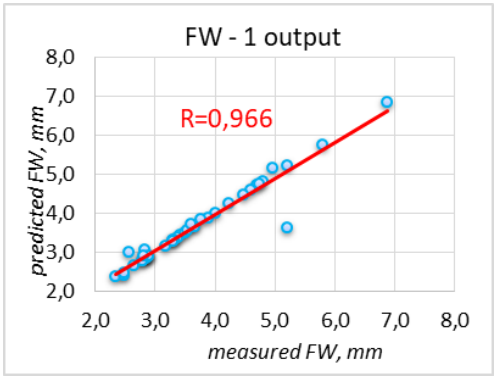

Fig. 6. Face width (mm), experiment vs. prediction

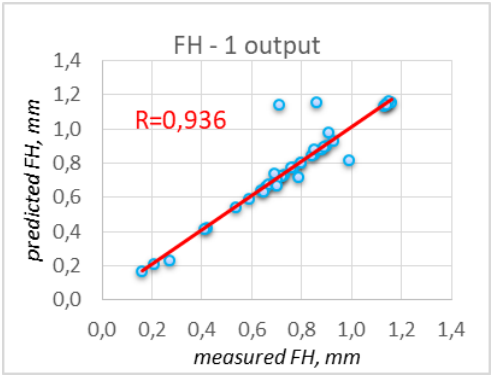

Fig. 7. Face height (mm), experiment vs. prediction

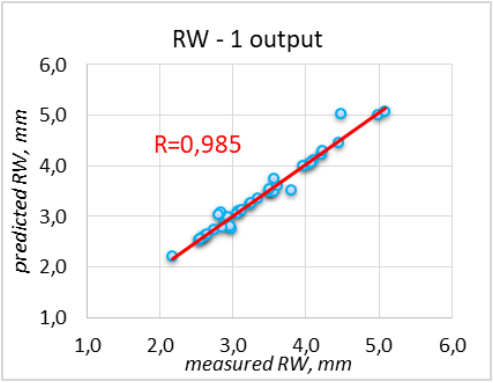

Fig. 8. Root width (mm), experiment vs. prediction

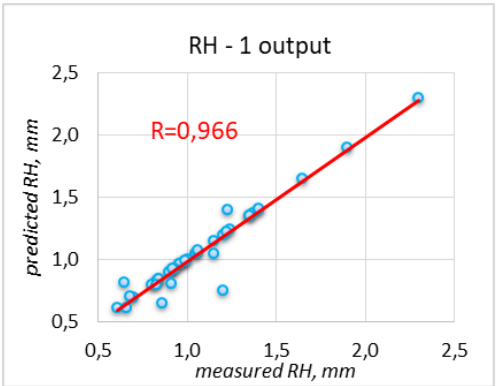

Fig. 9. Root height (mm), experiment vs. prediction

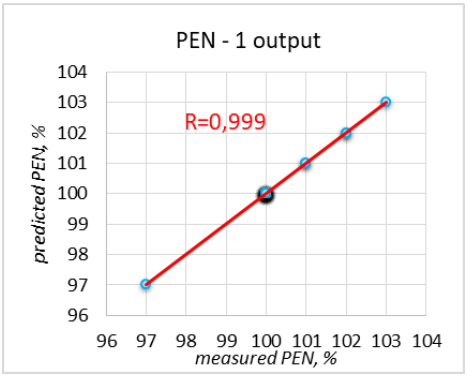

Fig. 10. Penetration per weld length (%), experiment vs. prediction

If MRE of all results are analyzed, it is obvious that the relative error values are significantly lower for models with one weld geometry features compared to models with 4 and 5 output neurons. But, if magnitudes of MRE are observed, it is concluded that models with 4 or 5 output neurons can be successfully used in practical applications for selected alloy and welding process.

4. CONCLUSIONS

Based on data presented and analysed in this work, it is concluded that welding current, arc voltage and consequently arc power have crucial influence on welding process and weld geometry. The application of nominal values of welding parameters plays a significant role in defining quality welds, but the real effect of measured parameters, which depends on process control by the manufacturer, affects process stability, heat input and thus the weld geometry.

It is especially important to use real, measured values of welding current and arc voltage in modelling and prediction the weld geometry. Deviations of the mean values of welding current compared to nominal values were shown to be up to 13.1 %, the arc voltage up to 7.9 % and the instantaneous arc power up to 11.3 %.

The developed models of neural networks have shown more precise results from point of view of MRE when the measured values, standard deviation or root mean squared values are taken into account in relation to the nominal values. This is especially true for the application of 1 hidden layer, where the selected models for one weld geometry feature in the output layer of

ANN structure have MRE values ranging from 0,0025 % (penetration per weld length) to 4,33 % (face height).

Appropriate selection of input data type can significantly affect to desired effects of welding process. The recommendation for further research is the application of multiple selection criteria for ANN model development with measured welding parameters, to avoid possible occurrence of outliers.

5. REFERENCES

[1] S. Jachner; K.G. van den Boogaart; T. Petzoldt, Statistical Methods for the Qualitative Assessment of Dynamic Models with Time Delay. Journal of Statistical Software (2007), 22, Issue 8.

[2] K. Gurney, An introduction to neural networks. UCL Press Limited, London, (2004).

[3] G. Dreyfus, Neural networks – methodology and applications. Springer-Verlag, Berlin-Heidelberg, (2005).

[4] R. Rojas, Neural Networks. Springer-Verlag, Berlin, (1996).

[5] M.T. Hagan, H.B. Demuth, M.H. Beale, O. De Jesus, Neural Network Design. Second edition, eBook, (2014).

[6] K.G.Sheela; S.N. Deepa, Review on Methods to Fix Number of Hidden Neurons in Neural Networks. Mathematical Problems in Engineering, (2013), pp.1-11.

[7] A.J. Thomas; M. Petridis; S.D. Walters; S.M. Gheytassi; R.E. Morgan, On Predicting the Optimal Number of Hidden Nodes. Proceedings of the 2015 International Conference on Computational Science and Computational Intelligence, Las Vegas, (2015), pp.565-570.

[8] S.R. Joshi; Dr.J.P. Ganjigatti, Comprehensive Development and Comparison of two Feed Forward Back Propagation Neural Networks for Forward and Reverse Modelling of Aluminium Alloy AA5083; H111 TIG Welding Process. International Journal of Engineering Research and Application, 6(5), (2016), pp.98-111.

[9] N.P. Kumar; P.K. Devarajan; S.A. Vendan; N. Shanmugam, Prediction of bead geometry in cold metal transfer welding using back propagation neural network. The International Journal of Advanced Manufacturing Technology, 93, (2017), pp.385–392.

[10] A.S. Baskoro; D.A. Purwanto; A. Widyianto, Controlling the Width of Weld Bead from the Weld Pool Using Machine Vision and Artificial Neural Network. MATEC Web of Conferences, 269, 04003, (2019), pp.1-10.

[11] E. Maleki, Artificial neural networks application for modelling of friction stir welding effects on mechanical properties of 7075-T6 aluminium alloy. IOP Conference Series: Materials Science and Engineering, 103(1), (2015), pp.1-15.

[12] Ž. Jurišić, Analysis of robotized GMAW welding process of thin AlMg3 sheets. Thesis to obtaining the Master of Science Degree in Mechanical Engineering, University of Split, Faculty Electrical Engineering, Mechanical Engineering and Naval Architecture, Split, (2012), (e.g. in Croatian).

[13] D.C.C. Silva; A. Scotti, Using either Mean or RMS values to represent current in modelling of arc welding bead geometries. Journal of Materials Processing Technology, 240, (2016), pp.382-387.

[14] V.L. Jorge; R. Gohrs; A. Scotti, Active power measurement in arc welding and its role in heat transfer to the plate. Welding in the World, 61(5), (2017), pp.847–856.

[15] S.Pal; S.K.Pal; K. Samantaray, Artificial neural network modelling of weld joint strength prediction of a pulsed metal inert gas welding process using arc signals. Journal of Materials Processing Technology, 202 (1-3), (2008), pp.464-474.

Heat treatment of a stamp for marking metal products

S. Kladarić [a], K. Čuljak [b], I. Kladarić [c]

[a] University of Slavonski Brod, Technical Department, Ulica 108. brigade ZNG, 35 000 Slavonski Brod, Croatia, skladaric@unisb.hr

[b] SIGMAT d.o.o., Dr. Franje Tuđmana 35, Gromačnik, 35252 Sibinj, Croatia, krunoslav.culjak@sigmat.hr

[c] University of Slavonski Brod, Mechanical Engineering Faculty, Trg Ivane Brlić Mažuranić 2, 35 000 Slavonski Brod, Croatia, ikladaric@unisb.hr

Abstract

The paper presents the manufacture and heat treatment of a stamp for marking metal products. This hand tool should be wear-resistant and dimensionally stable, so it is made of high-alloy tool steel for cold working X210Cr12. Production and heat treatment by hardening and tempering were carried out in the production facilities of the company Sigmat d.o.o. Based on the results of hardness tests and tool function tests, a technological process for the production of a stamp was defined and technical and technological documentation was prepared for the needs of the company.

Keywords: tool steel, stamp, heat treatment, hardening, tempering.

1. INTRODUCTION

A tool is any means by which a person facilitates or enables the performance of a desired action, either directly by the power of the hand or indirectly by the power of the machine. [1]

Most hand and machine tools are made from tool steels that are used in a heat treated condition.

Heat treatment of tool steels is more demanding compared to other steels due to higher carbon content, lower thermal conductivity of tool steels and higher austenitizing temperatures. [2]

Based on the theoretical knowledge of materials for the manufacture of tools and available recommendations from manufacturers and users, a material must be selected for the manufacture of a particular tool that has the required properties after heat treatment and a suitable microstructure.

Accordingly, the high-alloy cold-work tool steel X210Cr12 was selected for the manufacture of a stamp for embossing markings on metal products.

2. REQUIREMENTS ON PROPERTIES OF TOOL MATERIALS

Tool materials must meet basic, special, and manufacturing requirements. [1, 3]

The basic requirements for tool material properties are wear resistance (abrasion, adhesion, surface fatigue, tribocorrosion) and toughness (high value of impact energy).

Special requirements are temper resistance, hardenability, dimensional stability during

hardening and use, austenite grain size, corrosion resistance, etc.

Production requirements are purchase price, availability, machinability by separation of particles, resistance to decarburization, etc.

Each type of tool has a specific combination of requirements for the properties of the tool material.

The requirements for the properties of tool steel for the production of a stamp for marking metal products are: wear resistance, toughness, hardenability, temper resistance, dimensional stability and purchase price.

The wear resistance of tool steels depends on their microstructure, which is achieved by suitable chemical composition and heat treatment. The tool steel should have a hard iron matrix with martensitic structure, additionally reinforced with high quality carbides. The steel X210Cr12 has a very high wear resistance due to the high content of chromium carbides in the microstructure.

X210Cr12 steel does not have high toughness due to its high carbide content.

The hardenability of steel depends on the amount of carbon dissolved in the austenite at the austenitizing temperature. Through hardenability depends on the proportions of carbon and alloying elements. X210Cr12 steel has high hardenability and through hardenability.

X210Cr12 steel has satisfactory temper resistance, i.e., a small decrease in hardness with an increase in working temperature.

X210Cr12 steel belongs to the group of steels with minimal deformation during and after heat treatment and is used in cases where dimensional stability is very important. [2]

The price of high-alloy tool steels depends on the production method. Steels produced by powder metallurgy have better quality and are more expensive than steels produced by conventional methods. Among tool steels, X210Cr12 steel has an average price.

3. TOOL STEELS

Tool steels are carbon steels with carbon content of 0.6...2.06 % or alloy steels with chromium (Cr), tungsten (W), vanadium (V), molybdenum (Mo), cobalt (Co) and other alloying elements and they are intended for the production of various tools. [4]

Considering the chemical composition and intended use, tool steels are divided into:

- unalloyed, low-alloyed and high-alloyed tool steels for cold working

- low-alloyed and high-alloyed tool steels for hot working

- high-alloyed high-speed steels. [4]

X210Cr12 steel belongs to the group of high-alloyed tool steels for cold working. The main alloying element of these steels is chromium (> 5 %Cr), and vanadium, molybdenum and/or tungsten are also added. Chromium alloying leads to the formation of carbides $(Fe,Cr)_3C$, Cr_7C_3 or $Cr_{23}C_6$, increases wear resistance and corrosion resistance, and also increases the austenitizing temperature.

These steels can be divided into the following groups:

a) steels with about 5 %Cr, such as X100CrMoV5-1

b) high-carbon ledeburitic steels with 12 %Cr, such as X210Cr12, X210CrW12, X165CrMoV12, X155CrVMo12-1

c) martensitic stainless steels, such as X20Cr13, X42Cr13, X45CrMoV15, etc. [3]

4. HEAT TREATMENT OF TOOL STEELS

Tool steels are heat treated by the following processes: annealing (stress relief annealing, soft annealing, normalising), hardening, tempering, surface hardening processes, thermochemical processes, and surface coating processes.

The embossing marking stamp is heat treated by hardening and tempering.

Hardening of steel is a heat treatment consisting of heating to the austenitizing temperature, holding at the austenitizing temperature for the purpose of dissolving carbon and alloying elements in the austenite, and quenching.

Figure 1. shows the pseudo-binary Fe-Fe_3C diagram for the steel X210Cr12. For this hypoeutectic ledeburitic steel, the austenitizing temperature is determined according to the "0.6 %C criterion", i.e. the steel is heated to the austenitizing temperature at which at least 0.5...0.6 %C is dissolved in the austenite. The content of carbon and alloying elements in the martensite is equal to that in the austenite, and the hardness after hardening depends on the carbon content in the martensite.

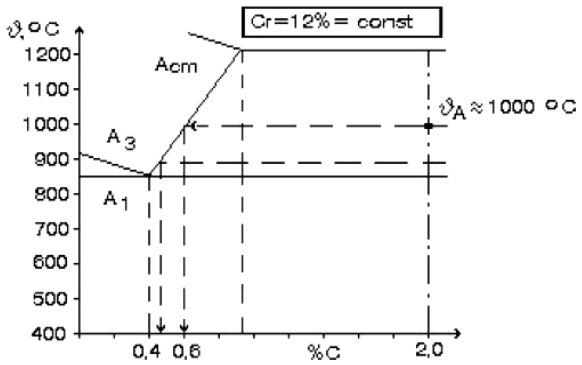

Figure 1. Determination of austenitizing temperature in pseudo-binary diagram of steel X210Cr12 [5]

The thermal conductivity of alloy tool steels is low, so they should be heated carefully to avoid large temperature differences between the hotter surface and the colder core. Heating should be done slowly or with adequate preheating.

The duration of heating to a given temperature is determined by various analytical (Newton, Smoljnikov, Ordinanz) and numerical methods (finite element method, control volume method, finite difference method).

The best recommendations for preheating and austenitizing temperatures and the duration of heating and holding at these temperatures are given by steel manufacturers.

After hardening, the steel structure consists of martensite, retained austenite, and carbides.

Tempering is the heating of hardened steel to a temperature below the eutectoid temperature to increase the toughness of the martensite, reduce residual stresses in the martensite, and achieve dimensional stability. For high-alloy tool steels, high-temperature tempering converts the retained austenite into tempering carbides and secondary martensite.

The purpose of tempering is to achieve an optimum combination of mechanical properties for specific operating conditions of a product.

5. STAMP PRODUCTION AND HEAT TREATMENT

Within the production program of the company Sigmat d.o.o., stamps for marking metal products with rectangular and round marks are produced (Figures 2. and 3.).

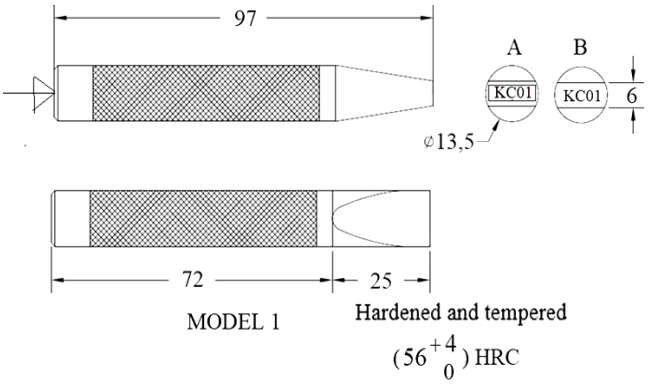

Figure 2. Drawing of a stamp with a rectangular mark

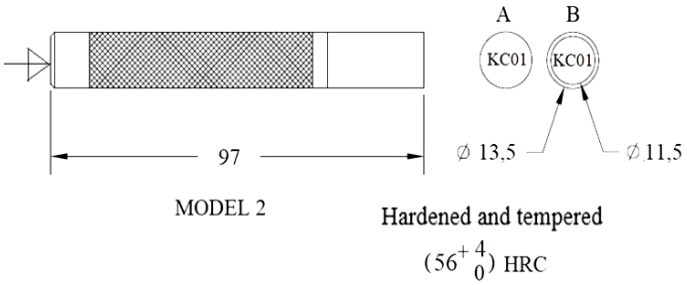

Figure 3. Drawing of a stamp with a round mark

The stamp has a round cross-section, smaller dimensions and a 0.5 mm deep engraving of an alphanumeric character on one side. On the stamp engraving sharp transitions are slightly rounded on a numerical milling machine, so that they do not affect the functionality of the tool and do not become places of high stress during heat treatment.

The markings on the stamps are alphanumeric, depending on the customer's requirements. These stamps are most often used in welding operations, where the marking ensures the traceability of information about the welders, which is especially important in responsible construction.

The high-alloy tool steel X210Cr12, which was developed in America around 1915 with the aim of replacing high-speed steel, was chosen for the manufacture of the stamp. Due to poor tempering resistance, this replacement for high-speed steels was not successful, but it was observed that the wear resistance during cold working was very high and there was very little dimensional change. For this reason, this steel is now widely used for cold working.

X210Cr12 steel is used for the production of the following tools: highly stressed cutting and punching tools, knives and shears for thin paper and plastics, cold forming and stamping tools, deep drawing tools, wire drawing tools, thread rolling dies, drawing pins, extrusion tools, milling slots, slitting tools, etc. [1, 3, 6]

The material for the production of the stamp was purchased from the SIJ Metal Ravne ironworks from Ravna na Koroškem, Slovenia, and according to the submitted certificate A18-20424 and the standard EN 10204/3.1 it has the following chemical composition: 2.04 %C; 0.18 %Si; 0.26 %Mn; 0.022 %P; 0.008 %S; 11.24 %Cr.

The stages of stamp production and heat treatment are as follows:

- turning on a universal lathe
- milling of the taper on one side of the stamp
- engraving of the stamp on the program milling machine
- heat treatment by hardening and tempering in an electric furnace
- hardness test and functional test of the stamp engraving.

The machined stamps with rectangular marks are shown in Figure 4.

Figure 4. Stamps with rectangular marks after machining

For the experimental part of this work, stamps with round markings were used. Four stamps were made, on which the markings KC01, KC02, KS01 and KS02 were engraved.

Preheating and austenitizing of the stamps were performed in the electric furnace VPH125. After austenitizing, the stamps were quenched in oil. Immediately after quenching, the stamps were tempered. The heat treatment was carried out according to the recommendations in the literature and from the steel manufacturers.

In order to control the obtained results, the hardness of the punches was tested after the heat treatment of hardening and tempering.

5.1. Hardening process

For austenitizing workpieces, the following information is required: the austenitizing temperature, the method of heating to the austenitizing temperature, the time (duration) of austenitizing, and the agent (medium) and device in which the austenitizing is performed.

The steel selected for the production of the stamp X210Cr12 belongs to the group of high-alloy hypoeutectic ledeburitic steels with 12 %Cr, which should be heated to an austenitizing temperature of ~1000 °C according to the "0.6 %C criterion".

Figure 5. shows the heat treatment diagram of theX210Cr12 steel as recommended by the tool steel manufacturer Dörrenberg Edelstahl GmbH from Germany.

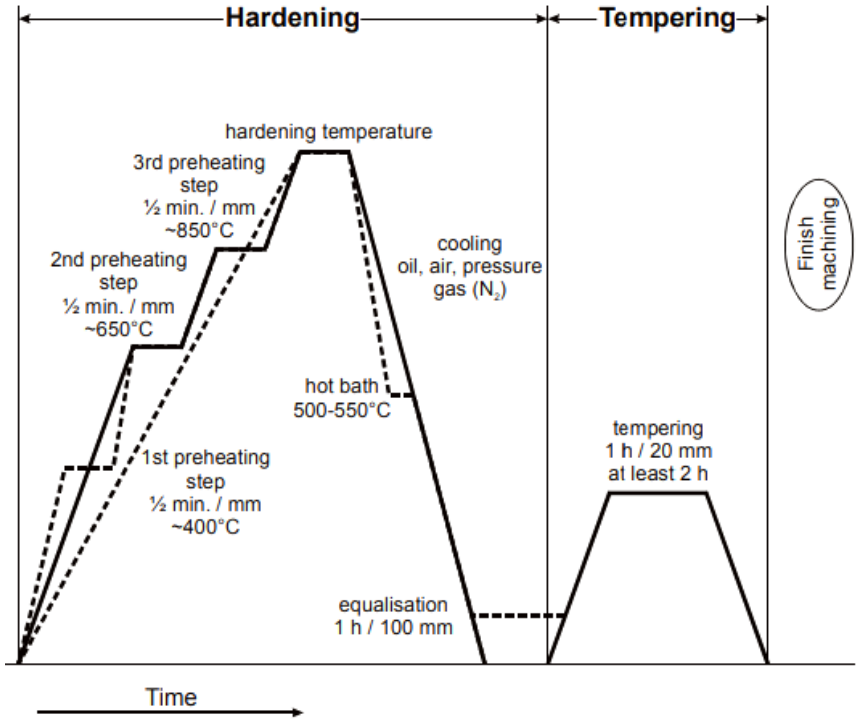

Figure 5. Heat treatment diagram of X210Cr12 steel [6]

This manufacturer recommends the hardening process as follows:

- I. preheating at a temperature of 650 °C
- II. preheating at a temperature of 850 °C
- austenitizing at a temperature of 980 °C.

When the temperatures of the first and second preheating are reached during heating, it is necessary to hold the samples at these temperatures in order to equalize the temperature of the core and the surface, and at a temperature of 980 °C also because of the austenitizing process.

The tool steel manufacturer recommends a holding time of 0.5 min/mm of the characteristic specimen dimension.

The diameter of the stamp is 13.5 mm, from which it follows that the holding time is:

$t = 0.5 \times 13.5 = 6.75$ min

The defined holding time at the reached temperatures is $t = 10$ min for all three temperatures.

Newton's analytical method was chosen to calculate the duration of heating to the defined temperatures.

On the cross-section of the metal workpiece, the equality of surface and core temperatures cannot be achieved immediately during heating. If the temperature difference is negligible, such an object is considered "thermodynamically thin", which means that the object is heated and reheated simultaneously. Otherwise, the object is considered "thermodynamically massive".

The thinness and massiveness of the object depend not only on the dimensions of the object, but also on its physical properties, which is expressed by Biot's characteristic. Biot's characteristic is calculated by the following formula [5]:

$$Bi = \frac{\alpha X}{\lambda} \quad (1)$$

where is:

Bi - Biot's characteristic

α - convection heat transfer coefficient, W/(m^{2}K)

X - characteristic heat length, m

λ - thermal conductivity coefficient, W/(mK).

If the Biôt characteristic is $Bi \leq 0.25$, the workpiece is considered "thermodynamically thin", and if $Bi > 0.25$, the workpiece is considered "thermodynamically massive".

Stamps are stacked side by side in an electric furnace, so this type of stacking can be considered as round bars stacked side by side.

When a round bar of diameter *D* and length *l* is placed in the furnace and comes into contact with other round bars, it is heated on both sides, so that the thermal length X is calculated according to the formula:

$$X = \frac{D}{8} \quad (2)$$

where is:

X - characteristic heat length, m

D - diameter of the bar, m. [5]

The convective heat transfer coefficient α depends on the steel grade, temperature, and heating method.

The thermal conductivity coefficient λ depends on the steel grade and temperature.

The duration of heating the workpieces in the furnace is calculated according to Newton's formula:

$$t_{heat} = \frac{V\rho c}{\alpha A} ln\left(\frac{\vartheta_{fur}-\vartheta_{in}}{\vartheta_{fur}-\vartheta_{fin}}\right) \quad (3)$$

where is:

t_{heat} - heating time to ϑ_{fin}, s

V - volume of the workpiece, m^3

A - surface area of the workpiece, m^2

ρ - density of the material of the workpiece, kg/m^3

c - specific heat capacity of the material, J/(kgK)

ϑ_{fur} - temperature of the furnace near the workpiece, °C

ϑ_{in} - initial temperature, °C

ϑ_{fin} - final temperature, °C. [5]

The specific heat capacity of a material depends on the steel grade and temperature.

The volume and surface area of the workpiece are calculated based on the dimensions of the stamp.

$V = 1.39 \times 10^{-5}$ m^3

$A = 4.1 \times 10^{-3}$ m^2

The data used to calculate the heating time [5], as well as the calculated and defined (indicated in brackets) values of the heating time in minutes are listed in Table 1.

Table 1. Used and calculated values according to Newton's method

Temperature range, °C	**α, W/(m^{2}K)**	**λ, W/(mK)**	***Bi***	***c*, J/(kgK)**	**t_{heat}, min**
20-650	100	29	0,007	501	13.3 (15)
650-850	173	26	0,013	633	7.8 (8)
850-980	232	27	0,017	636	5.3 (6)

Heating to the austenitizing temperature was carried out in a VPH125 electric furnace. Butane gas was used for the protective atmosphere.

The execution of the heat treatment process in this furnace can be manual or programmed. The process of heat treatment of the stamp was controlled by software.

The program requires the input of parameters such as temperatures and duration (time) of heating. After the heat treatment is completed, a diagram is printed, i.e. a record of the performed heat treatment. Figure 6. shows a diagram for entering the program data for temperature and heating duration.

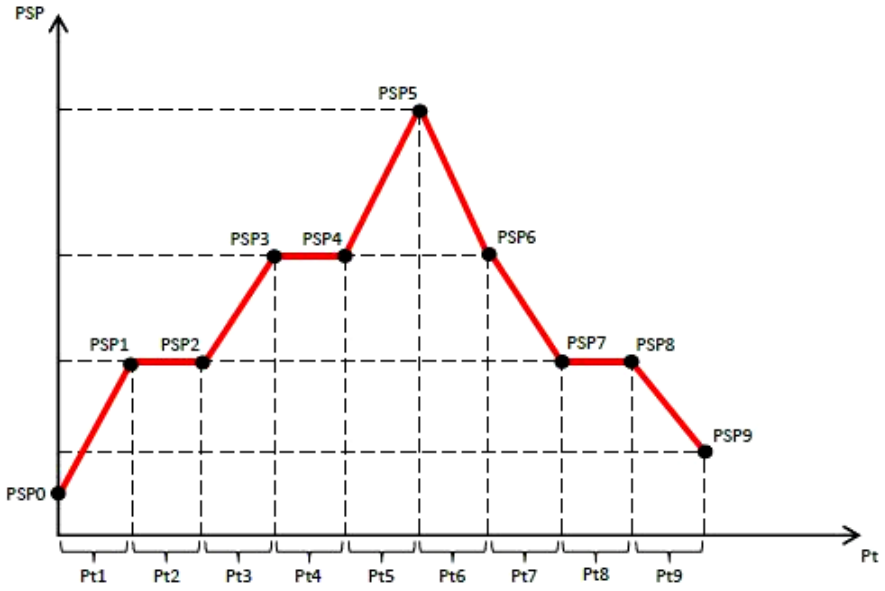

Figure 6. Diagram for entering the program data for temperature and heating duration

The parameters of the individual phases of the heat treatment process are entered on the control panel of the furnace, and on the basis of them a program is created, according to which the heat treatment is carried out in a particular case. The furnace has the possibility to enter data for nine segments. After the last segment entered, you must enter the values 0 (zero) until the end of the program. If nine segments are not enough for programming, there is a possibility to connect programs. The data for programming the electric furnace for heat treatment of the stamp are given in Table 2.

Table 2. Data for programming the electric furnace for heat treatment of the stamp

PSP_0 = 20 °C					
Pt_1 = 15 min	Pt_2 = 10 min	Pt_3 = 8 min	Pt_4 = 10 min	Pt_5 = 6 min	Pt_6 = 10 min
PSP_1 = 650 °C	PSP_2 = 650 °C	PSP_3 = 850 °C	PSP_4 = 850 °C	PSP_5 = 980 °C	PSP_6 = 980 °C
Pt_7 = 0 min	Pt_8 = 0 min	Pt_9 = 0 min			
PSP_7 = 0 °C	PSP_8 = 0 °C	PSP_9 = 0 °C			

Quenching was performed in FAMKAL 22 oil by vertical immersion of the stamp and circular movements in the oil.

5.2. Tempering

After hardening, tempering was performed in a welding electrode furnace type PS 200/400, which is a product of Sigmat.

The diagram in Figure 7. shows the dependence of the hardness of the X210Cr12 steel on the tempering temperature, measured after cooling. To achieve the required hardness of the stamp of 56...60 HRC, a tempering temperature of 300 °C and a tempering time of two hours were specified.

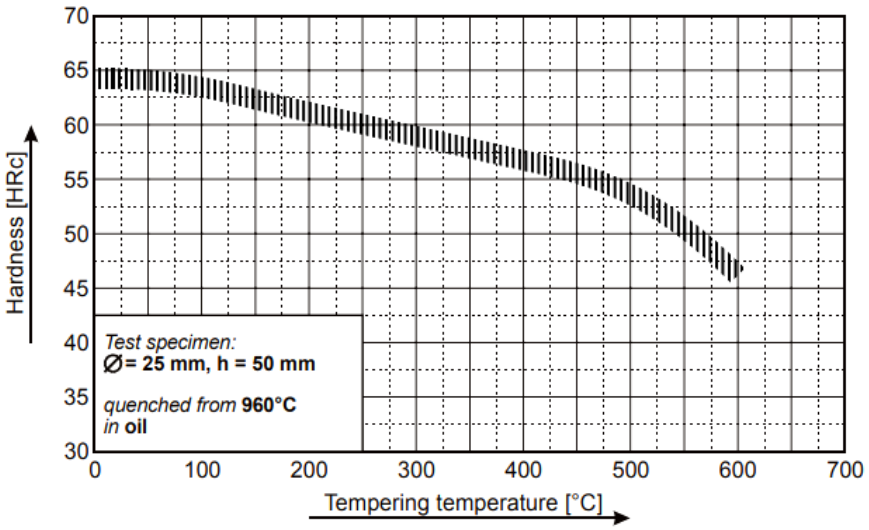

Figure 7. Diagram of hardness after tempering for the steel X210Cr12 [6]

5.3. Hardness test

The hardness test of the stamps before and after heat treatment was performed with a hardness tester model 200HBRY-187.5D, also in the Sigmat company. This hardness tester can be used to test Brinell, Rockwell and Vickers hardness. The measured hardness is read directly on the scale of the instrument.

The hardness was measured on the front side of the stamp on the side opposite to the engraving. The hardness was measured after machining, after hardening and after tempering. The measured values are shown in Table 3.

The hardness values of all four specimens after heat treatment are in accordance with the requirements on the stamp drawing.

Table 3. Measured values of hardness

	Hardness, HRC			
Hardness testing	1. sample	2. sample	3. sample	4. sample
After machining	24	31	34	28
After hardening	61.5	59	67	61
After tempering	58	56	58	57

After measuring the hardness, a functional test of the stamping was performed. Each stamp was used to stamp a mark on a 5 mm thick sheet of X5CrNi18-10 stainless steel.

After stamping the mark, it was determined that the mark had the correct depth and was clearly legible. An examination of the engraving of the mark on the stamp showed that it was undamaged.

6. CONCLUSIONS

The high-alloy tool steel for cold working X210Cr12 is recommended in the literature and by tool steel manufacturers for the production of stamps for stamping marks on metal products.

The material was chosen mainly due to the requirement that the tool to be machined must be wear resistant and dimensionally stable. In designing the stamp, care was taken to ensure that it was fit for purpose and had no sharp transitions or edges.

For the heat treatment of hardening and tempering, the steel manufacturer's recommendations were followed regarding the required number of preheats, temperatures, heating durations, and holding times at specific temperatures.

The measured hardnesses and the functional test performed show that the tool is correctly sized and well heat treated.

7. REFERENCES

[1] M. Novosel, F. Cajner, D. Krumes, Tool materials (Alatni materijali). Josip Juraj Strossmayer University in Osijek, Mechanical Engineering Faculty in Slavonski Brod, (1996)

[2] F. Cajner, D. Landek, Specificities of the heat treatment of tool steels (Posebnosti toplinske obrade alatnih čelika), Proceeding of the International Conference on Heat Treatment and Surface Engineering, Rijeka, Croatian Society for Heat Treatment and Surface Engineering, (2012), pp 57-66

[3] T. Filetin, F. Kovačiček, J. Indof, The properties and application of materials (Svojstva i primjena materijala). University in Zagreb, Faculty of Mechanical Engineering and Naval Architecture, (2002)

[4] R. Sunulahpašić, M. Oruč, Tool steels and other tool materials - properties and applications (Alatni čelici i ostali alatni materijali - svojstva i primjene). University in Zenica, Faculty of Metallurgy and Technology, (2019)

https://
www.researchgate.net/publication/338765814, last access 20/06/2022

[5] D. Krumes, Heat treatment (Toplinska obradba). Josip Juraj Strossmayer University in Osijek, Mechanical Engineering Faculty in Slavonski Brod, (2000)

[6] Data Sheet 1.2080 (D3) Dörrenberg Edelstahl GmbH.

https://www.finemetal.ro/wp-content/uploads/2020/09/1.2080-CP10V-X210Cr12.pdf, last access 25/06/2022

Optimization of structural elements of subsoiler by response surface method

M. Kokić [a], P. Konjatić [a], M. Karakašić [a]

[a] University of Slavonski Brod, Trg Ivane Brlić Mažuranić 2, 35000 Slavonski Brod, Croatia

Abstract

The aim of the research presented in the paper is to reduce the mass of the structural elements of the subsoiler using the response surface optimization method. Two structural elements are optimized tine and structural support. The CAD model of the subsoiler was created in SolidWorks, a CAD system for parametric modeling using features. For the purpose of optimizing structural elements, soil load calculations were made using the Matlab software package. The geometric parameters of the structural elements, which represent the input parameters, were optimized. Output parameters (responses) consist of mass, maximum equivalent stress according to von-Mises and deformations. After the optimization, the control calculation of the optimized structural elements was made again with regard to s tresses and deformations. Through the control calculation, the stresses and deformations of the optimized structural elements meet the permissible values.

Keywords: Subsoiler; Tine; Soil load; Optimization; Response surface

1. INTRODUCTION

With the increase of standard of living and population, more efficient and better quality food production is needed. Which requires the development of agricultural mechanization. For greater soil efficiency it is necessary to treat the soil well before sowing, to have good results subsoiler is necessary.

A subsoiler is an agricultural machine that is used for surface tillage, it is used to prepare the soil before sowing crops. The main functions of the machine are improving soil fertility, protection against soil erosion and maximum soil moisture retention.

1.1 Subsoiler model

CAD Model of subsoiler was made from measurement of existing subsoiler Pöttinger Synkro 3020.

Optimization will be performed for elements shown on Fig. 1 where most loaded is number 1 tine and number 5 structural support.

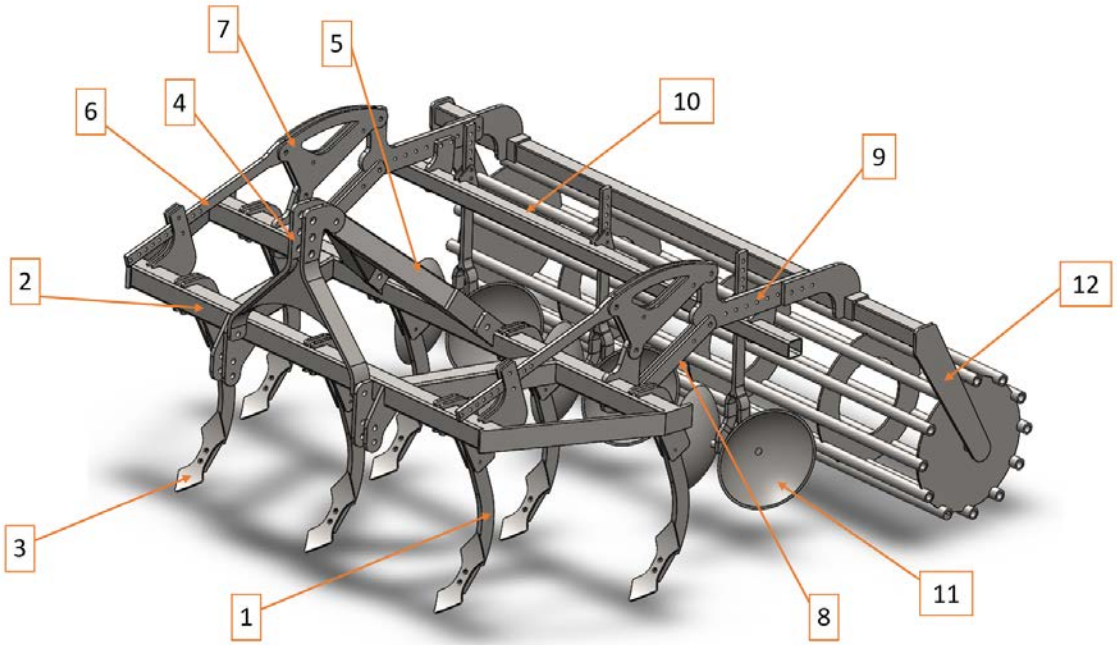

Fig. 1. CAD model of subsoiler

2. SOIL LOAD CALCULATION FOR TINE

The mechanics of earthmoving are similar in many respects to the bearing capacity of shallow foundations on soil. The quantitative effects on maximum bearing pressure of soil weight, cohesion and surcharge pressure above the foundation level can be separated and are additive algebraically. Following as a universal earthmoving equation for describing the force necessary to cut soil with a tool [1].

$$P = \left(\gamma g d^2 N_\gamma + c d N_c + q d N_q\right) w \qquad (1)$$

where:
P – total tool force, N
γ – total soil density, kg/m^3
g – acceleration due to gravity, m/s^2
d – tool working depth below the soil surface, m
c – soil cohesion strength, Pa
q – surcharge pressure vertically acting on the soil surface, Pa
w – tool width, m
N_γ, N_c, N_{ca} i N_q – factors which are depend on the soil frictional strength, on the tool geometry and tool to soil strength properties.

The variables of tool geometry which influence the magnitudes of the N factors include the angle of the tool from horizontal plane, the possible curvature of the tool shape and the depth to width ratio of a narrow tool. It remains to be seen for what complexity of tool shapes the N factors of Eq. 1 can be determined analytically, so that predictive calculations can be made of soil cutting forces [1].

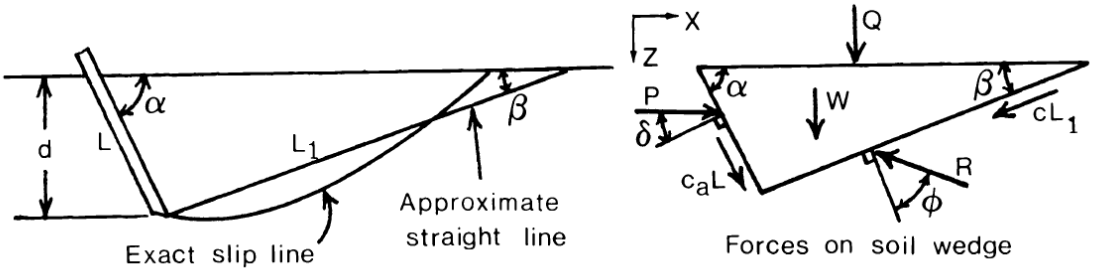

Fig. 2. Forces on soil wedge [1]

N factors calculation:

$$N_\gamma = \frac{\frac{1}{2}[\cot\alpha+\cot\beta]}{\cos(\alpha+\beta)+\sin(\alpha+\beta)\cot(\beta+\phi)} \quad (2)$$

$$N_c = \frac{1+\cot\beta\cot(\beta+\phi)}{\cos(\alpha+\beta)+\sin(\alpha+\beta)\cos(\alpha+\beta)} \quad (3)$$

$$N_q = 2N_\gamma \quad (4)$$

$$N_{ca} = \frac{1-\cot\alpha\cot(\beta+\phi)}{\cos(\alpha+\beta)+\sin(\alpha+\beta)\cot(\beta+\phi)} \quad (5)$$

where:
α – tool angle, rad
δ – tool to soil friction angle, rad
φ – soil friction angle, rad
c – soil cohesion resistance, Pa
c_a – tool to soil cohesion resistance, Pa
β – angle of the soil failure wedge, rad

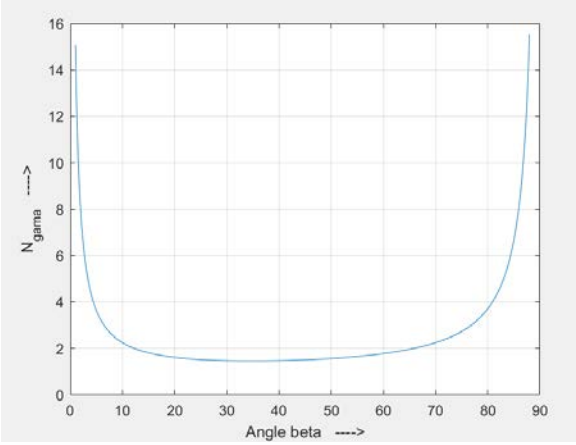

Fig. 3. Value of the angle β for factor N_γ

Calculated are values $\beta = 34{,}8389°$ and $N_\gamma = 1{,}4493$, now is possible calculate other *N* factors. Horizontal and vertical force of soil to tool is calculated:

$$H = P\sin(\alpha+\delta) + c_a dw\cot\alpha \quad (6)$$

$$V = P\cos(\alpha+\delta) - c_a dw \quad (7)$$

Also:

$$H = \left(\gamma g d^2 N_\gamma + cdN_c + c_a dN_{ca}\right) w \sin(\alpha+\delta) + c_a dw\cot(\alpha) \quad (8)$$

$$V = H\cot(\alpha+\delta) - c_a dw(\cot\alpha\cot(\alpha+\delta)+1) \quad (9)$$

Dimensions of subsoiler tool:

$\alpha = 40°$
$w = 0{,}14$ m
$d = 0{,}3$ m

Mechanical properties of clay loam soil:

$\gamma = 2000$ kg/m^3
$\delta = 20°$
$\varphi = 30°$
$c = 30\,000$ Pa
$c_a = 12\,000$ Pa

To find the most appropriate angle of the soil failure wedge, it is therefore logical to determine that value of the angle β, which causes N_γ to be a minimum using Eq. 2.

Value of the angle β is determined by iteration in Matlab in causes to N_γ to a minimum (Fig. 3).

In Matlab forces are calculated, horizontal force values $H = 3195{,}1312$ N and vertical force $V = 993{,}928$ N, what is needed for analysis of equivalent stress and total deformation.

3. OPTIMIZATION

3.1 Analysis of design features of subsoiler

Input parameters are determent for tine and structural support which will be used for optimization (Fig. 4). Input parameters are defined for tine: *L1* as *Width*, *L5* as *Hight*, *L8* as *Distance*, *R2* as *Radius* and *FD1* as *Thickness.*

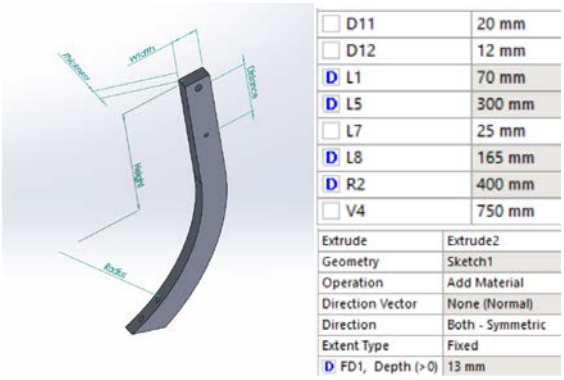

Fig.4. Input parameters for model of tine

Frictionless support is defined as boundary condition for tine on two surface of holes at the top of model. Other boundary condition is load defined at surface at bottom of model (Fig. 5). Defined load is combined horizontal force H and vertical force V calculated by Matlab.

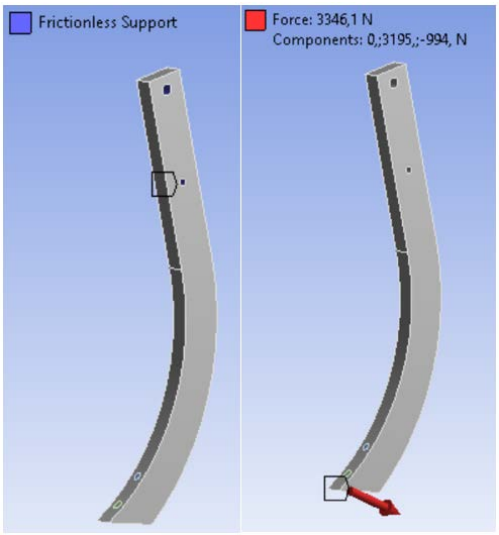

Fig. 5. Placement of frictionless support(left/purple) and load(right/red) for tine

For structural support load is defined on surface of hole and fixed support is defined on surface of other hole (Fig. 6).

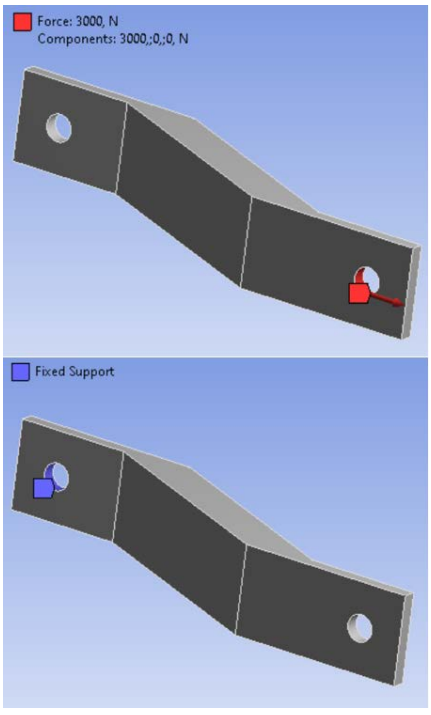

Fig. 6. Placement of load(up/red) and fixed support(down/purple) for structural support

3.2 Convergence solutions

Tetrahedral finite elements are used in analysis. To check accuracy of the analysis, the convergence was performed for the stress and deformation analysis.

The convergence of the solutions was made for tine and structural support elements.

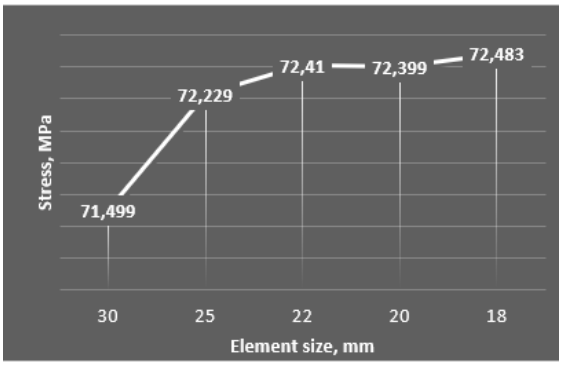

Fig. 7. Graph of convergence solutions for stress of tine

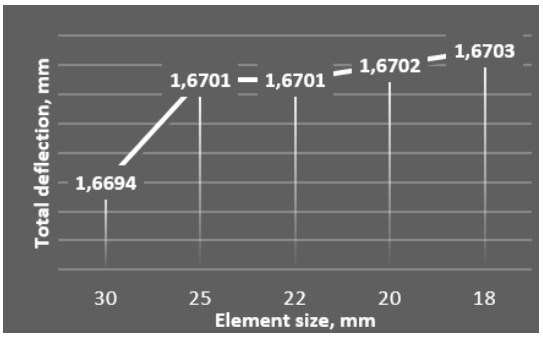

Fig. 8. Graph of convergence solutions for total deflection of tine

Results of convergence for tine are presented in graphs (Fig. 7 and Fig. 8) therefore element size 20 mm was chosen. With that element size, analysis mesh counts 3352 elements and 7385 nodes.

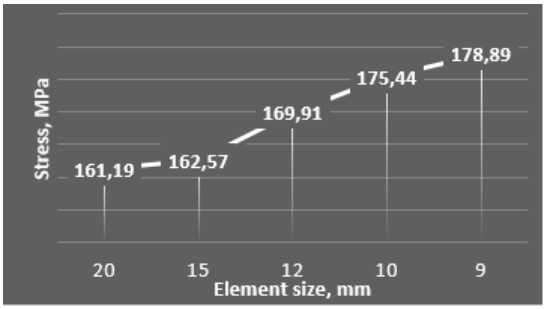

Fig. 9. Graph of convergence solutions for stress of structural support

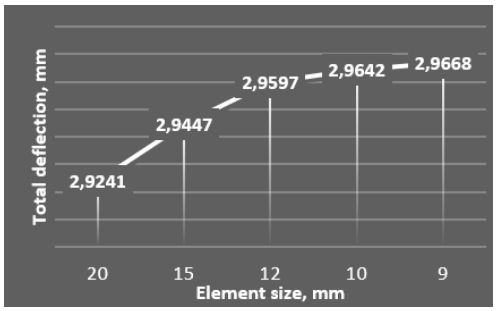

Fig. 10. Graph of convergence solutions for total deflection of structural support

Results of convergence for structural support are presented in graphs (Fig. 9 and Fig. 10) therefore element size 10 mm was chosen. With that element size, analysis mesh counts 11276 elements and 20776 nodes.

3.3 Output and input parameters

Chosen output parameters are mass, maximum equivalent stress and maximum total deformation. They are necessary for optimisation.

Then the lower and upper values of input parameters are defined for tine and structural support.

3.4 Response surface

Response surfaces are generated and then it's possible to choose different diagrams for showing the influence of input parameters on the value of output parameters. Response surface can display only three dimensions, so only the most influential parameters will be shown for tine and structural support.

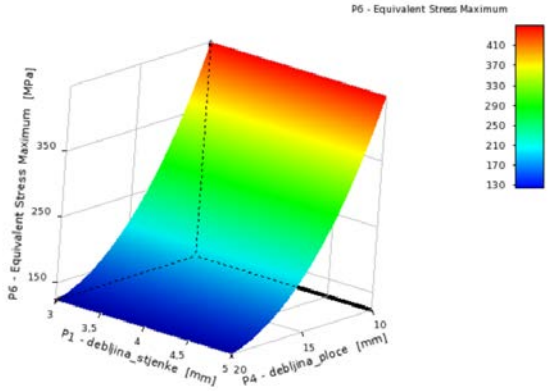

Fig. 11. Response surface of stress for tine

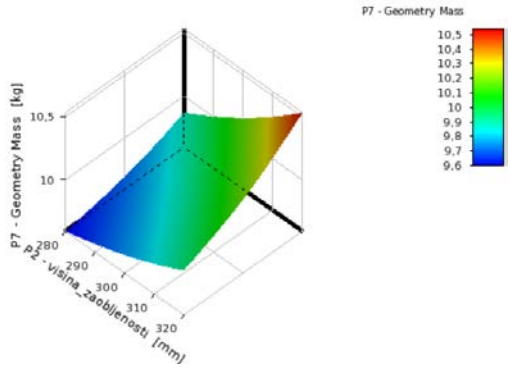

Fig. 12. Response surface of mass for tine

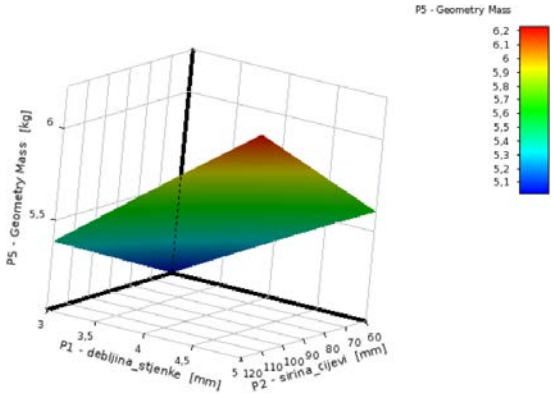

Fig. 13. Response surface of mass for structural support

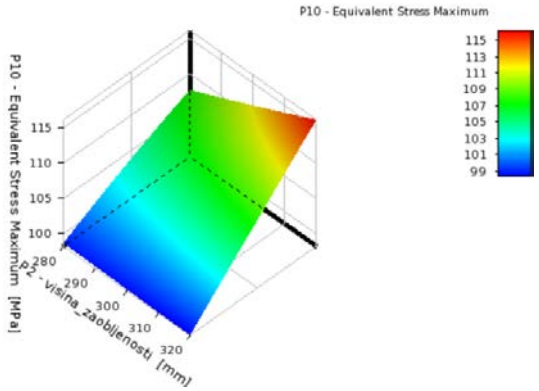

Fig. 14. Response surface of stress for structural support

3.5 Local sensitivity

Local sensitivity shows influence of each input parameter on output parameters. Most influential parameters for tine are width and thickness (Fig. 15 and Fig. 16).

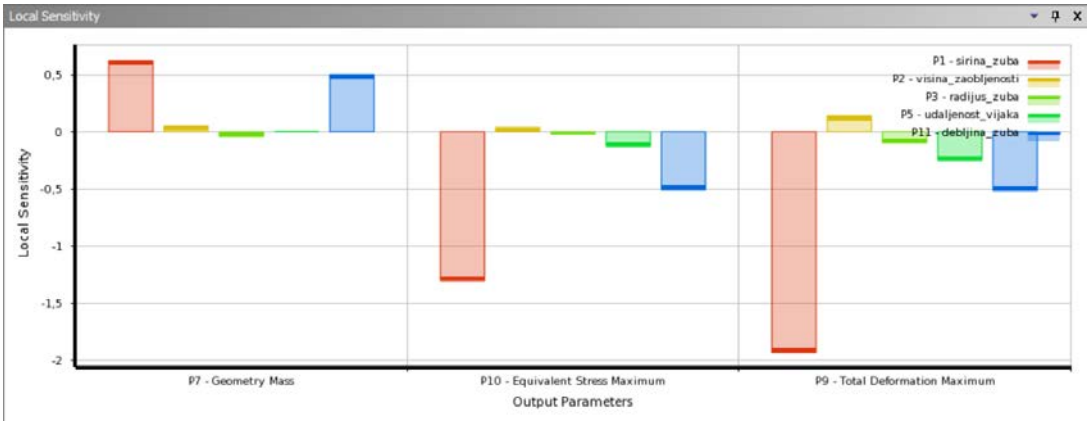

Fig. 15. Local sensitivity diagram for tine

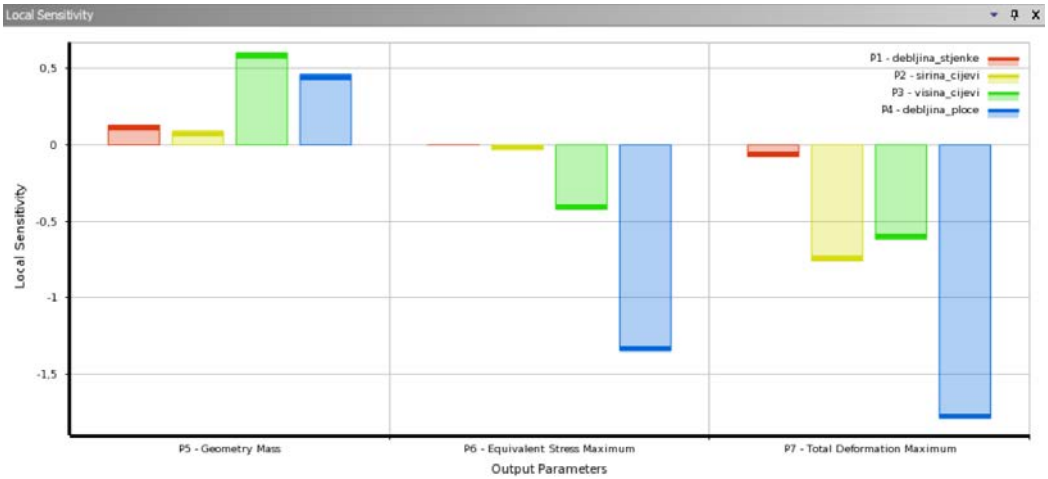

Fig. 16. Local sensitivity diagram for structural support

Structural support height is most influential parameter for mass, as thickness has great influence on stress and total deformation.

4. RESULTS AND ACHIEVEMENTS

Comparison of initial and optimized values of tine is displayed by Table 1. Changed input parameters are: mass with -55,1% deviation, stress with +146% and total deformation with +157% deviation.

Comparison of initial and optimized values of structural support is displayed by Table 2. Changed input parameters are: mass with -38,7% deviation, stress with -0,1% and total defeflection with +50,6% deviation.

Table 1. Input and output parameter change due optimization of tine

	Parameter	Initial value	Optimized value	Deviation
Input	Width, mm	70	53,98	-22,9 %
	Height, mm	300	281,11	-6,3 %
	Radius, mm	400	433,78	+8,45 %
	Distance, mm	165	238,96	+44,8 %
	Thickness, mm	13	9,5628	-26,4 %
Output	Mass, kg	14,229	6,3831	-55,1 %
	Stress, MPa	72,339	177,99	+146 %
	Total deflection, mm	1,6702	4,286	+157 %

Table 2. Input and output parameter change due optimization of structural support

	Parameter	Initial value	Optimized value	Deviation
Input	Thickness, mm	5	3,109	-37,8 %
	Width, mm	100	85,343	-14,7 %
	Height, mm	100	61,511	-38,5 %
	Plate thickness, mm	16	18,165	+13,5 %
Output	Mass, kg	6,8864	4,2217	-38,7 %
	Mass, MPa	175,44	175,28	-0,1 %
	Total deflection, mm	2,9642	4,4648	+50,6 %

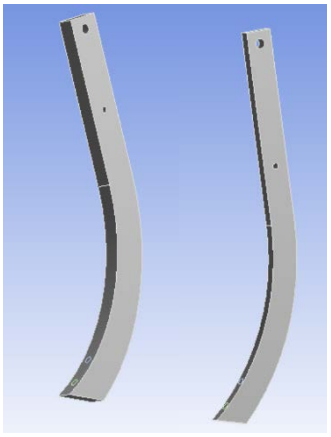

Fig. 17. Comparison of initial(left) and optimized(right) tine

With optimization of initial tine dimensions is achieved mass loss of 55,1%.

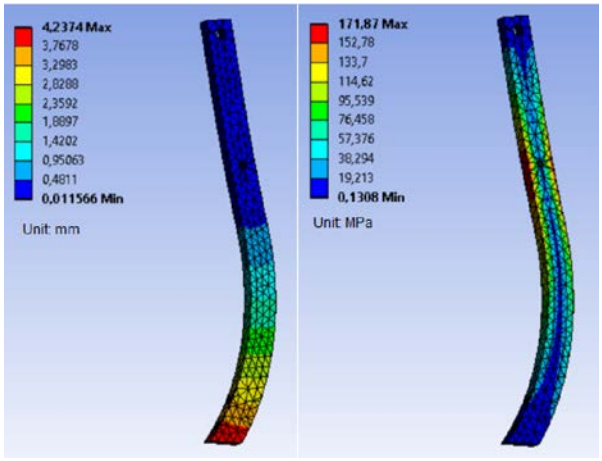

Fig. 18. Stress(left) and total deformation(right) results for tine

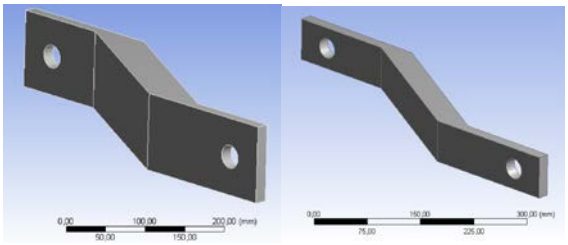

Fig. 19. Comparison of initial(left) and optimized(right) structural support

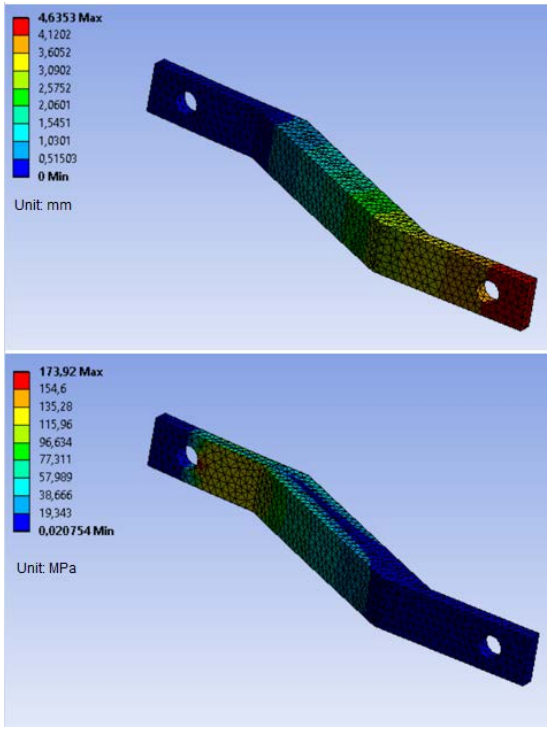

Fig. 20. Stress(up) and total deformation(down) results for structural support

With optimization of initial structural support dimensions is achieved mass loss of 38,7%.

5. CONCLUSIONS

A model for calculating the soil load on the working body of the underminer tooth was achieved. Achieved is change in geometry of subsoiler structural elements by application of response surface optimization. Geometry was changed with goal to reduce mass. With mass reduction of structural elements it lowers production cost of subsoiler.

By applying the response surface optimization method, the structural elements of the subsoiler were optimized. The structural elements tine and structural support have been optimized. A mathematical model was also obtained for determining the soil load on the structure. For the presented model, the program code was created in the Matlab program package.

By optimizing the geometry of the structural tine element, its weight was reduced by 55.1%, which represents a significant saving of the material needed for the construction. The mass of the structural support element has been reduced by 38.7%.

The paper shows how the application of modern computer optimization methods contributes to a significant saving of materials in the construction, while the function and functionality of the structure and structural elements remain unchanged.

6. REFERENCES

[1] Edward McKyes, Soil Cutting and Tillage, McDonald College of McGill University, Ste-Anne de Bellevue, Quebec, Canada, Elsevier, (1985.)

[2] Matlab, MathWorks, 2018

[3] SYNKRO PÖTTINGER two and three-row stubble cultivators https://www.poettinger.at/download/prospekte/POETTINGER_SYNKRO_220.EN.1114.PDF, last access 21/07/2022

[4] M. Kokić, Optimization of structural elements of the technical system of subsoiler by response surface method. University of Slavonski Brod, (2022).

Finite Element Simulation of Face Milling During Milling of Nickel-Based Superalloys

G. Kónya [a], E. Kókai [a], Zs. F. Kovács [a]

[a] John von Neumann University, Izsáki út 10., H-6000 Kecskemét, Hungary,
E-mail: konya.gabor@gamf.uni-neumann.hu

Abstract

In the present scientific work, the authors have dealt with face milling of nickel-based superalloy. During this research work, a cutting simulation environment was set up in Ansys finite element software can be studied the cutting process. To validate this model, the authors also performed the experiments in reality, within which were measured the forces and torques during machining. It gives the opportunity to be comparable with the results obtained in the simulation environment.

Keywords: Nickel-based superalloy, face milling, finite element method, 3D scanning, force- and torque measurement

1. INTRODUCTION

The Nickel-based superalloys are a special class of metallic materials developed in the United States in 1970s. It is used in many applications, most notably in the aerospace, medical and energy industries. These industries have grown significantly in the past, are still growing and will continue to do so in the future, as they are the foundation of our economy. For this reason, the study of the machinability of these alloys is an aera of current research [1], [2], [3], [4], [5].

These alloys are composed of two main phases: the Gamma (γ) and Gamma-prime (γ') solid solution. Both phases have FCC lattice structure, where in the γ-phase the Ni and Al atoms are disordered in the lattice, while in the γ'-phase the Ni atoms are located at the centre of the sheet and Al atoms at the peeks [6], [7]. Their lattice structure is shown in Figure 1.

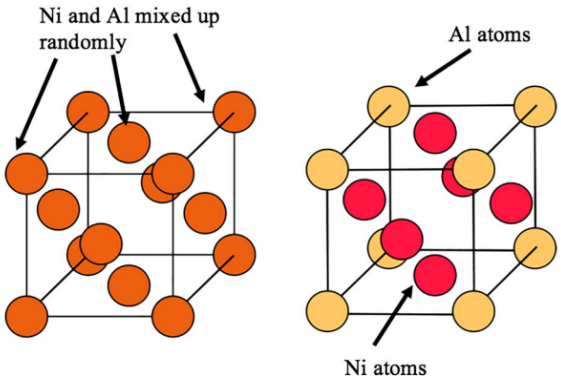

Fig. 1. The lattice structure of γ (left) and γ' (right) phases [6]

Metal alloys are generally characterised by a decrease in strength with increasing temperature, as the dislocations are easily displaced at high temperatures. In contrast, those superalloys which contains γ'-phase of Ni_3 (Ti, Al) can be retain their strength at very high temperatures. Basically, in the γ- and γ'-phases, the dislocations appear on the {111}-plane, however, the energy of the phase boundary in the {100}-planes decreases with increasing temperature, so the dislocations in the γ'-phase can move in these directions. This results in an increase in strength as the dislocations through the {111} and {100}

planes are blocked in the fabric structure [7], [8], [9].

This is the result of the low plastic deformation capacity of the material, which makes the machining process so difficult. The machining process usually produces sheared chips (eg. milling or turning).

As a result, the cutting force (Fc) and temperature are greatly increased the strong abrasive effect on the carbide tools. Furthermore, due to its poor thermal conductivity, the cutting temperature puts even more stress on the tool's edge, overall it results drastic reduction of tool life.

In the present research work, the authors investigated the machinability of a GTD111 type of nickel-based superalloy during face milling. To determine the machinability, the authors previously made virtual machining in simulation environment, which was designed in Ansys finite element software. In case of the real and the theoretical machining forces and torques were compared with each other. The machining simulations are very important in tool design, because it can help to radically reduce the cost of tool design and it is sufficient to produce only good tool geometries. Furthermore, this simulation environment give opportunity to testing cutting tool materials, which can help change the best material.

2. METHODS AND MATERIALS USED FOR RESEARCH

2.1. Material

In this research, the authors used GTD111 Nickel-based superalloy as work piece material. Chemical composition, mechanical properties and physical properties of GTD111 shown in Table 1., Table 2. and Table 3.

Table 1. Chemical composition of GTD111 (mean values) [10]

Fe (%)	Ni (%)	C (%)	Cr (%)	Co (%)	Al (%)	Ti (%)	W (%)	Mo (%)	Ta (%)	B (%)
-	62,37	0,08	13,7	9	2,8	4,7	3,5	1,4	2,4	0,05

Table 2. Mechanical properties of GTD111 (minimum values) [10]

Tensile strength R_m, (MPa)	Stretch A_5, (%)	Contraction Z, (%)	Hardness (HRC)
1310	5	5	41,4

Table 3. Physical properties of GTD111 [10]

Specific weight ρ, (kg/m^3)	Heat conductivity on 20 °C λ, (W/mK)	Specific heat on 20 °C c, (J/kgK)
8000	12,56	0,452x10^3

2.2. Experimental setup

The hard milling can cause extreme stress for the machine centre, so a robust and highly rigidity one is required, therefore the NCT EmL-850D 5AX was chosen.

The authors used a KISTLER 9125A24 rotary force meter to measure the axial cutting force and torque. A KISTLER 9257B linear force meter was used to measure the cutting force. We must used two type of force meter, because the rotary force meter can measure the axial cutting force and torque. The linear cutting force meter was used for measure the F_x, F_y and F_z cutting force components. It is necessary to compare the values and directions.

For signal processing a KISTLER 5697 signal processing unit was used. Results are recorded using DynoWare software and evaluated using OriginPro 2021 software. The experimental setup is shown in Figure 2.

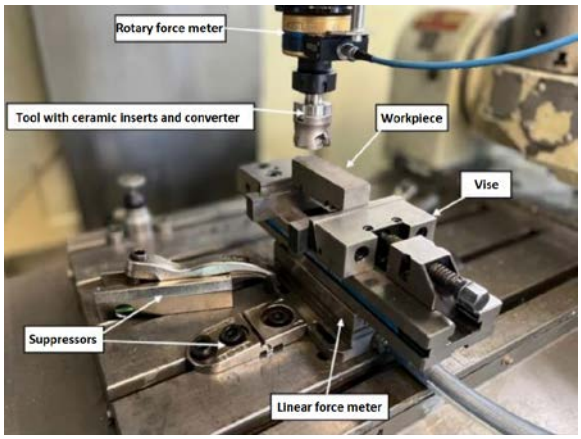

Fig. 2. Experimental setup

2.3. The tool was used in the experiments

For face milling, ceramic inserts were used, type of TaeguTec BNGX 0904 CH-E04 , which were placed in a TaeguTec TFMBN 350-22R-09CH tool holder (Figure 3.).

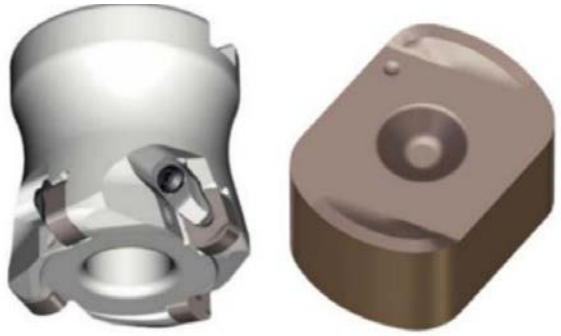

Fig. 3. Tool holder and inserts which used in experiments

2.4. Cutting parameters

The applied technological parameters for the experiments are based on the manufacturer's recommendation (cutting speed was v_c=900 m/min, feed per tooth was f_z=0,25 mm/tooth and the depth of cut was a_p=1 mm).

2.5. Cutting simulation

2.5.1. Design of material model

The simulation of the face milling was done in Ansys finite element software. The first step was to build the model, but to in case have to create the material model. The physical and mechanical properties of the material must be specified so that the material model matches reality.

A critical point in finite element simulations of machining processes is chip formation and separation. To solve the problems, a criterion is developed to detect cracks and failures localizes. These require complex physical and mechanical modelling, which is very difficult to do, therefore a separation criterion linked to a material boundary is introduced. This criterion is based on two separate values, this parameter is λ. The item is deleted if (λ=1) or not deleted if (λ=0). A criterion is based on the following cumulative plastic formula, as shown in Eq. 1. [11]:

$$\lambda = \langle \frac{\overline{\varepsilon^P} - \overline{\varepsilon_\infty}}{\left|\overline{\varepsilon^P} - \overline{\varepsilon_\infty}\right|} \rangle \; with \; \langle X \rangle = \begin{cases} 0 \; ha \; X \leq 0 \\ 1 \; ha \; X > 0 \end{cases} \quad (1)$$

where $\overline{\varepsilon_\infty}$ is the plastic deformation limit, which is 0,8 at milling, and determines the material removal.

Chip formation is strongly linked to the contact between the tool and workpiece. The contact between geometries must be established and take into account the friction due to energy generated by friction. These phenomena is extremely complex and changes by the cutting conditions. Usually in machining, these phenomena are approximated by a static Coulomb law, μ_s=0,8 [11]. The coefficient was derived from turning tests [12].

2.5.2. Design of geometric models

To build the simulation model, it is necessary to create a model of the raw material, the tool body and the insert, as simple as possible, because an excessively large model would require a lot of computing time.

3D scanning was used to create a model of the wafer, and the resulting point cloud was the functional surfaces relevant to the simulation was created.

The model of the tool body was placed in one model with the insert to avoid unnecessary contact and simplify the design of the computational requirements.

A model of the raw material had to be made, which was designed so that the cutting tool was already in the machining process, otherwise a significant amount of computation time would be

required. Accordingly, the tool was constrained relative to the workpiece so that the new cut was set to the insert. This simulation environment shown in Figure 4.

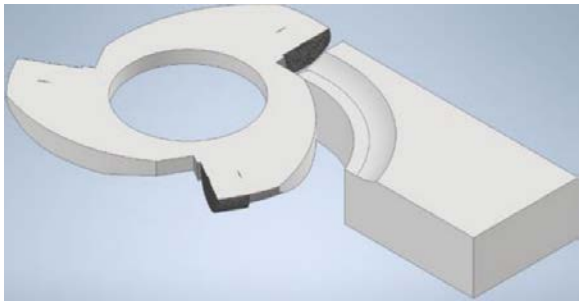

Fig. 4. Setting up the tool and the raw material

Hexahedron meshing was used on the workpiece, and tetrahedron meshing on the tool, as this tracking the deformations [13]. Meshing significantly affects the measurement results, so it has been designed so that cutting zone (element size was 0,035) with a depth of 0,5 mm corresponding to the depth of the mesh, in the other parts of the model, which were not directly involved in the machining operation.

As a final step in the simulation, constraints and displacements were defined. The primary focus is on tool rotation as a function of time was determined. The value of the rotation shall be recorded in degrees, for a total of 576° of angular rotation. In the other directions, displacement was limited, as the tool was substantially simplified in the axial direction, it must be prevented from moving into the deformation in that direction. So a constraint should also be applied on that surface.

On surface A (Figure 5.), the constraint to turn is the necessary rotation, while on surface B, the constraint to simplify to prevent deformation for simplification. On the workpiece only for displacement parameters necessary giving for the movement. Here, the workpiece will move 1.7 mm in the Y direction towards the tool during on the test. The applied constraints for the tool and workpiece are shown in Figure 5. and Figure 6.

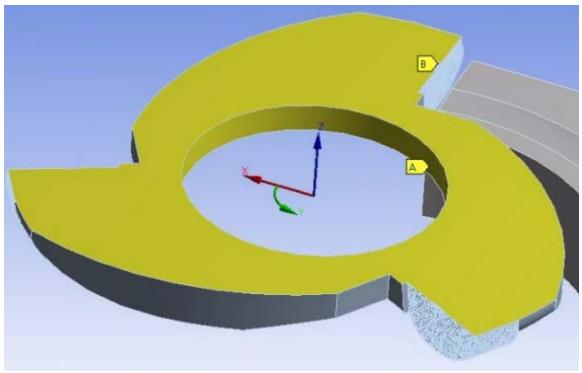

Fig. 5. Applied constraints on the tool

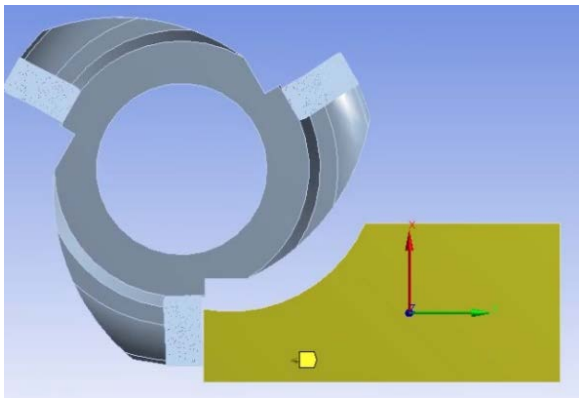

Fig. 6. Applied constraints on the workpiece

3. RESULTS AND ACHIEVEMENTS

3.1. Cutting force and torque

The measured cutting force components and torque shown in Figure 7. and Figure 8.

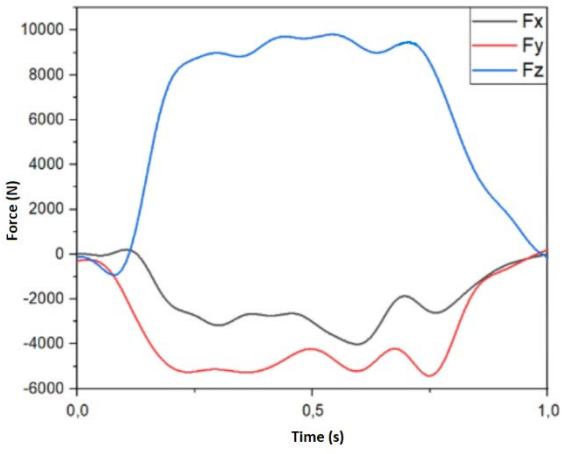

Fig. 7. Measured cutting force components

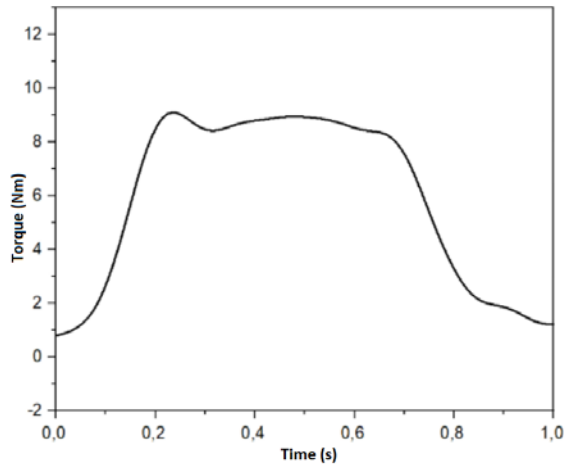

Fig. 8. Measured cutting torque

3.2. Achievements of cutting simulation

The force components and torque obtained as a result of the simulation are shown in Figure 9. and Figure 10.

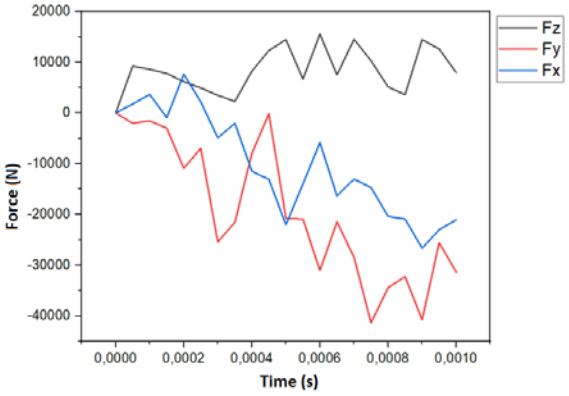

Fig. 9. Given cutting force components from simulation

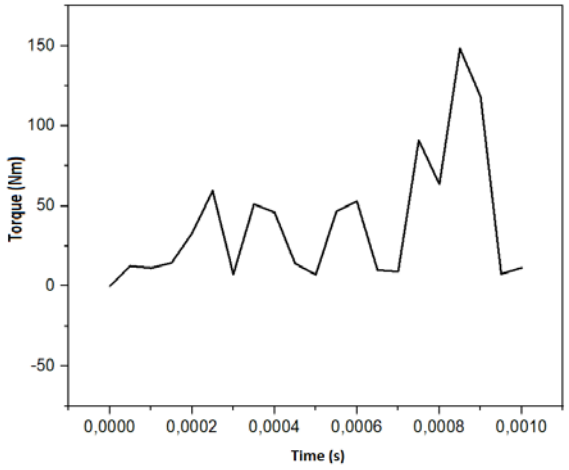

Fig. 10. Given cutting torque from simulation

As shown in Figures 7-10., the direction of the cutting force and torque measured in reality and the direction of the cutting force and torque obtained in the simulation are the same, which indicates that the constraints are well set. However, there are multiple differences in values. This could be because the scan of the geometry of the insert may not hava been accurate enough.

4. CONCLUSIONS

In the present research work, the authors investigated face milling of Ni super alloy by finite element simulation. Set up a realistic model of the cutting process in Ansys finite element software, and then these results were compared with the results of experiment which carried out in real life. For numerical values, it is clear that there are order of magnitude differences between the measured and simulated results, but they are predictive. This implies that the constraints and displacements defined in the simulation model are correspond to reality.

5. REFERENCES

[1] D. Ulutan and T. Ozel, “Machining induced surface integrity in titanium and nickel alloys: A review,” *International Journal of Machine Tools and Manufacture*, vol. 51, no. 3, pp. 250–280, Mar. 2011, doi: 10.1016/J.IJMACHTOOLS.2010.11.003.

[2] S. D. Antolovich, “Microstructural aspects of fatigue in Ni-base superalloys,” *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, vol. 373, no. 2038, Mar. 2015, doi: 10.1098/RSTA.2014.0128.

[3] E. Kaya and B. Akyüz, “Effects of cutting parameters on machinability characteristics of Ni-based superalloys: a review,” *Open Engineering*, vol. 7, no. 1, pp. 330–342, Feb. 2017, doi: 10.1515/ENG-2017-0037/ASSET/GRAPHIC/J_ENG-2017-0037_FIG_013.JPG.

[4] K. Gábor, I. Járművek és Anyagok Tanszék, G. Műszaki és Informatikai Kar, and N. János Egyetem, "NIKKEL-BÁZISÚ SZUPERÖTVÖZET MEGMUNKÁLHATÓSÁGA MANUFACTURING OF NICKEL-BASED SUPERALLOY," vol. 9, no. 1, 2022, doi: 10.47833/2022.1.ENG.004.

[5] K. Gábor, "NIKKEL-BÁZISÚ SZUPERÖTVÖZET FORGÁCSOLHATÓSÁGA EGYES CAM STRATÉGIÁK FÜGGVÉNYÉBEN HSC TARTOMÁNYBAN MANUFACTURING OF NICKEL BASED SUPERALLOY AS A FUNCTION OF CAM STRATEGIES IN THE HSC RANGE," vol. 9, no. 1, 2022, doi: 10.47833/2022.1.ENG.006.

[6] Y. M. Wang-Koh, "Understanding the yield behaviour of L12-ordered alloys," *http://dx.doi.org/10.1080/02670836.2016.1215961*, vol. 33, no. 8, pp. 934–943, May 2016, doi: 10.1080/02670836.2016.1215961.

[7] "Nickel Based Superalloys." http://www.phase-trans.msm.cam.ac.uk/2003/Superalloys/superalloys.html (accessed May 23, 2022).

[8] "Designing for Creep Resistance - Nickel Based Superalloys." https://www.doitpoms.ac.uk/tlplib/creep/creep_resistance.php (accessed May 23, 2022).

[9] Z. L. Kowalewski and A. Ustrzycka, "Creep Deformation," *Encyclopedia of Continuum Mechanics*, pp. 499–508, 2020, doi: 10.1007/978-3-662-55771-6_157.

[10] K. János, Z. János, K. Zsolt, and K. Főiskola, "A forgácsolhatóság meghatározásának módszerei Ni-bázisú szuperötvözetek horonymaráskor Kulcsszavak: forgácsolhatóság; Ni-bázisú szuperötvözet; horonymarás; forgácsolási nyomaték; forgácsolási hőmérséklet," no. 2, p. 125, 2015.

[11] A. Maurel-Pantel, M. Fontaine, S. Thibaud, and J. C. Gelin, "3D FEM simulations of shoulder milling operations on a 304L stainless steel," *Simulation Modelling Practice and Theory*, vol. 22, pp. 13–27, Mar. 2012, doi: 10.1016/J.SIMPAT.2011.10.009.

[12] M. Rodríguez-Millán, J. Díaz-Álvarez, R. Bernier, J. L. Cantero, A. Rusinek, and M. H. Miguelez, "Thermo-Viscoplastic Behavior of Ni-Based Superalloy Haynes 282 and Its Application to Machining Simulation," *Metals 2017, Vol. 7, Page 561*, vol. 7, no. 12, p. 561, Dec. 2017, doi: 10.3390/MET7120561.

[13] P. Chakrapani, C. Prakash, and V. Sekar, "3D Finite Element Analysis Simulation Of Slot Milling Process For Titanium Alloy Ti6Al4V Currently I am working on modelling of machining of GFRP/CFRP Drilling and Milling and turning of Inconel 718. View project Cryogenic treatment of tungsten carbide tool material View project 3D Finite Element Analysis Simulation Of Slot Milling Process For Titanium Alloy Ti6Al4V," *International Conference On Progressive Research In Applied Sciences, Engineering And Technology*, vol. 22, 2018, Accessed: Jul. 03, 2022. [Online]. Available: www.iosrjen.org

Control of the surface roughness parameters of painted aluminium sheets by femtosecond laser surface modification

Zs. Könyves [a], M. Berczeli [b]

[a] Department of Innovative Vehicles and Materials, GAMF Faculty of Mechanical Engineering and Computer Science, John von Neumann University, Kecskemét, HU-6000, Hungary, konyves.zsolt@gamf.uni-neumann.hu

[b] Department of Innovative Vehicles and Materials, GAMF Faculty of Mechanical Engineering and Computer Science, John von Neumann University, Kecskemét, HU-6000, Hungary, berczeli.miklos@gamf.uni-neumann.hu

Abstract

The aim of this research is to support the theory that it is possible to create controlled surface roughness using femtosecond laser beam modification techniques. In this case, the material under investigation is a 5005 aluminium sheet with polyester painting. In the experimental design, the fixed, variable and investigated parameters were determined. The surface modification experiments were achieved by varying the laser beam technology parameters such as scanning speed, laser scanning path distances and average power of the pulsed laser. During the tests, the resulting surface structure was investigated by light microscopy and the stability of the process was verified by geometry measurements. The roughness of the resulting surfaces was determined. Further measurements will be added to the experiment to find an exact correlation between the laser parameters and the microgeometric characteristics. From the interpretation of the results it can be seen that different laser beam technology data can produce different surface profiles and roughness Ra, Rz values. It is possible to create surfaces on the paint with different distances but controlled roughness. And microscopic images give an idea of the material removal performance of the fs-laser beam. As a result of this research, the surface roughness characteristics of the painted surface could be modified from Ra 0.5 µm to 3.8 µm and from Rz 2.8 µm to 14.4 µm.

Keywords: material science, fs-laser, aluminium, surface treatment, surface roughness, surface modification

1. INTRODUCTION

Laser beam technologies are nowadays very widespread due to their versatility and efficiency. Large, multi-kW installations are already widespread in the automotive industry and other fields. A few years ago, laser micromachining was only used in laboratories or for exceptional industrial applications, but today more and more people are discovering it for themselves. This branch of laser technology can be used to solve problems that are difficult or impossible to solve using conventional manufacturing processes. Some of the possible applications of the technology presented are, but are not limited to: electrotechnical soldering stencils, springs made of shape-memory metal, biocompatible materials for medical devices, endoscope frames, gas nozzles, micro-filters, small ceramic components [1].

A femtosecond is one billionth of a second, or one billionth of a billionth of a second. In layman's terms, a femtosecond is proportional to a second as one second is to roughly 31.7 million

years. In that time, a ray of light travels about 0.3 μm [2].

Femtosecond lasers are the shortest pulse duration lasers on the industrial market. The pulse duration of industrial femtosecond lasers is typically 300-400 femtoseconds or 300-400 10^{-10}-10^{-15} s. When trying to create a laser that emits such a short beam of light while having sufficient pulse energy to process the material, the peak power will be so high that it will damage the excited medium. To avoid this, the pulse is usually amplified with a spread pulse, which is later compressed. The phase modulated pulse amplification process spreads the pulse by a few orders of magnitude. This reduces the peak power and allows the amplification to occur below the threshold that would damage the medium. After amplification, the pulse is restored to its original pulse duration and beam quality. For some lasers, it may not be necessary to spread the pulse. In addition, femtosecond lasers are available in a variety of wavelengths from infrared to ultraviolet (although UV is not available for all lasers) through frequency conversion with non-linear optics [2].

The pulse length of the laser is very short, so it can work on almost any material from glass to hardened steel and plastic. Since the pulse duration of the laser is shorter than the conduction time of the material, no heat signature occurs during machining. The material goes from solid to air - a phenomenon often referred to as "cold ablation", which allows for the highest quality machining and offers unique machining performance [2].

These disk-based femtosecond lasers provide a pulse below 400 fs, in addition to the best beam quality and peak power available. This results in an extremely high quality, cold ablation cutting process compared to the melt ablation process [2].

The aim of the current series of experiments is the femtosecond laser-assisted surface treatment of painted aluminium sheet surfaces in such a way that the surface roughness parameters can be changed.

2. METHODS AND MATERIALS USED FOR RESEARCH

2.1. Material

Aluminium sheet 5005, 2 mm thick, manufactured and distributed by AssanAlüminyum from Turkey. The aluminium sheet is a polyester pre-painted aluminium sheet with grey colour. The thickness of polyester painting is 22 μm. The mass per unit area if dry polyester paint is 0,02678 kg/m2. In aluminium, regardless of wavelength, the laser beam is extremely difficult to absorb (<10%), so this has a big influence on the parameters we have to work with in the experiments.

2.2. Coherent Monaco femtosecond laser.

The laser treating process was performed using a Coherent Monaco Femtosecond Laser with wavelength of 1035 nm. The laser impulses had 277 fs – 10 ps of width, 188 kHz – 50 MHz of the frequency and the average power was set between 3 W and 60 W (ie. from 5% to 100% power). The beam was focused on the surface with a diameter of 60 μm.

Table 1. Data of Coherent Monaco.

No.	Parameter	Value
1.	Wavelenght	1035 ± 5 nm
2.	Output Average Power	60 W
3.	Frequency range	188 kHz – 50 MHz
4.	Pulse Width	277 fs – 10 ps
5.	Focus spot diameter	60 μm
6.	Energy	80 μJ (at 750 kHz)
7.	Marking Speed	0 – 20 m/s
8.	Focal length	300 mm

2.3 Surface roughness measurement system Formtracer SV-C3100

The Formtracer SV-C3100 computerized surface roughness measurement system was used to measure the surface roughness of the treated

sheet in three repetitions at a measurement length of 4.8 mm perpendicular to the surface treatment direction. When evaluating the data, the average surface roughness and the roughness height were examined.

2.4. Microscope

The microgeometry of the surface treatment was examined using a Zeiss AxioImager.M2 light microscope. The evaluation software was AxioVision software, which was used to take high resolution images of the treated surface.

2.5 Experiment plan

To carry out the surface treatment experiments, an experimental design has been defined as a function of the parameters to be varied. It shows the fixed and variable process data, which have been optimised mainly for laser beam material removal. The fixed technological data were determined on the basis of a series of preliminary experiments in order to achieve the most precise removal of material from the painted surface without burning or degrading it. The variable parameters are of a geometrical nature and the results of this research have been calculated on the basis of the data measured with measuring instruments.

Table 2. Fixed parameters.

No.	Parameter	Unit/*Value*
1.	Power	P *[W%] = 30%*
2.	Marking speed	Vc *[m/s] = 6 m/s*
3.	Marking Count	Mc *[1] = 10*

Table 3. Variable parameter

No.	Parameter	Unit/*Value*
1.	Line distance	l *[Control, 60...120 µm]*

Table 3. Examined parameters

No.	Parameter	Unit/*Value*
1.	Line distance	l *[µm]*
2.	Average surface roughness	Ra *[µm]*
3.	Inequality height	Rz *[µm]*

3. RESULTS AND ACHIEVEMENTS

3.1. Microscopic examination

The micrographs in Fig. 1. and 2. show the resulting surface structure. The figures below show how the surface changes as the distance between the lines is increased. The thickness of the lines is the same as the spot diameter of the laser beam, so the minimum line spacing is chosen accordingly and the maximum line spacing is the same as the value when a line is dropped.

An important condition was that no solidified melt droplets should remain on the treated surface, which could affect the processability of the surface treatment. By using line parameters that meet the requirements, it can be seen that the laser treated surface is pure aluminium with no residual melt droplets. The melting is due to the high line energy density, which was avoided in the experiments.

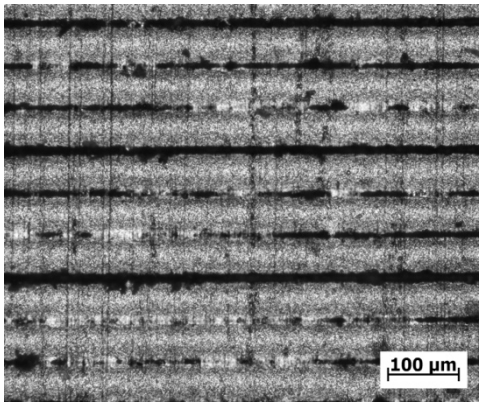

Fig. 1. Field structure with 60-micron line spacing

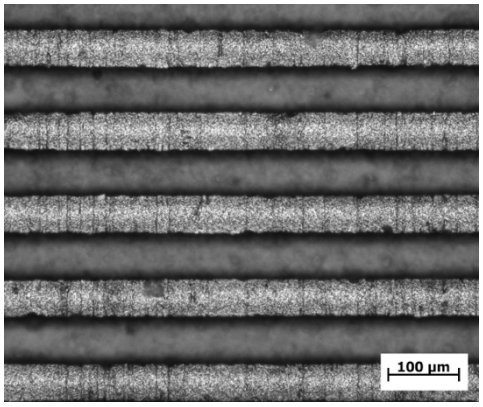

Fig. 2. Field structure with 120-micron line spacing

3.2. Repeatability of surface treatment lanes

The aim was to create a surface structure that periodically repeats, and the repetition is of programmed size. To achieve this, the repetition was checked on a control chart known from statistical process control (SPC) with all variable values. The measurements were made on the microscope images.

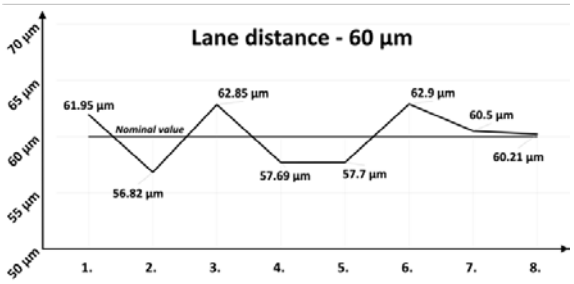

Fig. 3. Control chart of 60-micron line spacing

3.3. Controlled surface roughening

By varying the laser power, surface treatment speed and number of repetitions, and by placing the laser in a structured form on the surface, the microgeometric properties can be controlled in a controlled way. In addition to fixed line parameters, many combinations are available, whether the target is to achieve a rougher or smoother surface.

3.4. Microgeometry of surface profiles

The microgeometric characteristics are shown in the diagram in Fig. 4., given by varying the line spacing with fixed line parameters. The maximum surface roughness is clearly seen at 80 micrometres. At distances below this, the surface roughness is affected by the caustics of the laser beam, because the Gaussian intensity affects the adjacent lines, resulting in overlapping.

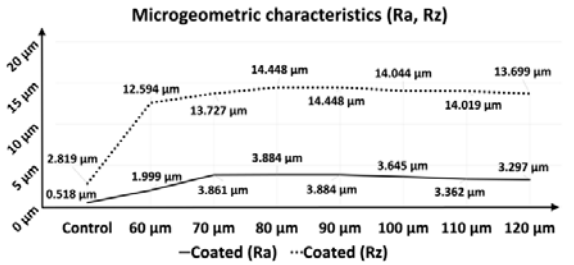

Fig. 4. Microgeometric characterisics of surfaces

4. CONCLUSIONS

Through the example presented in this thesis, it can be shown that ultrashort pulse lasers and modern software can be used to create processes to modify the microgeometry of a surface in a controlled way.

In addition to measuring roughness, changes in surface structure can be investigated in more depth using scanning electron microscopy (SEM), addressing basic science questions.

In the future, even more line parameters can be defined in order to find a correlation with surface roughness and to meet different requirements, for example to increase the strength of bonded joints in the construction industry or to produce etalons.

Laser systems meet the requirements of Industry 4.0, such as automation and continuous measurement and evaluation during production. Rapid material processing also makes manufacturing processes more economical.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

[1] Amada webpage: Femtosecond Laser [Online] https://www.amadamiyachi.eu/knowlegde-base/femtosecond-laser, last access 22/06/2022

[2] Zsolt Puskás et al: Laser micromachining, Technical Review Special Issue 2009, (p. 335)

[3] Endurance lasers webpage: Laser beam absorption [Online] https://endurancelasers.com/absorption-wavelength-spectrum-for-different-materials, last access 25/06/2022

Load Carrying Capacity of the Multi-Beam Structure with Length Tolerances

S. Kotšmíd [a], P. Beňo [a]

[a] Faculty of Technology, Technical University in Zvolen,
Studentska 26, 960 01 Zvolen, Slovak Republic,
E-mail: stanislav.kotsmid@tuzvo.sk; pavel.beno@tuzvo.sk

Abstract

The paper presents theoretical and experimental analyses of the axial load carrying capacity for the multi-beam structure made up of six steel circular beams. The loading tests were conducted on the three beam sets of different lengths where the maximum axial load was determined, while numerical solutions were obtained using the finite element method. To make a computation faster and simpler, a new algorithm was developed where the relation between the axial load and axial displacement for a single beam is used to optimize the load carrying capacity of the structure considering the beam length tolerances. The developed approach is in a good agreement with the complex FE analysis and can be used in a wide range of applications. The results show a significant load decrease in the carrying capacity when using non-equal beam lengths compared to the equal ones where the discrepancies are up to 40% considering the used length tolerance standard.

Keywords: Load Carrying Capacity; Buckling; Length Tolerance; Multi-Beam Structure; Optimization

1. INTRODUCTION

Multi-beam structures are worldwide used systems which provide a higher carrying capacity and a better stability than single-beam structures. The beams can be connected to each other either along the whole length or on the tips only. When loading the slender beams by an axial force, there occurs buckling. The formulas for the buckling load have been derived and have a long history.

Zhang et al. [1] investigated buckling of the double-beam system under the compressive axial loading. The beams were joined by the Winkler elastic layer and the effect of the applied force ratio and the layer properties on the critical buckling load was studied. Similar research in which the double-beam system with the Kerr-type layer was axially loaded and the buckling behaviour was investigated was carried out by Kozić et al. [2]. The formula for the critical buckling load was derived in terms of spring layer parameters. The former research for a single beam linked to rotational spring or a preloaded beam bimorph and elastic layer was performed by Xiao and Li [3]. The elastically connected double-beam system on the elastic foundation where the effect of layer parameters and axial loading was considered was studied by Hao et al. [4]. To extend the knowledge of the multi-beam systems and their behaviour under the axial loading, the triple and multi-Timoshenko beam systems were studied by Stojanović et al. [5]. The buckling force was increased by an increase in the number and stiffness of the connections and decreased by an increase in the number and length of the beams.

When discussing the multi-beam systems, their appearance can be seen in building structures. Due to the complex shape of structures, many papers dealing with the buckling

behaviour have been published. Girgin and Ozmen [6] brought a simplified procedure to compute the buckling load for the spatial multi storeyed frame structure. Bayo and Loureiro [7] presented the direct one-step method to perform the buckling analysis of the steel frame structure that improved standards of that time. Both regular and irregular frames were analysed to determine the buckling lengths of multi-storey columns by Girgin et al. [8]. Their improved procedures eliminated some erroneous results obtained by the design code and specification formulas.

To increase the load carrying capacity, the buckling restrained braces (BRB) have been widely used in structures. Eletrabi and Marshall [9] showed the advantage of using the BRB at three, five and eight storey steel frames. Another research into the BRB where two side columns at the bottom storey of a steel concentrically braced frame were replaced by two buckling-restrained columns and the seismic performance was studied was conducted by Qing et al. [10]. Vatansever [11] investigated the buckling phenomenon on the structure containing the Mero node system that is prone to collapse initiated by buckling of the truss bars. The Chevron-Braced frames were studied by Barbagallo et al. [12], where a new design procedure was developed. Concentrically Braced Frames were studied by Mohammadi et al. [13] where ductility was increased and premature buckling was removed.

In the paper by Szymczak [14] was studied the hall construction modelled by rigid plane frames and elastically connected on upper ends with the roof. It has been proved that a fixed or elastic connection of the frame with the foundation increases the critical buckling loads of the frame system in comparison with some hinged connections. The double-beam frame of different lengths connected by a rigid beam was studied by Gonçalves and Camotim [15] where a system-based approach was used to determine the buckling resistance. The effective length of the beams in multi-storey frames where an assumption of adjoining column buckle was improved was investigated by Webber et al. [16]. The steel double-beam floor systems were studied by Choi et al. [17], where the LM index approach was used to minimize material quantity. Naidoo and Li [18] brought a design optimization of plane, rigid no sway frame structures based on the buckling load. Bidmeshki and Habibi [19] studied the post-buckling of several plane trusses where a new procedure was developed to predict buckling load. An important aspect of the beam elements concerning the nonlinearities arising from the force equilibrium conditions in a beam significantly affect its properties as a constraint element was studied by Awtar et al. [20].

A special kind of the multi-beam structure is the one where the beams are not connected to each other and the connection with the axially loaded rigid plate is defined as a sliding clamp. Obviously, it can be assumed that the axial load carrying capacity of the structure is the buckling load of the single beam multiplied by the number of beams. It is correct only when the beams are of the same lengths. This condition is not usually met in practice due to the discrepancies during the cutting process. The paper provides a theoretical background of the multi-beam structure considering the beam length tolerance where dependence of the axial load on the beam axial displacement is derived. On the basis of the formula, the complex axial loading is determined and the given claims are proved by the experiments and finite element analyses. The conclusion, resulting in a significant decrease of the load carrying capacity can be brought by the optimized algorithm based on the single beam finite element analysis that is simpler and less time-consuming.

2. EXPERIMENTAL STUDY

The loading test was performed on the universal testing machine Testometric M500-100 CT where the axial load was gradually applied on the beams mounted on the fixture (Fig. 1). The beams were embedded into the fixture holes to simulate a sliding clamp. The loading velocity corresponded to the static load and the data were collected by force and displacement sensors and processed by the winTest software.

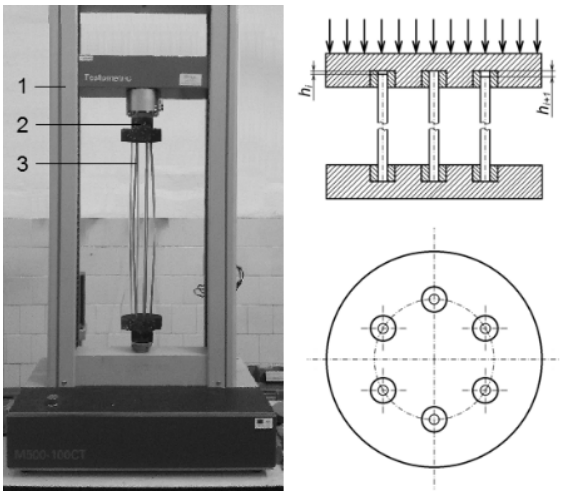

Fig. 1. Experimental measurement (1 – testing machine, 2 – fixture, 3 – specimens)

The tested structure consisted of the steel beams with the circular cross section and the diameter of 5 mm. Each specimen set contained 6 beams which were embedded on a pitch circle with the diameter of 50 mm to avoid a mutual coupling during the loading in the investigated displacement region. Overall, 65 sets were tested with the beam lengths of 330, 395, and 460 mm, which corresponds to the slenderness of 124, 150, and 176 when considering the embedding. As a beam material, structural steel S235 (E = 210 GPa; μ = 0.3) was used and the stress-strain curve was considered to model a material nonlinearity (Fig 2).

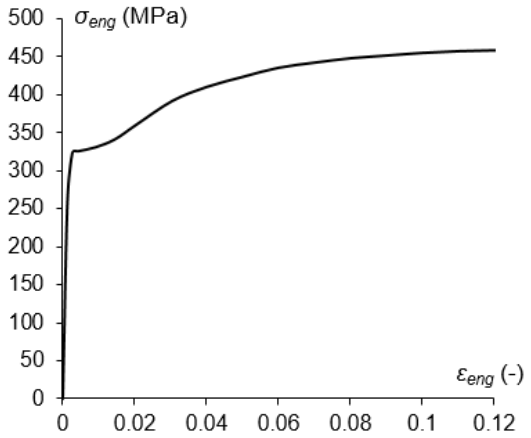

Fig. 2. The stress-strain curve for S235 steel beam

The specimens were cut with tolerances according to the standard ISO 2768, which gives us the beam lengths with the tolerance fields of 330 ± 0.5, 395 ± 0.5, and 460 ± 0.8 mm.

3. THEORETICAL STUDY

The governing differential equations for a beam buckling is derived based on a 2D element using the second order theory (Fig. 3). The Timoshenko theory using a shear coefficient κ is used while large deformations are considered in the equations.

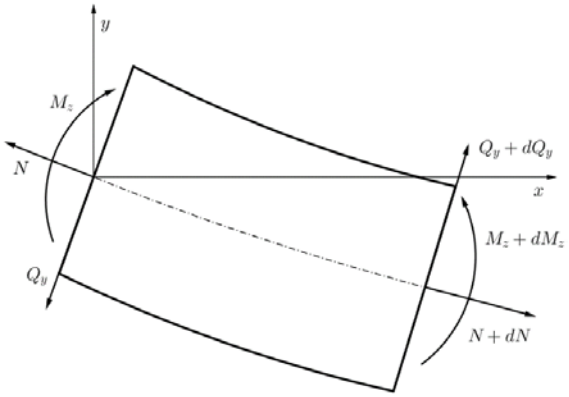

Fig. 3. The beam element

According to Fig. 3, the equilibrium equations are derived as follows

$$\frac{dN}{dx} = 0, \quad \frac{dQ_y}{dx} = N\frac{d^2v}{dx^2}, \quad \frac{dM_z}{dx} = -Q_y \tag{1}$$

where N, Q_y, and M_z are the axial force, shear force, and bending moment. For the Timoshenko theory, the displacement field can be expressed in the form

$$U(x,y) = u(x) + y\varphi_z(x), \quad V(x,y) = v(x) \tag{2}$$

where $u(x)$, $v(x)$, and $\varphi_z(x)$ are the translation and rotation displacements. According to the strain-displacement relations and using the Green tensor, the following equations are used for the Timoshenko theory with large deformation

$$\varepsilon_x = \frac{du}{dx} + y\frac{d\varphi_z}{dx} + \frac{1}{2}\left[\left(\frac{du}{dx} + y\frac{d\varphi_z}{dx}\right)^2 + \left(\frac{dv}{dx}\right)^2\right]$$

$$\varepsilon_y = \frac{1}{2}\varphi_z^2 \tag{3}$$

$$\gamma_{xy} = \varphi_z + \frac{dv}{dx} + \varphi_z\frac{du}{dx} + y\varphi_z\frac{d\varphi_z}{dx}$$

For a solid that has an isotropic material symmetry equivalent to the geometry axes, 3 x 3 symmetrical matrix for the constitutive equations is obtained.

$$\begin{Bmatrix}\sigma_{xx}\\ \sigma_{yy}\\ \sigma_{xy}\end{Bmatrix} = \frac{E}{1-\mu^2}\begin{bmatrix}1 & \mu & 0\\ \mu & 1 & 0\\ 0 & 0 & \frac{1}{2(1-\mu)}\end{bmatrix}\cdot\begin{Bmatrix}\varepsilon_x\\ \varepsilon_y\\ \gamma_{xy}\end{Bmatrix} \quad (4)$$

Considering the following equations

$$N = \int_A \sigma_{xx} dA,\ \ Q_y = \int_A \kappa\sigma_{xy} dA,\ \ M_z = \int_A -y\sigma_{xx} dA \quad (5)$$

the governing system of differential equations for a beam with a circular cross-section *A* and second moment of area *I* is in the form

$$\begin{aligned}&\frac{A}{4\pi}\frac{d\varphi_z}{dx}\frac{d^2\varphi_z}{dx^2} + 2\frac{dv}{dx}\frac{d^2v}{dx^2} + \mu\varphi_z\frac{d\varphi_z}{dx} = 0\\ &\frac{d\varphi_z}{dx} + \frac{d^2v}{dx^2} + \frac{du}{dx}\frac{d\varphi_z}{dx} = \frac{2N(1+\mu)}{\kappa AE}\frac{d^2v}{dx^2}\\ &\frac{2I}{\kappa A(1-\mu)}\left(\frac{d^2\varphi_z}{dx^2} + \frac{du}{dx}\frac{d^2\varphi_z}{dx^2}\right) = \varphi_z + \frac{dv}{dx} + \varphi_z\frac{du}{dx}\end{aligned} \quad (6)$$

For our purpose, the axial load *N* is determined as a function of the axial displacement *u(x)*

$$N = \vartheta\frac{u(l_0)\kappa AE}{(l_0 - u(l_0))(1-\mu^2)} \quad (7)$$

where the factor υ is equal to 1. For a nonlinear region, the factor can be substituted by a sum of exponential functions.

When performing the finite element analysis, the buckling load for a single beam was determined by the linear and non-linear buckling analyses while the linear solid element with eight nodes and incompatible mode (C3D8I) was used as the element type. Regarding the mesh independence study, a review of element lengths along the beam and circumferential edge distribution was carried out by Kotšmíd [21]. On the basis of the review, the element length does not significantly affect the buckling load while maintaining an appropriate element quality. On the other hand, significance of the circumferential edge distribution was proved. Owing to this, the distributions of 12, 16, 20, 24, 28, and 36 elements on the circumferential edge were used and the boundary conditions simulated the embedding were considered according to Fig. 4. In order to achieve a lateral displacement for the non-linear buckling analysis, one thousandth of the beam length was used as a geometrical imperfection.

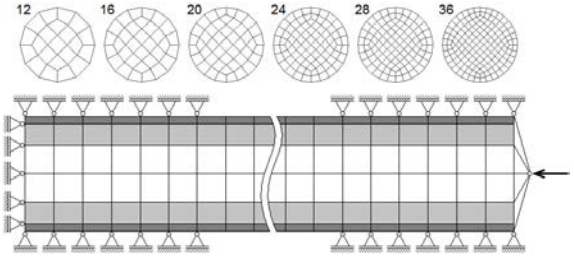

Fig. 4. The beam FE model

The buckling loads were taken to create their dependence on the circumferential edge distribution shown in Fig. 5.

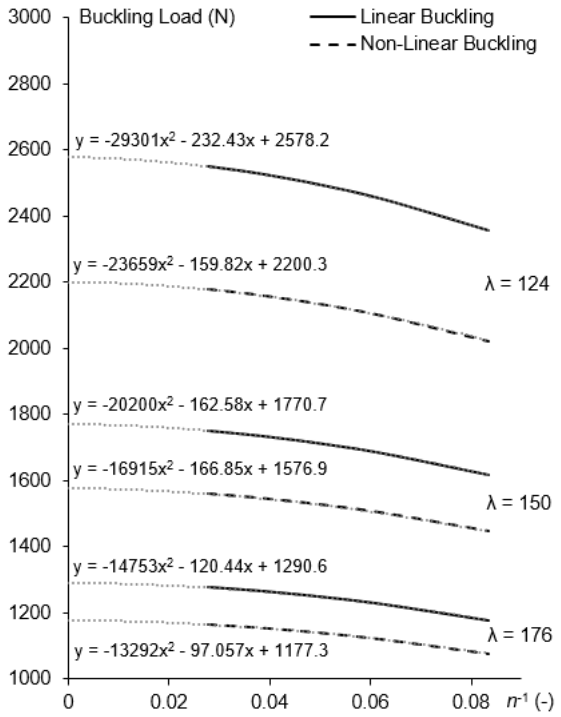

Fig. 5. Dependence of the buckling load on the circumferential edge distribution

The curves are approximated by a quadratic parabola where the constant term represents the load for an infinite number of elements on the circumferential edge and thus for the circular cross-section. The critical buckling load for this type can be computed by the Euler formula in terms of a radius *r*

$$N_{crit,cir} = \frac{\pi^2 EI}{l_{eff}^2} = \frac{\pi^3 Er^4}{4l_{eff}^2} \quad (8)$$

The second moment of area for a regular polygon with *n* sides is

$$I = \frac{nr^4}{48}\left(4\sin\frac{2\pi}{n} + \sin\frac{4\pi}{n}\right) \quad (9)$$

Hence, the second moments of area for 12, 16, and 20 circumferential edge elements are

$$I = \frac{r^4}{4}\left(4\sin\frac{\pi}{6} + \sin\frac{\pi}{3}\right) \quad for\ n = 12$$
$$I = \frac{r^4}{3}\left(4\sin\frac{\pi}{8} + \sin\frac{\pi}{4}\right) \quad for\ n = 16 \qquad (10)$$
$$I = \frac{5r^4}{12}\left(4\sin\frac{\pi}{10} + \sin\frac{\pi}{5}\right) \quad for\ n = 20$$

When approximating the critical buckling loads with 12, 16, and 20 circumferential edge elements by a quadratic parabola and expressing the constant term, we get

$$N_{crit,cir} \cong \frac{\pi^2 E}{24 l_{eff}^2}\begin{bmatrix} 125\left(4\sin\frac{\pi}{10} + \sin\frac{\pi}{5}\right) - \\ -128\left(4\sin\frac{\pi}{8} + \sin\frac{\pi}{4}\right) + \\ +27\left(4\sin\frac{\pi}{6} + \sin\frac{\pi}{3}\right) \end{bmatrix} \qquad (11)$$

The discrepancy between the term and Eq. (8) is 0.38% and thus it is proved that the distributions of 12, 16, and 20 are appropriate to make the approximation, which was also verified by a comparison with the constant terms in Fig. 5. Therefore, the distributions of 12, 16, and 20 are used in further analyses while the aspect ratio is kept close to 1.

The decrease of the maximum axial load for a non-linear analysis can be expressed in dependence on the slenderness λ by a polytropic function. Regarding the described parameters, the maximum axial load is

$$N_{max} = N_{crit}(1 - 182\lambda^{-1.4784}) \qquad (12)$$

When loading the set of six equally long beams, obviously, the load carrying capacity might be six times higher than the single beam provides. In fact, the value is slightly different (less than 1 %) due to the energy transformation to deform the fixture. Using the beam length tolerances, an empty space appears between the shorter beams and the fixture hole bottom. Therefore, the beams are going to be deflected later and the load-displacement characteristics will be changed. The reference beam lengths are used to create the load-displacement relation (Fig. 6).

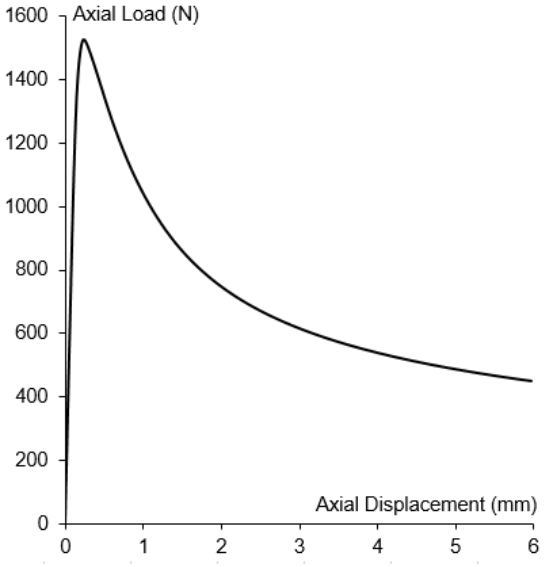

Fig. 6. The load-displacement relation for λ = 150

The obtained curves can be approximated either by a single function (e.g. polynomial of 9th degree) or by two discontinuous functions; one for load increase and the other one for load decrease. To avoid small coefficients at higher polynomial degrees, two functions were created. The axial displacement domains are taken from the load-displacement relations and the individual beam shortening h_i is in the range of double tolerance 2ε while the maximum beam lengths are at the upper limit. Hence

$$u_1 = [0, u_{\max}], \quad 0 \le h_i \le 2\varepsilon \quad \text{for } i = 1, \ldots, 6 \qquad (13)$$

The axial load for the i^{th} beam is defined as

$$F^{(i)}(u_1) = \begin{cases} a_0 + \sum_{j=1}^{k}\left\{\begin{matrix} a_j \cos[jp(u_1 - h_i)] + \\ +b_j \sin[jp(u_1 - h_i)] \end{matrix}\right\} \\ \sum_{j=0}^{m}\left[c_j(u_1 - h_i)^j\right] / \sum_{j=0}^{m}\left[d_j(u_1 - h_i)^j\right] \\ 0 \end{cases} \qquad (14)$$

The first term is used for $0 \le u_1 - h_i \le u_c$; the second one is used for $u_c < u_1 - h_i \le u_{max}$; otherwise it is 0.

During the optimization process, the beam shortenings h_i are searched for when meeting the condition

$$\left\{\max\left[\sum_{i=1}^{6} F^{(i)}(u_1)\right]\right\} = min \qquad (15)$$

Obviously, $h_1 = 0$ and the constants a_j, b_j, c_j, d_j, and p are given by the method of least squares. For the beam parameters described in the paper, we got $k = 4$ and $m = 6$ to obtain the differences less than 1 N for each displacement compared to the FE analysis. The evolutionary method based on the theory of natural selection was used to solve the Eq. (15). To verify the approach, we have performed the FE analysis with optimized beam lengths.

4. RESULTS AND DISCUSSION

The lowest axial load carrying capacity is achieved when the individual beam lengths are as shown in Table 1.

Table 1. The optimized beam lengths

Beam	Length (mm)		
1	330.50	395.50	460.80
2	330.50	395.50	460.80
3	330.50	395.50	460.80
4	330.37	395.50	460.80
5	330.00	395.06	460.08
6	329.50	394.50	459.20

The axial displacements for $\lambda = 150$ and 176 can be described in three phases. In the first one, only four equally long beams are loaded, the other two slide along the holes. This phase is characterized by the load increasing with a subsequent decrease when post-buckling occurs there. When the length difference of the following beam vanishes, it begins to be loaded and the load increases again. Finally, the same process happens for the last beam. Achieving the third load peak, all the beams appear in the post-buckling mode and the axial load decreases.

To compare the optimization approach with the finite element analysis, the loads at peaks and valleys were considered. For the slenderness of 124, the highest discrepancy of 1% is at the first load peak for $n = 12$ while the first load valley achieves the highest discrepancy of 0.66% for $n = 20$. The highest discrepancy of 0.58% for the slenderness of 150 is achieved at the second load peak for $n = 12$ and at the first load valley for $n = 16$ where the highest discrepancy is 0.72%. For the slenderness of 176, the highest discrepancy of 0.54% and 0.75% is achieved for $n = 12$ at the second load peak and the first load valley respectively. The load-displacement relations are shown in Fig. 7.

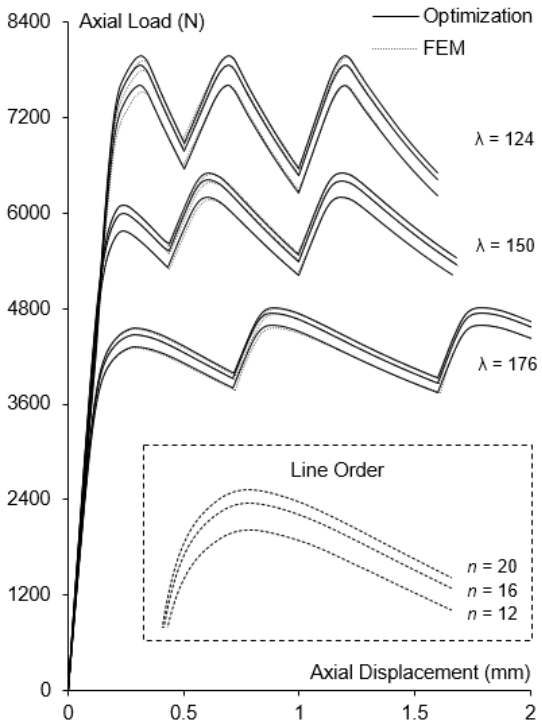

Fig. 7. The load-displacement relations for the optimized beam lengths

A dependence of the axial load carrying capacity on the circumferential edge distribution is shown in Fig. 8. The curves are approximated by quadratic parabolas and the constant terms are evaluated further. The discrepancies between the FE analysis and the described approach are 0.21%, 0.15%, and 0.08% for the slenderness of 124, 150, and 176 respectively. When comparing the load carrying capacity of the structure with the equally long beams and the one with the optimized beams, the discrepancies are significant. For the slenderness of 124, 150, and 176, the load carrying capacity decreases are 38.22%, 29.33%, and 30.10% respectively.

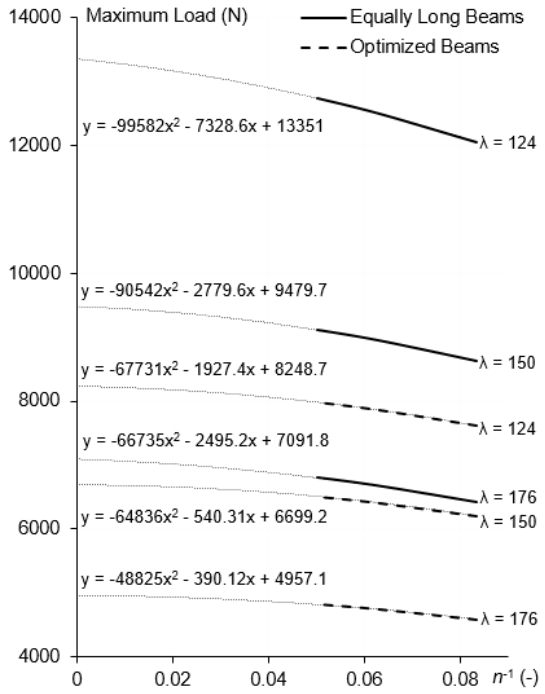

Fig. 8. Dependence of the load carrying capacity on the circumferential edge distribution

As it is shown in the comparison between the experimental and theoretical results (Fig. 9), the latter ones create the load intervals where the experimental values should occur. It can be assumed that the higher slenderness, the shorter load interval. The maximum load values for the equally long beams can be approximated by a polytropic function; however, the values for optimized beams are the functions of the tolerance field that is not a continuous variable. Furthermore, it depends on the used standard and thus the exact formula is hardly to be created.

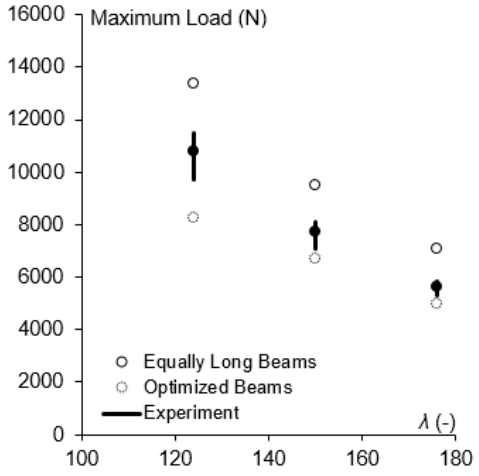

Fig. 9. Theoretical and experimental values of the load carrying capacity

5. CONCLUSION

In this paper, the multi-beam structure made up of six vertical beams was studied to compute the axial load carrying capacity. Owing to the beam length tolerance, a theoretical computation of six equally long beams is not suitable since it provides the overestimated results. In fact, the beams are not equally long; therefore, the longest beams are loaded and deflected first. The others are loaded afterwards and the longest ones can be in a post buckling status already. Hence, the load-displacement course contains peaks and valleys that decrease the maximum possible load value.

In the beginning, the load-displacement relation for a single beam was created based on the governing equations and finite element analysis using the defined geometrical and material parameters. The relation is further used as a base for the optimization procedure where various beam length combinations are created and the lowest axial load carrying capacity is searched for. The evolutionary method based on the theory of natural selection is used to solve the problem while the results were verified by the finite element analysis. Only a single beam load-displacement relation is needed for the approach where different method is used to compute the optimization equations. This simpler and less time-consuming way gives the results of neglected discrepancies compared to the finite element analysis.

As shown, it is possible to create such combination of the beam lengths within the tolerance that the load carrying capacity decreases up to 40%. This reminds the importance of the tolerance inclusion into the computational process. Together with the analysis of the equally long beams, the load carrying capacity boundaries were obtained. The real load carrying capacity should lie within the interval bounded by the equal and optimized beam lengths, which is proved experimentally.

6. ACKNOWLEDGEMENTS

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7. REFERENCES

[1] Y. Q. Zhang; Y. Lu; S. L. Wang; X. Liu, Vibration and Buckling of a Double-Beam System under Compressive Axial Loading. Journal of Sound and Vibration 318 (2008), pp. 341-352

[2] P. Kozić; R. Pavlović; D. Karličić, The Flexural Vibration and Buckling of the Elastically Connected Parallel-Beams with a Kerr-type Layer in between. Mechanics Research Communications 56 (2014), pp. 83-89

[3] B. J. Xiao; X. F. Li, Exact solution of buckling load of axially exponentially graded columns and its approximation. Mechanics Research Communications 101 (2019), pp. 6

[4] D. Hao; Ch. KaiDong; Ch. Wei; Z. ShouGen, Vibration and Buckling Analysis of Double-Functionally Graded Timoshenko Beam System on Winkler-Pasternak Elastic Foundation. Composite Structures 160 (2017), pp. 152-168

[5] V, Stojanović; P. Kozić; G. Janevski, Buckling Instabilities of Elastically Connected Timoshenko Beams on an Elastic Layer Subjected to Axial Forces. Journal of Mechanics of Materials and Structures 7 (2012), pp. 363-374

[6] K. Girgin; G. Ozmen, Simplified Procedure for Determining Buckling Loads of Three-Dimensional Framed Structures. Engineering Structures 29 (2007), pp. 2344-2352

[7] E. Bayo; A. Loureiro, An Efficient and Direct Method for Buckling Analysis of Steel Frame Structures. Journal of Constructional Steel Research 57 (2001), pp. 1321–1336

[8] K. Girgin; G. Ozmen; E. Orakdogen, Buckling Lengths of Irregular Frame Columns. Journal of Constructional Steel Research 62 (2006), pp. 605-613

[9] H. Eletrabi; J. D. Marshall, Catenary Action in Steel Framed Buildings with Buckling Restrained Braces. Journal of Constructional Steel Research 113 (2015), pp. 221-233

[10] J. Qing; W. Hanqin; F. Yulong; Ch. Xun; W. Xiaowei; Z. Yi, Experimental and Numerical Studies of a Controlled Rocking Steel Frame with Buckling-Restrained Columns. Structures 24 (2020), pp. 690-704

[11] C. Vatansever, Investigation of Buckled Truss bars of a Space Truss Roof System. Engineering Failure Analysis 106 (2019), pp. 1-12

[12] F. Barbagallo; M. Bosco; M. Caragliano; E. M. Marino; P. P. Rossi, An Alternative Approach for the Design of Chevron-Braced Frames. Applied Sciences 11 (2021), pp. 14

[13] M. Mohammadi; M. A. Kafi; A. Kheyroddin; H. R. Ronagh, Performance of innovative composite buckling-restrained fuse for concentrically braced frames under cyclic loading. Steel and Composite Structures 36 (2020), pp. 163-177

[14] C. Szymczak, Stability and Initial Post-Buckling Behaviour of Frame System with Vertical Bracings. Thin-Walled Structures 49 (2021), pp. 669-673

[15] R. Gonçalves; D. Camotim, A System-Based Approach for the Design of Laterally Unbraced Multi-Span Steel Columns and Beams. Engineering Structures 135 (2017), pp. 10-20

[16] A. Webber; J. J. Orr; P. Shepherd; K. Crothers, The Effective Length of Columns in Multi-Storey Frames. Engineering Structures 102 (2015), pp. 132-143

[17] I. Choi; D. Kim; J. Kim, Development of Optimal Design Method for Steel Double-Beam Floor System Considering Rotational Constraints. Applied Sciences 11 (2021), pp. 16

[18] D. Naidoo; K. Li, Optimization of No Sway Plane Rigid Frames against Buckling. Journal of Civil Engineering Research 9 (2019), pp. 1-15

[19] S. Bidmeshki; A. Habibi, A new procedure for post-buckling analysis of plane trusses using genetic algorithm. Steel and Composite Structures 40 (2021), pp. 817-828

[20] S. Awtar; A. H. Slocum; E. Sevincer, Characteristics of Beam-Based Flexure Modules. Journal of Mechanical Design 129 (2007), pp. 625-639

[21] S. Kotšmíd, The Effect of Finite Element Mesh Size on a Buckling Load for a Linear and Non-Linear Analysis. Progress and Application of Educational Methods in the Mechanics of Solids 2019

Investigation of edge rounding by magnetic assisted ball burnishing tool

Kovács, Zsolt [a]; Kónya, Gábor [a]; Kodácsy, János [a]

[a] John von Neumann University GAMF Faculty of Engineering and Computer Science, Izsáki út 10., H-6000 Kecskemét, Hungary, kovacs.zsolt@gamf.uni-neumann.hu

Abstract

Edge of the milled surfaces always contain sharp edges and/or burr, which are not allowed in case of today's modern parts (e.g. sliding elements or machine beds). The removing or forming of these phenomena not easy and may also require further expensive processes and machining. During of the magnetic assisted ball burnishing process the burnishing ball can move flexible in the tool so that the balls can harmonically follow the surface and the edge of workpiece. In this research the authors investigated the effect of the overrun of the balls, burnishing speed, direction and feed by Taguchi DoE. The aim of this research is to show the size of formation of the edge after ball burnishing. To achieve a rounded edge should be well known the effect of the burnishing technological parameters. Based on the research results, it can be clearly stated that burnishing speed has a significant effect for edge rounding. Furthermore, necessary different technological parameters for the different form of rounded edge. This means, before the edge rounding must be known the right technological parameters which this study contains as a result.

Keywords: ball burnishing, edge rounding, magnetic assisted machining

1. INTRODUCTION

During the machining of metal parts, burrs are created in all cases, which significantly affect the usability of the final product. A burr is those material which left on the workpiece after machining, it is created when the tool enters or exits the workpiece in most cases [1]. It appears in many different shapes and sizes after machining, and its formation is influenced by countless circumstances [2-4], so the type of burr can also be various [5].

The removal of the burr and the rounding of the edge at the same time are justified by several factors, including the risk of accidents, the assembly of components, the possibility of scratches on sliding surfaces, and not beneficial from an aesthetic point of view. There are many processes in industry to remove the burr and create edge rounding [6, 7], but in these case the rounded edge machined by chip removing. Unfortunately, these are not burr-free because every cutting process cause micro-burr [8]. All this entails that a minimal burr is always left behind due to machining [9].

The magnetic assisted ball burnishing (MABB) tool plastically forms or removes the burr, creating an almost burr-free rounded edge. In this procedure, the burr can be removed in such a way that it breaks off, but in most cases, it is only deformed in a beneficial way.

2. MAGNETIC ASSISTED BALL BURNISHING TOOL

During MABB process, the tool travels along the surface of the workpiece by moving in a straight line or along a given path at a given speed and feed. The special feature of the tool is in the generation of burnishing force because it can be created by magnetic force. A detailed presentation of the MABB tool and its application options can be found in the authors' previous articles [10, 11].

With the MABB tool, deburring/edge rounding can be achieved in such a way that during the burnishing of the flat surface, the tool does not stop when it reaches the edge of the workpiece, but "overruns" it to a certain extent, thus burnishing down the edge/burr, in this way realizing the desired deburring and edge rounding (Figure 1).

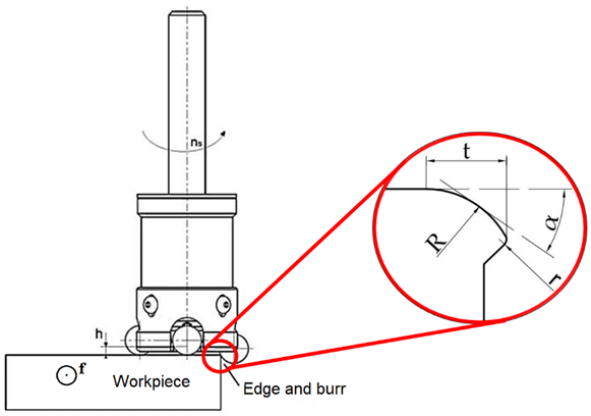


Fig. 1. Edge rounding process by MABB tool and parameters of the rounded edge

This flexibility allows for the balls to hang over of edge of the workpiece so the balls able to form the edge and the burr, of course the MABB tool can reduce the surface roughness and improve the surface hardness too.

During the research, the authors examined the changes in *R*, *t* and *α* dimensions of the rounded edge. The size *r* has no role in terms of use or other aspects, so the research did not cover it.

3. DESCRIPTION OF THE EXPERIMENT

For the experiments, flat-milled workpieces were used, which were burnished with pre-designed technological parameters by Taguchi's experimental design method, to be investigated the edges rounding. During the selections of technological parameters the main priority was given to those affecting edge rounding.

3.1. Workpiece material

The workpiece material was hot-rolled C45 steel, 300 mm long, 75 mm wide and 20 mm thick. The surface milling of the workpiece and the edge-rounding experiments were carried out on a Kondia B-640 three-axis machining center. The technological parameters of face milling are listed in Table 1.

Table 1. Technological parameters of milling.

Cutting depth, a_p (mm)	1,5
Cutting speed, v_c (m/min)	200
Feed, v_f (mm/min)	150
Tool tip radius, r_ε (mm)	0,8

3.2. Design of experiment

The authors used Taguchi's method for the experimental design, since the experiments contained several factors and with this method the number of necessary experiments can be kept at a relatively low level. The experimental design has 4 factors and 4 levels, the exception is the machining direction (factor D), because only two directions (climb and conventional direction) are possible, so these 2 factors were included in the experimental design. The values of the feed (factor A) and the burnishing speed (factor B) were already examined by the authors in their previous articles, so they determined the current values using that experience [12, 13]. The value of the overrun of the tool (factor C) was taken to be smaller than the diameter of the Ø16 mm burnishing ball, so that it does not get stuck. Table 2 contains the values of the selected levels.

Table 2. Technological parameters for burnishing.

Factors		Levels
A	Feed, v_f (mm/min)	20; 40; 60; 80
B	Burnishing speed, v_h (m/min)	30; 50; 70; 90
C	Tool overrun, *b* (mm)	6; 8; 10; 12
D	Direction of burnishing (1-climb / 2-conventional)	1; 2

The experiment plan was created in the Minitab 17® statistical software. Based on the available technological parameters, the L16 $(4^3)(2^1)$ type experimental matrix was selected to determine the optimal technological parameters and the effects of individual factors (Table 3.).

Table 3. DoE table by Taguchi method.

Levels	Factors			
	A	B	C	D
1	20	30	6	1
2	20	50	8	2
3	20	70	10	1
4	20	90	12	2
5	40	30	8	1
6	40	50	6	2
7	40	70	12	1
8	40	90	10	2
9	60	30	10	2
10	60	50	12	1
11	60	70	6	2
12	60	90	8	1
13	80	30	12	2
14	80	50	10	1
15	80	70	8	2
16	80	90	6	1

4. RESULTS

After the performing of experiment, the formed edges were measured with a Mitutoyo Formtracer SV-C3000 surface roughness and contour tester. Based on the results were established the effect of the individual factors and the optimal technological parameters.

4.1. Measuring of edge rounding

To measure the edge roundness, must be tilted the workpiece by 45° so that the theoretical edge forms a perpendicular angle with the probe of the contour gauge, for which the workpiece must be placed in a prism with an opening angle of 45°. The measurement setup for edge rounding is shown in Figure 2. The measurement result of the 5th experiment is shown in Figure 3.

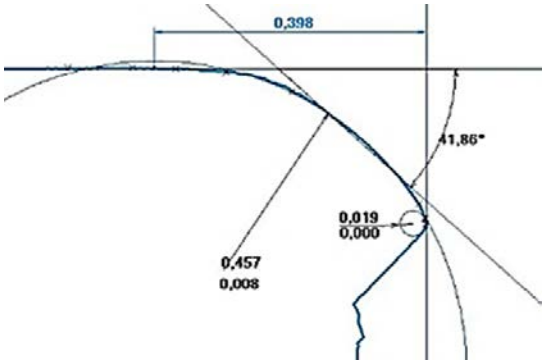


Fig. 3. The result of the contour measurement of the 5th experiment

After the contour measurement, the dimensions of each rounded edges were made on the drawn contours in Mitutoyo's contour measuring software. In this software it is possible to fit a straight line by selecting a curve or an arc, which function was used to measure the α angle.

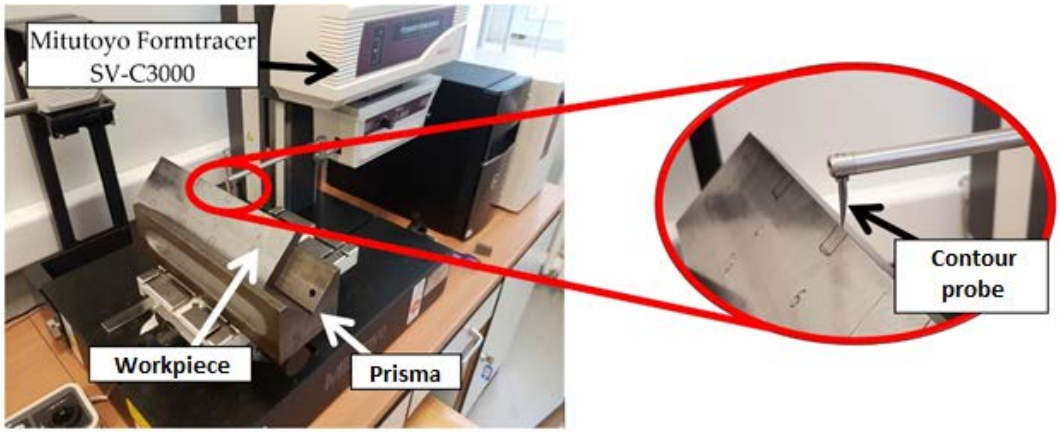


Fig. 2. The measurement arrangement of edge rounding

Table 4. Parameters of rounded edges.

No.	Length of rounded edge, *t* (mm)	Radius of rounded edge, *R* (mm)	Nominal angel of rounded edge, α (°)
1	0,538	0,785	29,59
2	0,359	1,128	17,6
3	0,474	1,379	10,76
4	0,749	0,576	36,15
5	0,398	0,457	41,86
6	0,659	0,756	26,87
7	0,379	0,413	30,58
8	0,745	0,552	44,41
9	0,607	0,653	50,78
10	0,423	0,673	25,31
11	0,322	0,311	40,04
12	0,533	0,501	40,83
13	0,384	0,493	47,18
14	0,447	0,778	16,97
15	0,406	0,410	29,68
16	0,588	0,640	33,58

The measurement was performed on the edge rounding obtained with all 16 experiments, each edge was measured three times, the average of which was used to evaluate the experiment. Table 4. summarizes the average values of the measurement results.

4.2. Evaluation of the dimensions of edge roundings

The measurement results (Table 4) were evaluated in the Minitab 17 statistical software. During the evaluation, the "Larger is better" formula (1) was used, because the goal of the research is to achieve the largest value of the dimensions (*R, t, α*) that can be measured for the created edge rounding.

$$(S/N)_B = -10 * log_{10} \frac{1}{n} \sum_{i=1}^{n} (\frac{1}{y_i})^2 \qquad (1)$$

Since the highest value of all three examined dimensions can be achieved with the application of different technological parameters, they are evaluated separately. In each case, the optimal technological parameter to be used (A-feed, B-burnishing speed, C-tool overrun, D-direction of burnishing) and the factor with the greatest influence were determined separately.

a) Length of rounded edge

Based on the S/N values, the influence diagram of length of the rounded edge (*t*) shown in Figure 4.

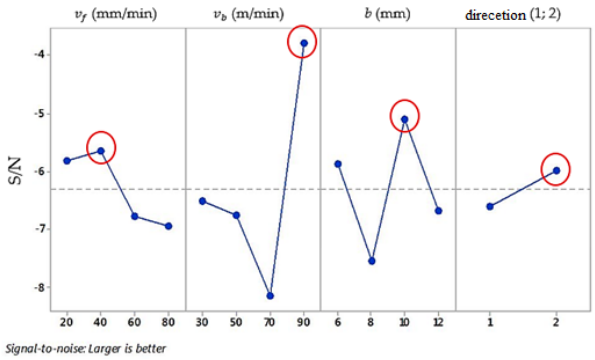


Fig. 4. Effects of edge rounding technological parameters for the length of rounded edge

Based on the Figure 4. the optimal technological parameters to achieve the largest size of *t* dimension:

A-2: v_f= 40 (mm/min)

B-4: v_b= 90 (m/min)

C-3: *b*= 10 (mm)

D-2: 2 - climb machining

Furthermore, it can be concluded that the v_b burnishing speed has the greatest effect on the change of *t* dimension.

b) Radius of rounded edge

Based on the S/N values and about the "Larger is better" analysis on the Figure 5. it can be prepared for *R* dimension.

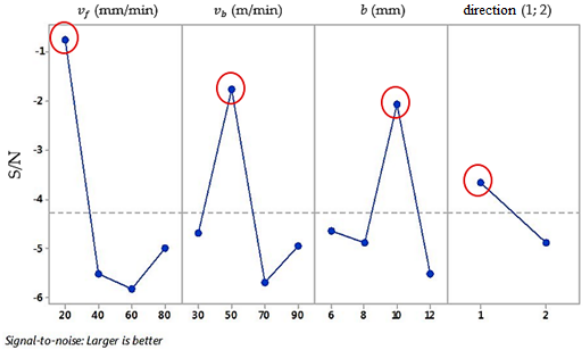


Fig. 5. Effects of edge rounding technological parameters for the radius of rounded edge

Based on the Figure 5. the optimal technological parameters to achieve the largest size *t* dimension:

A-1: v_f= 20 (mm/min)

B-2: v_b= 50 (m/min)

C-3: *b*= 10 (mm)

D-1: 1 - conventional machining

Furthermore, it can be concluded that the v_f feed has the greatest effect on the change of *R* dimension.

c) Nominal angel of rounded edge

Based on the S/N values and about the "Larger is better" analysis on the Figure 6. it can be prepared for *α* dimension (radius of the largest circle that can be insert).

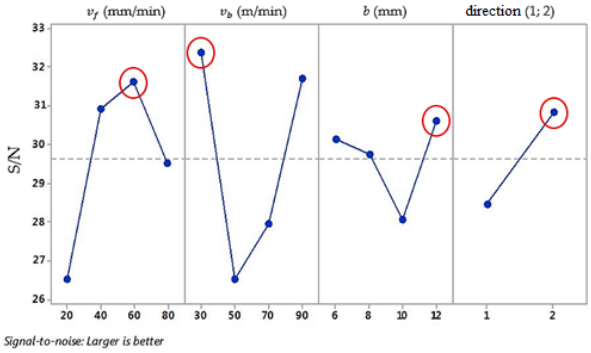


Fig. 6. Effects of edge rounding technological parameters for the nominal angel of rounded edge

Based on the Figure 5. the optimal technological parameters to achieve the largest size *α* dimension:

A-3: v_f= 60 (mm/min)

B-1: v_b= 30 (m/min)

C-4: *b*= 12 (mm)

D-2: 2 - climb machining

Furthermore, it can be concluded that the v_f feed has the greatest effect on the change of *α* dimension.

5. CONCLUSIONS

Based on the results of the evaluation, it can be determined which machining parameters have the greatest effect on the resulting edge rounding. According to this, the burnishing speed and the feed have the greatest effect on the formation of edge rounding with the magnetic assisted ball burnishing tool. At the same time, the evaluation also showed that the direction of machining (climb/conventional) has the least influence on the creation of edge rounding, which is recommended to be considered during subsequent experiments.

During the research, the authors recommend the following optimal technological parameters by Taguchi's experimental design method for the workshop practice:

- if the goal is to achieve a large size of *t*: v_f= 40 (mm/min), v_b= 90 (m/min), *b*= 10 (mm), climb machining
- if the goal is to achieve a large size of *R*: v_f= 20 (mm/min), v_b= 50 (m/min), *b*= 10 (mm), conventional machining
- if the goal is to achieve a large size of *α*: v_f= 60 (mm/min), v_b= 30 (m/min), *b*= 12 (mm), climb machining

Where *t* (mm) is the length of the rounded part, *R* (mm) is the radius of the largest circle that can be inserted, α (°) is the normal angle fitted to the rounded arc, v_f (mm/min) is the

feed, v_b (m/min) is the burnishing speed and b (mm) represents the tool overrun.

6. REFERENCES

[1] J.C. Aurich, D. Dornfeld, P.J. Arrazola, V. Franke, L. Leitz, S. Min: Burrs—Analysis, control and removal, CIRP Annals - Manufacturing Technology vol. 58, (2009) pp. 519-542

[2] L. K. Gillespie, P. T. Blotter: The Formation and Properties of Machining Burrs. Transactions of ASME Journal of Engineers for Industry 98, (1976) pp. 66–74.

[3] M. Akuszewski: A Standard Approach to Classifying Burrs, Productionmachining (2014).

[4] https://www.productionmachining.com/articles/a-standard-approach-to-classifying-burrs

[5] J. C. Aurich, D. Dornfeld, P.J. Arrazola, V. Franke, L. Leitz, S. Min: Burrs—Analysis, control and removal, CIRP Annals - Manufacturing Technology 58, (2009) pp. 519–542

[6] F. Schäfer (1975) Entgraten, Krausskopfverlag, Mainz.

[7] Wu, X., Du, M., Shen, J. et al.: Experimental research on the top burr formation in micro milling. Int J Adv Manuf Technol vol. 117, (2021), pp. 3477–3486

[8] J. Matuszak: Comparative Analysis of the Effect of Machining with Wire and Ceramic Brushes on Selected Properties of the Surface Layer of EN AW-7075 Aluminium Alloy. Advances in Science and Technology Research Journal vol. 16, (2022) pp.50-56.

[9] Yoshichika Oya: Edge-rounding method and apparatus therefor, Patent number: US4078905A, Japan (1978)

[10] Zs. F. Kovács, Zs. J. Viharos and J. Kodácsy: Determination of the working gap and optimal machining parameters for magnetic assisted ball burnishing, Measurement vol. 118, (2018) pp. 172-180

[11] Kónya Gábor, Dr. Kodácsy János, Dr. Kovács Zsolt Ferenc: Mágnesezhető és nem mágnesezhető anyagok hengerlése permanens mágneses síkfelület hengerlő szerszámmal, Gradus vol. 9, (2022)

[12] Zs. F. Kovács, Zs. J. Viharos and J. Kodácsy: Surface Flatness and Roughness Evolution After Magnetic Assisted Ball, Measurement vol. 158, (2020) 107750

[13] J. Kodácsy, J. Líska, Zs. Kovács: Surface finishing by roller burnishing using apparatus of permanent magnet, Tehnicki Vjesnik vol. 24, (2017) pp. 49-54

Flow curve definition of thin sheet by uniaxial compression tests

M. L. Kölüs[1a], R. Borbély[1b], G. J. Béres[1c]

[1] John von Neumann University, GAMF Faculty of Engineering and Computer Science, Izsáki road 10., 6000 Kecskemét, Hungary,

[a] martin.kolus@gamf.uni-neumann.hu

[b] borbely.richard@gamf.uni-neumann.hu

[c] beres.gabor@gamf.uni-neumann.hu

Abstract

This study presents the experimental results of uniaxial compression test for determining the flow curve of DC04 automotive thin sheet. The common method for flow curve definition is the tensile test, which is not reliable for high strains due to the necking phenomenon. For this reason, we used compression test that resulted two-or- three magnitude higher strains than in case of tension. To lower the friction, two types of lubricants were used. The friction coefficient was obtained measuring the buckling of the test pieces by cutting all the specimens in the rolling direction and perpendicular to it. For measuring the geometry, microscopic investigations were used. To obtain the flow stress, the Siebel equation and the Christiansen et al. method were used. Lastly, the Swift and Hockett-Sherby equations were applied for the calculation of the flow curve. Our results show that although the flow curve can be plotted with good approximation, the small plate thicknesses result in large scatter.

Keywords: flow curve, compression test, thin sheets.

1. INTRODUCTION

Nowadays, the importance of sheet metals in the industry is increasing. Many sheet forming technologies are used every day with some important input parameters, one of which is the flow curve. In order to determine the flow curve of a given material, it is important to use a method that produces almost identical forming conditions to the technology that will be used to form the material.

The ultimate goal was to be able to use our results to construct the flow curve with a higher range of deformations than the tensile test could achieve.

Nobuo Yoshikawa et al. used pre-strained specimens to obtain the flow curve, therefore several shear test, was done with different pre-strained sheet metals [1]. The problem is that preparing plates and evaluating the tests is a very time-consuming process.

M. Merklein et al. done stack compression test on sheet metal with a ratio of length and diameter equal to one in order to obtain the flow curve. A huge disadvantage of this method is that it requires two 3D optical strain measurement system to evaluate test properly [2]. Later, Kraus, Lenzen and Merklein developed the method for one layer of specimen, too [3].

Marcel Graf et al. investigated how different flow curve acquisition methods for specimens with well-defined parameters and nearly identical properties compare to each other. They concluded that by applying the appropriate correction factor, good approximations can be obtained [4].

These results all illustrate that the flow curve of a given material can be taken in a myriad of ways.

However, most procedures are cumbersome and complicated. Therefore, we considered it the most obvious method to perform simple compression tests on the specimens and investigate the geometrical deformations for given loads. The flow curve can then be determined.

2. METHODS AND MATERIALS USED FOR RESEARCH

The material used for the experiment is DC04, a cold-rolled mild steel with a ferritic structure and very good ductility properties.

2.1. Specimen

For the test we used cylindrical specimens which can be seen in Fig. 1. The test specimens were cut from board using a Trumpf TruLaser Cell 7020, a 4KW diode beam source laser system. The cutting accuracy of the device is ± 0,02 mm. The cutting was performed using nitrogen gas.

The height of the test pieces is equal to the sheet thickness, which is 1 mm. For the diameter, 10 mm has been selected. It gives an exceedingly small ratio of height and diameter.

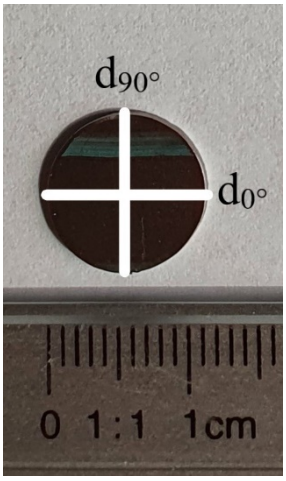


Fig. 1. The cylindrical specimen

In Fig. 1 the rolling direction and the perpendicular direction was marked.

2.2. Uniaxial compression test

The compression test was done on ZD40 universal testing machine which is shown at Fig. 2. The reason why we chose this device is that it can provide a significant load that is enough to reach much higher strains. For the test, five different loads were used such as 80, 120, 160, 200 and 240 kN. The speed was consistent during the test.

Fig. 2. ZD40 universal testing machine

The compression tests were carried out at room temperature using two different lubricant pairings. In the first case, BWS lubricating oil was applied to the surfaces of the test pieces in contact with the tool, and a thin (~0,05 mm) polyamide film was placed between the two surfaces. In the other case, BWS type lubricating oil was also applied to the surfaces of the test pieces in contact with the tool, but here a polytetrafluoroethylene film (~0,1 mm) was used.

Of paramount importance for the experiment was to ensure the best possible lubrication conditions, thus reducing the uncertainty caused by friction. To this end, we have chosen this lubrication form and lubricants with excellent friction reducing properties.

2.3. Buckling measurement

To measure the phenomenon of buckling especially with a height and diameter ratio this low is a bit of a challenge. First of all, the specimens had to be cut in half in the rolling direction and perpendicular to it. Therefore, the positioning and the fixing must have been precise and stable. The cut was made on Wirtz Cuto 20 which is abrasive disc precision cutting equipment. Each workpiece was then subjected to microscopic examination. The aim of the test

was to measure the degree of buckling. This is the distance between the end blade diameter and the centre diameter.

Before measurements were taken, it was advisable to grind the half-cut specimens to ensure that the line created during cutting did not interfere with the measurement. It also improves the image quality. The grinding was carried out in two steps. First, 1200 grit sandpaper was used, followed by 2400 grit sandpaper.

For measuring purposes, I used the Zeiss Axio Imager.M2m metal microscope. This device has a motorized focus and slide stage movement. In addition, the maximum magnification available is 500 close. In order to obtain a satisfactory image of the edges of the specimen, it is necessary to use the function of the microscope to form a sharp image by superimposing several sharp images. This is necessary to eliminate image degradation due to possible surface defects. Fig. 3 shows the buckling of a specimen that was compressed with 240 kN. The cut was mad in the rolling direction.

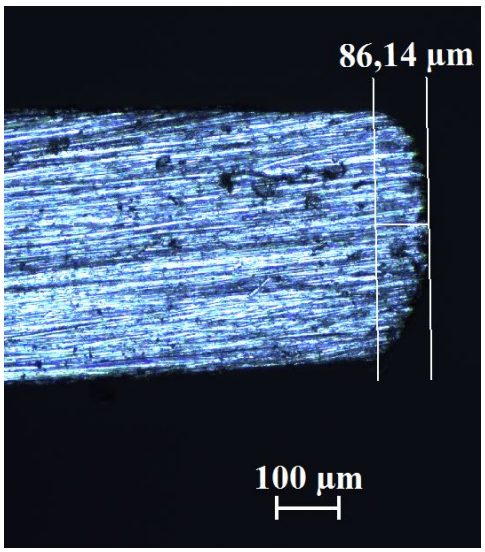


Fig. 3. The buckling of the specimen that was compressed with 240 kN

2.4. Obtaining the friction coefficient

The friction phenomenon has a significant influence on the shape of the flow curve. As a consequence, it is essential that the correct lubrication conditions are established. Measured geometrical displacements were an important tool for the determination of the friction coefficient and were used to derive the average value of the *R*-factor, which can be calculated from the thickness variation:

$$R_{ave} = r_0 * \sqrt{\frac{h_0}{h_v}} \quad (1)$$

where, r_0 is the initial radius, h_0 is the initial height and h_v is the height after filling. A friction sensitive shape factor is also introduced [5]:

$$b = 4 * \frac{\Delta r}{R_{ave}} * \frac{h_v}{\Delta h} \quad (2)$$

where Δr is the rate of change of radius and $\Delta h = h_0 - h_v$ is the change in height of the test specimen. The Kudo friction coefficient (m) was determined using the formulae so far [6]:

$$m = \frac{\left(\frac{R_{ave}}{h_v}\right) * b}{\left(\frac{4}{\sqrt{3}}\right) - \left(\frac{2b}{3\sqrt{3}}\right)} \quad (3)$$

finally, using this formula, we obtain the coefficient of friction [7]:

$$\mu = \frac{m}{\sqrt{3}}. \quad (4)$$

After the calculation, the following coefficient of friction values were obtained.

1. 90°	1. 0°	2. 90°	2. 0°
µ	µ	µ	µ
0,190	0,187	0,161	0,211
0,126	0,138	0,117	0,160
0,130	0,152	0,116	0,151
0,119	0,117	0,110	0,124
0,149	0,144	0,122	0,126

In the table, mark 1 refers to polyamide and oil lubrication and mark 2 to polytetrafluoroethylene and oil lubrication.

2.5. Obtaining the flow stress and strain

The deformation and flow strength were determined before the flow curve was constructed. The strain was determined using the following relationship [8]:

$$\bar{\varepsilon} = ln\frac{h_0}{h1} = \ln\left(\frac{h_0}{h_0 - \Delta h}\right) \quad (5)$$

The flow stress was derived using two methods, one was the Siebel equation, and the other was based on the Christiansen et al. The Siebel approach:

$$k_R(\bar{\varepsilon}) \cong \sigma_f(\bar{\varepsilon})\left[1 + \frac{2\mu r(\bar{\varepsilon})}{3h(\bar{\varepsilon})}\right] \quad (6)$$

Hereafter, $k_R\ (\bar{\varepsilon})$ will be referred to as mean strength and $\sigma_f\ (\bar{\varepsilon})$ as k_f. We then also determined the forming strength based on Christiansen et al. [6]

$$\bar{P} = 2\sigma_0\left(\frac{h_0-\Delta h}{\mu(D_0+\Delta D)}\right)^2\left[exp\left(\frac{\mu(D_0+\Delta D)}{h_0-\Delta h}\right) - \frac{\mu(D_0+\Delta D)}{h_0-\Delta h} - 1\right] \quad (7)$$

where $\bar{P}$ is the surface pressure, referred to as k_k, σ_0 is the yield strength, referred to as k_f, h_0 is the initial height and D_0 is the initial diameter.

3. RESULTS AND ACHIEVEMENTS

We have fitted the Swift flow curve equation [9] and the Hockett-Sherby flow curve equation [10] to our previous tensile and compression test results. The swift equation is:

$$k_f = K * (S_0 + \bar{\varepsilon})^n \quad (8)$$

in which K is the strength coefficient, S0 is the pre-strain and n is the hardening exponent. The Hockett-Sherby equation is:

$$k_f = \sigma_s - \exp(-(N\varepsilon)^p)\,(\sigma_s - \sigma_y). \quad (9)$$

In this formula, σ_s belongs to the saturation stress, N and p are material parameters and σ_y refers to the yield stress obtained from uniaxial tensile test.

After performing the fitting, the following results were obtained. Fig. 4-5. show the case where polyamide and oil lubrication were used. It can be see that the data points originated from the Siebel equation to counterbalance the friction and the geometrical effect are fitted fairly well with both flow curve equations.

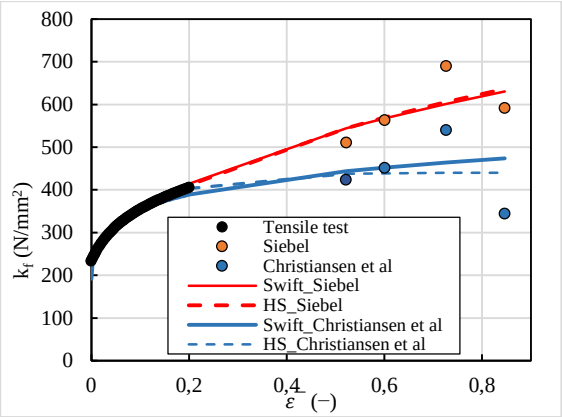


Fig. 4. Flow curve determined from compression and tensile tests, for polyamide and oil lubrication, orientation 0°

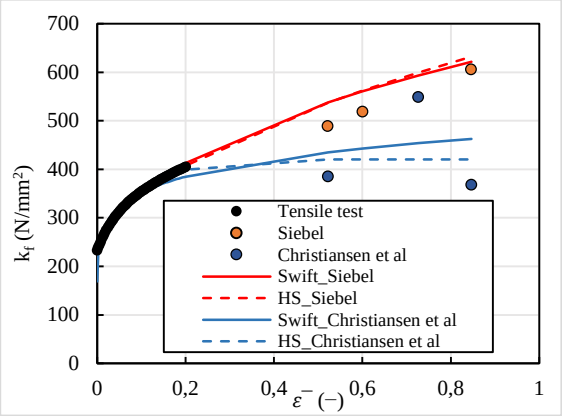


Fig. 5. Flow curve determined from compression and tensile tests, for polyamide and oil lubrication, orientation 90°

Fig. 6. and fig. 7. show the case where polytetrafluoroethylene and oil lubrication were used.

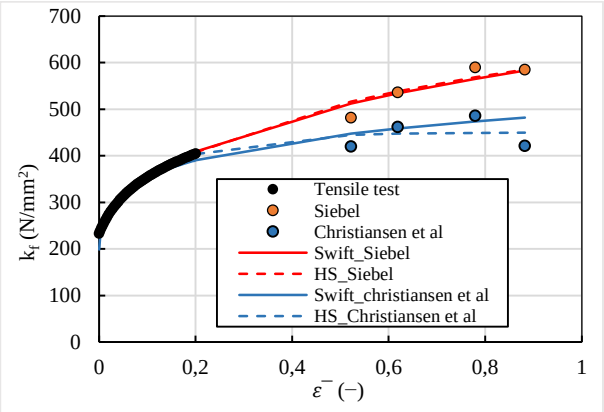


Fig. 6. Flow curve determined from compression and tensile tests, for polytetrafluoroethylene and oil lubrication, orientation 0°

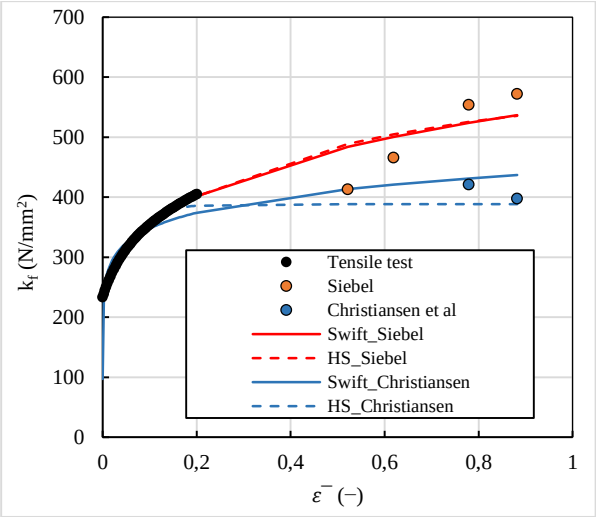


Fig. 7. Flow curve determined from compression and tensile tests, for polytetrafluoroethylene and oil lubrication, orientation 90°

The case is similar for the polytetrafluoroethylene-oil mixed lubricant, too, but the counterbalanced points become closer to each other.

4. CONCLUSIONS

From our results, it can be seen that a relatively high degree of uncertainty in the stress values obtained for the compression of thin plates occurred. This may be due to uncertainty in the measurement or in the calculations. In our future research we plan to study the factors that may be responsible for the resulting uncertainty.

5. ACKNOWLEDGEMENTS

We would like to thank John von Neumann University for providing us with the tools and materials essential for this research, and we would like to thank all our colleagues who contributed in some way to the research.

6. REFERENCES

[1] Nobuo Yoshikawa et al., Development of measurement method of work hardening behavior in large plastic strain for sheet metal forging, Iopscience Journal of Physics, Conference Series 734 (2016) 032050.

[2] M. Merklein, A. Kuppert, A method for the layer compression test considering the anisotropic material behaviour, Int J Mater Form (2009) Vol. 2 Suppl 1:483–486, Springer/ESAFORM 2009

[3] M. Kraus, M. Lenzen, M. Merklein, Contact pressure-dependent friction characterization by using a single sheet metal compression test, Wear 476 (2021) 203679.

[3] Marcel Graf, Sebastian Fritsch, Birgit Awiszus, Determination of Forming Behaviour of EN AW-6060 by Different Testing Methods under Cold Bulk Forming Conditions, ScienceDirect, 23rd International Conference on Material Forming (ESAFORM 2020).

[4] Soheil Solhjoo, A note on ‘‘Barrel Compression Test”: A method for evaluation of friction, Computational Materials Science 49,435–438, 2010.

[5] P. Christiansen, P.A.F. Martins, N.Bay, Friction Compensation in the Upsetting of Cylindrical Test Specimens, Experimental Mechanics, 56:1271–1279, 2016.

[6] Yang et al., Flow stress of wrought magnesium alloys during hot compression deformation at medium and high temperatures, Mater Sci Eng A, Vol 499 No 1 2 pp 238 241 2009.

[7] Kurt Lange et al., Handbook of Metalforming, Soceity of Manufacturing Engineers, Dearborn, Michigen 48121, U.S.A, 1985.

[8] Xin-cun Zhuang et al., Determination of Flow Curve and Plastic Anisotropy of Medium-thick Metal Plate: Experiments and Inverse Analysis, Journal of Iron and Steel Research, International, 2015.

[9] J. E. Hockett, O. D. Sherby, Large Strain Deformation of Polycrystalline Metals At Low Homologous Temperature, J. Mech. Phys. Solids, 1975.

Calculation of the supporting structure of a production hall

M. Labudovic [a], P. Konjatic [a], S. Radojicic [a], I. Gelo [a], M. Katinic [a]

[a] University of Slavonski Brod, Trg Ivane Brlic Mazuranic 2, 35000 Slavonski Brod, Croatia, mlabudovic@unisb.hr, pkonjatic@unisb.hr, sradojicic@unisb.hr, igelo@unisb.hr, mkatinic@unisb.hr

Abstract

The main objective of this paper is the calculation of the supporting structure of the production hall. The model of the production hall was previously modelled in 3D software and the model was used to obtain all the resulting displacements and stresses. The calculation of the elements of the production hall is conducted following the European standard Eurocode. Two cases of loads on the load-bearing structure were considered: Wind effects in combination with the weight of the roof and snow loads in combination with the weight of the roof.

Keywords: supporting structure, truss, calculation, load, wind, snow

1. INTRODUCTION

The structure of the production hall consists of a series of trusses, 5 m apart, connected to the columns by an end plate and bolts. The initial dimensions of the truss itself were based on a combination of real-world examples and suggestions for good engineering practice found in Eurocode guides. These were later refined after initial analysis to obtain a favourable combination of components.

It is imperative for an engineer to design and calculate the supporting structure that will provide safety, durability and serviceability to the end user. Accomplishing this task will require a very good knowledge of design parameters, snow and wind loads to comply design standards. In standards for structural design, models for snow loads on flat roofs generally provide the basis for determination of snow loads on any roof shapes. They are typically derived from ground snow loads and the predicted effects of exposure of flat roofs primarily due to wind, often conveyed through the exposure coefficient [1]. As for wind, research shows that the system of forces resulting from the wind action can be more complex than assumed in standards. Therefore, the question arises whether the standard recommendations guarantee that the design is always on the safe side from the point of view of the failure-free operational use of the construction [2]. For these reasons, Standards play a central role in construction because they specify the requirements for the construction engineer to attain a minimal acceptable safety level [3].

The load-bearing structure of the production hall was modelled using SolidWorks [4] and is shown in Figure 1.

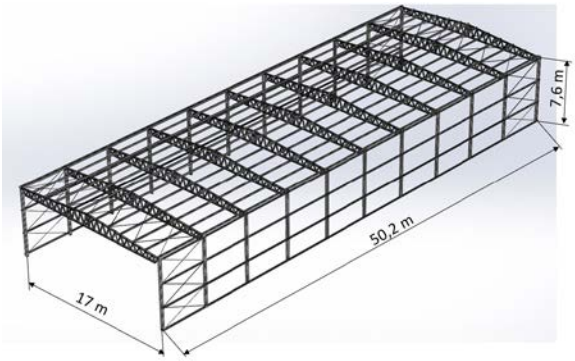


Figure 1. The model of the structure

The calculation of the load-bearing structure of the production hall is carried out according to Eurocode. Prior to the calculations, the permanent loads as well as the wind and snow

load on the structure have to be determined in order to calculate all resulting displacements and stresses with SolidWorks. The calculation of the load-bearing structure of the production hall is carried out by checking each element of the structure individually.

2. DETERMINATION OF LOADS ON THE SUPPORTING STRUCTURE

The structure is loaded with permanent loads as well as wind and snow loads. The load analysis was carried out on a representative roof truss.

The permanent loads are the dead load capacity of the truss, the weight of the secondary structure and bracing, and the weight of the roof slabs. The dead load capacity of the truss and the weight of the secondary structure were determined with SolidWorks, the weight of the roof slabs was taken from a catalogue [5].

In order to determine the distribution and the amount of wind pressure on the surfaces of the structure, the peak wind velocity pressure must first be calculated using expressions from Eurocode [6]. Once the wind peak velocity pressure is calculated, the wind pressure on the different surfaces of the supporting structure is determined. The snow load on the roof is calculated using the follow expression [7]:

$$s = \mu \cdot c_e \cdot c_z \cdot s_k \qquad (1)$$

where: s_k is the characteristic value of the snow load on the ground (for region of Slavonski Brod, Croatia), μ is snow load shape factor, c_e is exposure factor (generally $c_e = 1$), c_z is temperature factor (generally $c_z = 1$). The snow load on the roof of the structure is:

$$s = 0{,}8 \cdot 1 \cdot 1 \cdot 1{,}25 = 1\ \mathrm{kN/m^2}$$

2.1. Combinations of loads

In this paper, two different cases of load combinations were observed to determine the less favourable one:

1. permanent load + snow load
2. permanent load + wind load.

The load combination is the sum of permanent load multiplied by a factor 1,35 and wind or snow load multiplied by 1,5.

Accordingly, the combined load for the first case is 167,67 kN. The combined load for the first case is distributed along the beams of the structure as shown in Figure 2. The figure is obtained using SolidWorks.

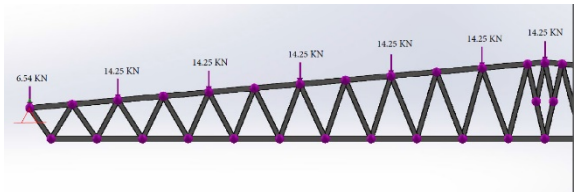


Figure 2. Distribution of loads for the first case

After determining and distributing the loads for the first combination, a diagram of the axial forces is obtained using SolidWorks as shown in Figure 3.

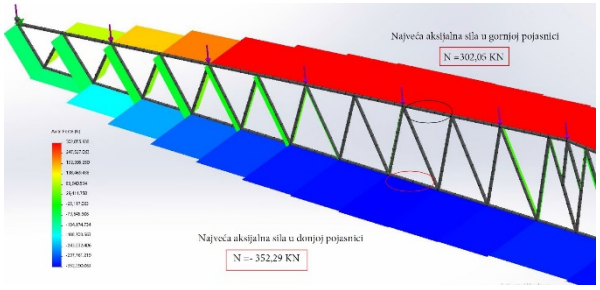


Figure 3. Diagram of axial forces for the first case

The combined load for the second case is 117,34 kN and it is distributed on the truss as shown in Figure 4. The figure is obtained using SolidWorks and shows two different load amounts depending on the wind zone.

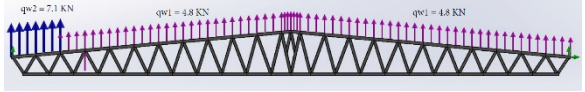


Figure 4. Distribution of loads for the second case

After determining and distributing the loads for the second combination, a diagram of the

axial forces is obtained using SolidWorks as shown in Figure 5.

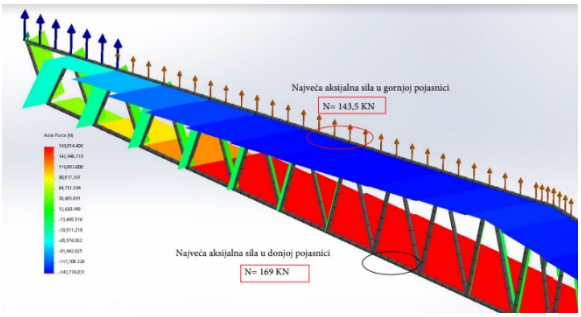


Figure 5. Diagram of axial forces for the second case

After determining that the greatest load on the structure is the combined load of snow and wind, the greatest forces and moments acting on the structure are determined using SolidWorks so that all the main elements of the structure can be verified.

3. VERIFICATION OF THE MAIN MEMBERS AND CONNECTIONS OF THE STRUCTURE

The main parts of the structure considered in this paper are the top and bottom chords of the truss, the diagonals of the truss, the connecting plate, the K joint of the diagonal and chord and the column.

3.1. Verification of the parts subjected to compression loads

The parts of the truss subject to compression are the top chord and the diagonal. The verification is carried out for the top chord and the diagonal under the action of the largest axial force.

For the top chord of the truss, the resistance of the cross-section to compression, to bending in the plane of the truss and to shear is calculated. In addition, the buckling resistance in and out of the plane of the truss is calculated. These values are then compared with the values obtained from SolidWorks and any additional conditions from Eurocode 3 [8] are checked.

For the diagonal of the truss, the resistance of the cross-section and the buckling resistance in and outside of the plane of the plane of the truss are calculated. These values are also compared with the values from SolidWorks and all other conditions from Eurocode 3 [8] are also checked.

3.2. Verifications of the parts under tension

Truss parts under tension are the bottom chord and the diagonal. The verification is carried out for the bottom chord and the diagonal under the action of the largest axial force.

The resistance of the cross-section under tension and the bending moment are calculated for both the bottom chord of the truss and the diagonal. These values are then also verified by comparison with the values given by SolidWorks.

3.3 Verification of the connecting plate

The truss is connected to the column by a connecting plate with 4 bolts. The thickness of the plate is 10 mm and the steel grade is S355. All other dimensions of the plate are shown in Figure 6. The bolts are M20 8.8.

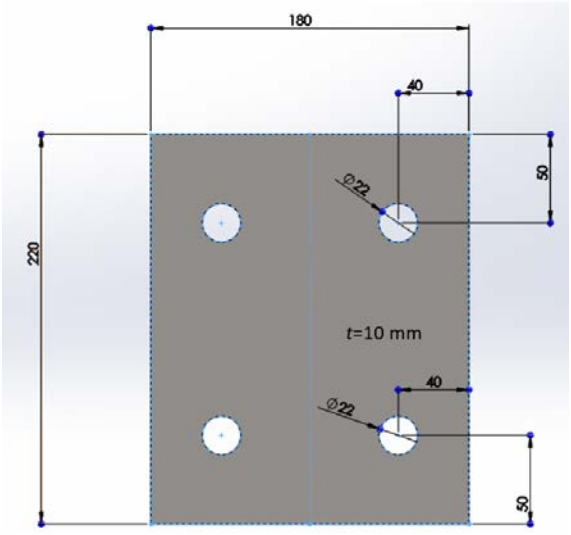


Figure 6. The connecting plate

First, the requirement for ductility is checked. The following condition must be satisfied:

$$t_p \leq \frac{d}{2{,}8}\sqrt{\frac{f_{ub}}{f_{y,p}}} \quad (2)$$

where: t_p is the thickness of the plate, $f_{u,b}$ is the ultimate strength of the material of the bolt, $f_{y,p}$ is the yield strength of the material of the plate. This condition is fulfilled.

The weld between the plate and the truss must also be verified according to the expressions given in Eurocode 3 [9]. The weld is shown in Figure 7.

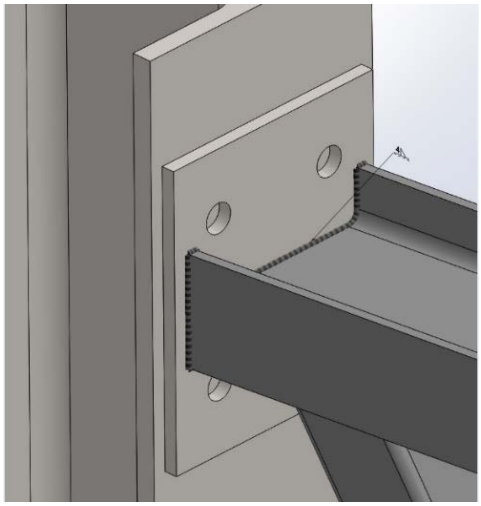


Figure 7. The welded connection of the plate and the truss

3.4. Verification of the K-joint of the diagonal and the chord

The truss chords are connected by diagonals welded in a K-joint without a gap. The diagonals are 100% overlapped, the connection is shown in Figure 8.

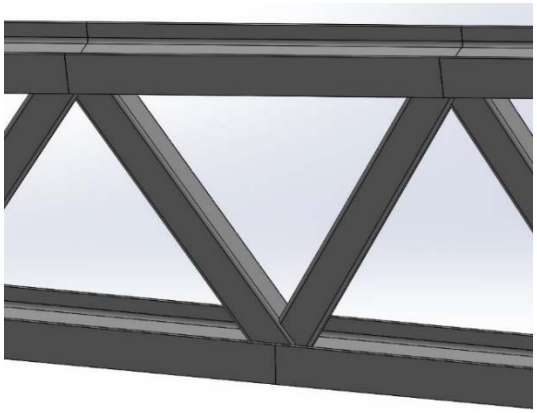


Figure 8. K-joint of the chords and the diagonals

Since the cord profile is arranged so that the web of the profile forms the base for the diagonals, the expressions provided for a rectangular chord are used in this paper.

The conditions that must be fulfilled are given in Eurocode 3 [8]. The resistance of the diagonals must be calculated and compared with the values from SolidWorks.

3.5 Verification of the support

The supports chosen for this structure are HEB 200 profiles made of quality steel S355. The critical buckling resistance and the buckling resistance moment must be calculated. After these values have been obtained, they must be compared with the values given by SolidWorks. If the values fulfil all conditions of Eurocode 3 [8], the column is then verified.

4. RESULTS

After checking all the main elements selected before, the structure is verified according to Eurocode [8].

The structure could be optimized by replacing the welds between the beams with bolts, this would simplify the assembly process.

The price of the structure could be reduced by replacing the K-joints without gap by K-joints with gap. K-joints without a gap are much more difficult to make because each diagonal has to be cut at a certain angle. However, if a gap were added, this could be avoided.

5. CONCLUSION

The aim of this paper was to show a concrete example of the calculation of a structure according to Eurocode. It also aims to present one of the possible constructions and uses of a truss.

In this calculation, both chords of the truss and the diagonals were checked. The resistance of the disputed elements to compressive, tensile and shear stresses and to buckling was confirmed. In addition, the main connections of the structure and the columns were calculated.

Due to the scope of the paper, the calculation of the foundation and the calculation of the connections of the truss were omitted

6. REFERENCES

[1] Thiis, T. K., Formichi, P., Landi, F., Sykora, M. *Physical-based model for exposure coefficient and its validation towards the second generation of Eurocode EN 1991-1-3 for roof snow loads.* Journal of Building Engineering 55, (2022) 104665

[2] Lipecki, T., Jami´nska-Gadomska, P., Błazik-Borowa, E. *Wind load on façade scaffolding without protective cover – Eurocode and in-situ measurement approaches.* Journal of Building Engineering 42 (2021) 102516

[3] Pasternak, H., Ciupack,Y. *Development of Eurocode based design rules for adhesive bonded joints.* International Journal of Adhesion & Adhesives 53(2014) 97–106

[4] *BIOVIA, Dassault Systèmes, SolidWorks, 2017 version, San Diego: Dassault Systèmes, 2020.*

[5] *Katalog proizvoda - sendvič paneli,* Gradiška: Lattonedil BiH, 2017.

[6] *Eurocode 1 - Action on structures - Part 1-4: General actions - Wind actions,* European comittee for standardization, 2010.

[7] *Eurocode 1 - Action on structures - Part 1-3: General actions - Snow loads,* European comittee for standardization, 2003.

[8] *Eurocode 3 - Design of steel structures - Part 1–1: General rules and rules for buildings,* European comittee for standardiozation, 2004.

[9] *Eurocode 3 - Design of steel structures - Part: 1-8: Design of joints,* European comittee for standardization, 2005.

Design and manufacturing of a hazelnut dryer

I. Lacković[a], I. Rajkovača[b], N. Veljić[c], M. Bošnjaković[d]

[a,b,c,d] University of Slavonski Brod, Trg Ivana Brlić Mažuranić 2, Slavonski Brod 35000, Republic of Croatia

Abstract

This paper is about the design and manufacturing of a hazelnut drying system. The way of design and installation, functioning, operation and maintenance of the plant are the reason why the design of such a plant was necessary. Recently, there has been a chronic shortage of nuts on the Croatian market. With the significant increase in subsidies, the number of hazelnut plantations has also increased, especially in small farms. Even with the first larger harvests, the problem of drying the fruit was recognized. Industrial plants are too large for family farms that simply cannot produce enough, and they are also too expensive. It was necessary to build a plant acceptable in terms of capacity, characteristics and price for farms with lower production, such as plantations of 1 to 2 hectares. The plant is designed so that you can build it yourself due to the simplicity of the individual parts, of course, with basic knowledge of mechanical engineering and also with some tools. Turning and bending the sheet metal for the tank on rollers is also required, but on a smaller scale.

Keywords: drying, hazelnuts, production, assembly

1. INTRODUCTION

Objective of the work

This work explains in detail how to solve the problem of small farms related to the drying of hazelnuts. The aim of this work is to develop an optimal and functional device for drying hazelnuts, which will significantly reduce the drying time of the fruit with minimal energy consumption. With the lowest possible cost of manufacturing the device, simplicity of all assemblies and installation, it was necessary to ensure ease of operation, maintenance, servicing and safe operation of the device.

Justification

Given the large increase in agricultural land planted with hazelnuts, mostly owned by small farms (family farms), there was a problem with drying the fruit. Many of these farms with 1 to 2 hectares of cultivated land sell their products "on the doorstep". The problem arises when it is necessary to dry the required amount of hazelnuts as soon as possible after receiving the order, in order to be able to separate the kernel from the shell. The traditional method of drying in air bags and with natural drafts is too slow to meet the agreed deadlines.

At harvest, the fruit has about 30 to 35% water. The humidity must be reduced to the usual 10% to be able to separate the shell from the kernel in special equipment [1].

Since the kernel of hazelnuts is very susceptible to shrinkage, the separation of the shell from the kernel should be done only after receiving the customer's order, until then it is optimal to leave the fruit in the shell. In this way, the fruits are protected from the appearance of mold and are less calcified, which means less loss for the producer.

After receiving the customer's order, it is necessary to dry the ordered quantity of hazelnuts as soon as possible, of course using as little energy as possible, and then separate the kernel of the fruit from the shell. About 50% of

the total mass of hazelnuts falls on the shell [2]. The shell that remains after hazelnuts are shelled can be used very well as a heating material for heating houses, in the ceramic industry for the production of ceramic tiles, for the production of activated carbon and so on. For each use, the shell must be prepared in advance.

In large industrial dryers, the drying air temperature is up to 40°C (normally 32 to 34°C), which is of course achieved by certain burners, gas or fuel oil. Nowadays, when energy prices are extremely high, this represents a significant cost factor for the manufacturer.

In practice, it has been shown that hazelnuts can be dried at room temperature with natural circulation (traditional drying method), but such a drying method takes a very long time.

The development of a hazelnut drier, which is processed in this last plant, significantly reduces the drying time, with minimal energy consumption (the drying air is not heated), which is very important given the affordable cost of manufacturing such a plant, about 10,000 kn. This type of drier can also be made in the "do-it-yourself", of course, with some tools and knowledge at least in the basics of mechanical engineering. Turning, bending on rollers and welding are required for the manufacture of some positions, but in the total price of the product this represents a lower cost factor. By purchasing prefabricated parts, which are available on the market at affordable prices, the construction of the equipment is simplified and the overall price is reduced. This type of drier can be manufactured in the desired capacity, depending on the production volume of the family business, and the principle of operation is the same.

2. DESIGN REQUIREMENTS

From conversations with smaller farmers who own hazelnut orchards and from observation of social networks, it became clear that most of them have a problem with drying a smaller amount of fruit. The dryers available on the market are not suitable for drying small quantities of hazelnuts and are simply too expensive for small family farms. The hazelnut dryers available on the market use an energy source to heat the air needed for drying, usually natural gas or fuel oil. In this way, drying time is reduced, but production costs are also increased, which directly affects the producer's profit.

From the problems identified, the idea developed to build a hazelnut drying plant that would be affordable for small family farms, adaptable to their capacity needs, and have the lowest possible energy consumption. Of course, the drying time is slightly longer than for dryers that use burners to heat the air, but the drying costs are significantly lower, which ultimately leads to lower production costs and better competitiveness in the market.

During the design process, care was taken to make the system as simple as possible to minimise the need for maintenance, as well as the maintenance of the system itself with absolute work safety. A low number of moving parts and low speeds guarantee the longevity of the plant. It is possible to build dryers with a capacity of 100 kg of hazelnuts.

Market research has tried to obtain as much information as possible about the availability of materials, finished products and semi-finished products for sale, which are needed for the construction of the plant. The use of prefabricated parts and assemblies greatly simplifies the construction of the plant, assembly and installation, and facilitates maintenance and replacement of parts. In this way, the price of the finished product is significantly reduced.

In this work, parts or components are highlighted, most of them with pictures, available on the market (belts, bearings, components of screw conveyors, perforated tank plates, square steel tubes ...).

3. TRADITIONAL WAY OF DRYING HAZELNUTS

After harvest, hazelnuts must be properly dried and stored to prevent them from becoming moldy and rancid. Until the appearance of dryers, hazelnuts were dried in a variety of ways, such as in the sun in boxes with occasional stirring, in breathable bags hung under canopies, on the floor in storage rooms, etc. Common to all these methods is a long drying time of 2 to 4 weeks. In the marketing of agricultural products, the best price is obtained by those that reach the market earlier, so it is necessary to shorten the drying time.

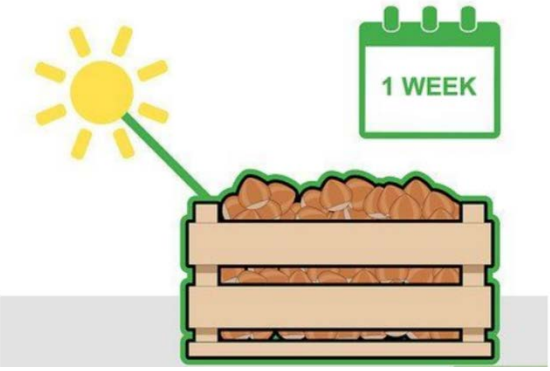


Fig. 1. Drying hazelnuts in the sun

Fig. 2. Drying hazelnuts on the attic floor

This method of drying not only takes a long time, but also requires mixing several times a week to dry the hazelnuts evenly, which is physically demanding for larger quantities. In this way, the dried hazelnuts can be stored and stirred occasionally. The optimum storage time is about one year, although there is of course some loss due to shrinkage.

For the above reasons, it is obvious that there is a need for faster, simpler and easier methods of drying hazelnuts. This is achieved through various hazelnut drying equipment. For smaller family farms, most of the dryers available on the market are either oversized or overpriced.

Fig. 3. Display of a factory-produced dryer

Most family farms have 1 to 2 hectares of hazelnut orchards, so dryers of this type are out of the question. A large number of family farms sell "at the door" in quantities up to 100 kg. Until sold, hazelnuts are best kept in the shell, as the kernel is very susceptible to shrinkage, so they require far fewer dryers.

In this paper, it is shown how a hazelnut dryer with a capacity that meets the needs of family farms can be made with a relatively small investment and is easy to operate and maintain. One of the most important features is the minimal energy consumption. Air without heating is used for drying, which significantly reduces the price of the product and increases the profit of the farm.

4. CONSTRUCTION AND MANUFACTURE OF HAZELNUT DRYER

Making a sketch

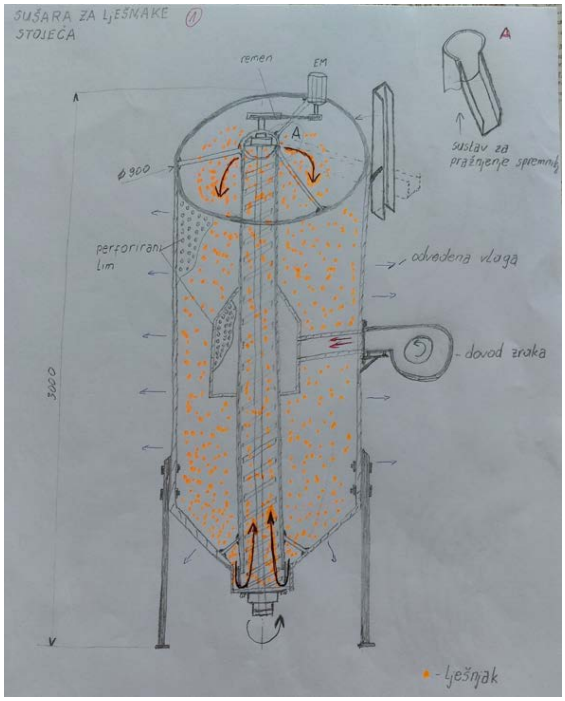


Fig. 4. Sketch of a dryer for hazelnuts

Once the problem to be solved was identified, and that is to make a dryer, but before starting the design, it was necessary to make a concept sketch that included all the important parts and the principle of operation. Making a sketch requires the creativity of the designer himself, as well as a lot of knowledge in the field of technical sciences, so that the product is ultimately functional.

Prototyping of the dryer

Once the sketch of the device is made, the details and solutions for each assembly are worked out, the material and finished parts to be used in the construction are selected, prototyping can begin. Since the functionality of the product was uncertain, as with most prototypes, the materials and parts that would cost the least were used for the design. Most of the materials and parts used in making the prototype were obtained from "waste" at a very low cost. This manufacturing method requires a little more time to customise some parts, but with an unknown outcome, this is acceptable. Once the prototype was completed and put into operation, the result was satisfactory, and at a very low price of the product. This prototype is on a family farm and has been in operation for 3 years and has proven to be very reliable and economical.

Fig. 5. A prototype of a dryer for hazelnuts was made

Creating a 3D model in SolidWorks

Solidworks is a 3D modeling tool and belongs to the middle category as far as the scope of this type of programs is concerned. AutoCAD and other 2D systems have a smaller scope and weaker 3D modeling capabilities. Solidworks ranks ahead of Autodesk Inverter, followed by CATIA, a powerful 3D modeling program. Solidworks is primarily a tool for modeling and creating technical documentation. However, it can be extended with additional modules and used in production together with the SolidCAM tool to create programs for CNC machines [3].

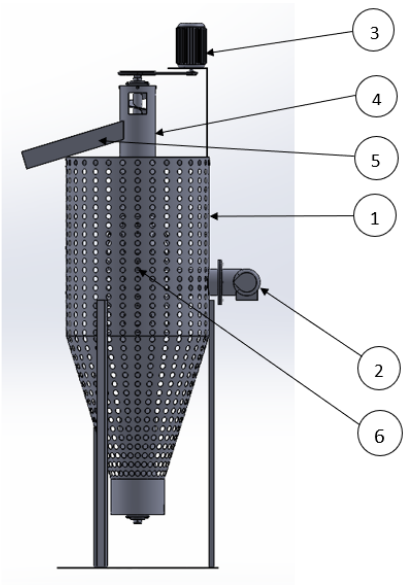


Fig. 6. 3D model of the dryer made in the Solidworks program

1. container with housing; 2. fan; 3. electric motor; 4. worm conveyor; 5. tank emptying channel; 6. air concentrator

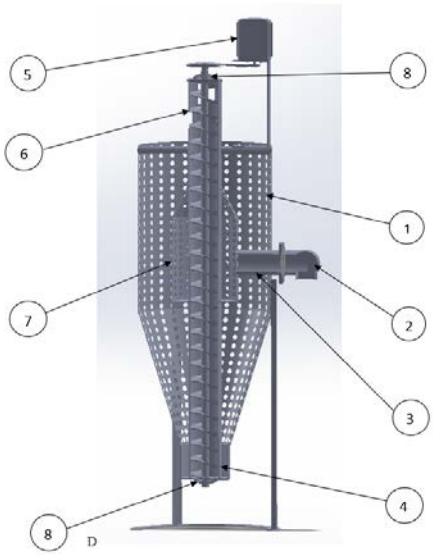


Fig. 7. Hazel dryer cross section made in the Solidworks program

1-housing with tank, 2-fan, 3-pipe for air supply, 4-range of hazelnut in worm conveyor, 5-electric motor, 6-worm conveyor, 7-air concentrator, 8-bearing.

To better understand the operation of the hazelnut dryer and the position and role of each part and assembly, a cross-section of the system is shown in Figure 7., which was created using the Solidworks program. The cross-section shows the parts and positions that are not visible in the overall model because they are located inside the tank. These are the air concentrator, the air supply pipe, the position of the screw conveyor, the spiral of the screw conveyor with the area where the screw conveyor collects the hazelnuts and transports them to the opening at the top of the Ø 200 pipe, through which the hazelnuts return to the tank. In this way, the hazelnuts are uniformly mixed in the tank.

Description of the dryer operation

The dryer tank must always be filled so that the air concentrator is covered with a layer of hazelnut at least as thick as the distance from the air concentrator to the tank wall, in this case 200 mm. Otherwise, it would not received the same air flow in all directions and therefore uniform drying would not be achieved. At the bottom of the Ø200 tube there is an opening of 150 * 120 mm through which the hazelnuts enter the tube, where they are collected by the screw conveyor. The screw conveyor pushes the hazelnuts up through the tube towards the top. At the top of the tube is an opening through which the hazelnuts fall back into the tank. In this way, the hazelnuts are evenly mixed in the tank, resulting in even moisture removal, i.e. drying.

The circular motion of the screw conveyor is generated by an electric motor via an open belt drive, a V-belt. On the shaft of the electric motor there is a drive pulley Ø50 mm, which is firmly connected to the shaft. The transmission of torque and movement is ensured by the pin. On the shaft of the screw conveyor there is a driven pulley Ø200 mm, which is also firmly connected to the shaft. Here, too, the transmission of torque is ensured by feather. The tolerances were chosen to achieve a tight fit with "light hammer blows", as this makes assembly easier and does not require a press [4].

The pressure fan that supplies the drying air must be strong enough to overcome the resistance of the hazelnut layer, in this case 200 mm. Another condition that must be met is that

it must supply as much drying air as possible in order to extract as much moisture from the hazelnuts as possible in the shortest possible time, thus shortening the drying process. It is also desirable to install a fan that has a low noise level. This method of drying is time-consuming, as the drying process can be carried out at night. The fan blows compressed air through the air supply hose into the air concentrator. The air supply hose has no holes, so all the air from the fan enters the air concentrator. The air concentrator is made of perforated sheet metal with Ø6 mm holes. When the air is pressurized, it flows from the concentrator through the hazelnut layer, absorbing some of the moisture. The tank of the dryer is also made of perforated sheet metal, so that the air containing part of the moisture absorbed by the hazelnuts can be freely released into the environment. This is the main principle of drying. The process lasts until the moisture content of the hazelnuts has dropped to about 10%. Only then can the hazelnuts be placed in a device for separating the kernel from the shell or for storage. The separated shell represents about 50% of the total mass of hazelnuts, so in this case the waste can be usefully used for heating in certain furnaces. For several reasons, it is desirable that the electric motor for driving the screw conveyor have the ability to regulate the speed. In the drying phase, the number of rotations of the worm conveyor should not be too high, about 50 rpm, so that the hazelnuts do not break. When emptying the tank, the speed of the conveyor can be the maximum allowed to shorten the emptying time, in this case not more than 150 rpm. The maximum permissible speed is calculated for each conveyor. If the tank with hazelnuts is emptied directly into the device for separating the kernels from the shell, the number of rotations of the conveyor can adjust the amount of hazelnuts at the exit of the tank to the capacity of the device for separating the kernels from the shell (cruncher).

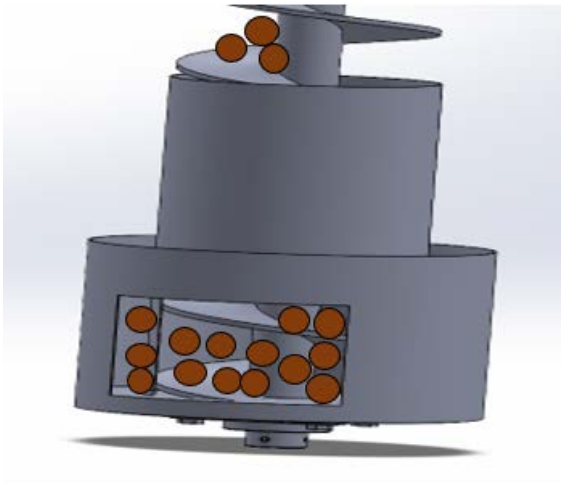


Fig. 8. Demonstration of hazelnut intervention in a screw conveyor

Figure 8 shows part of the plant where the screw conveyor collects the hazelnuts and pushes them up through the conveyor pipe towards the top.

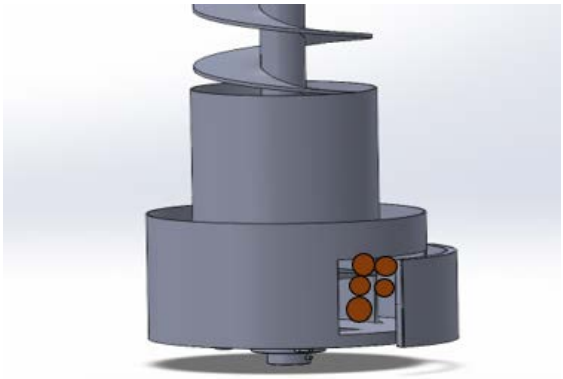


Fig. 9. Tank cleaning door

Figure 9 shows the door for cleaning hazelnut residues, shells and other impurities. Cleaning should be performed after each drying cycle.

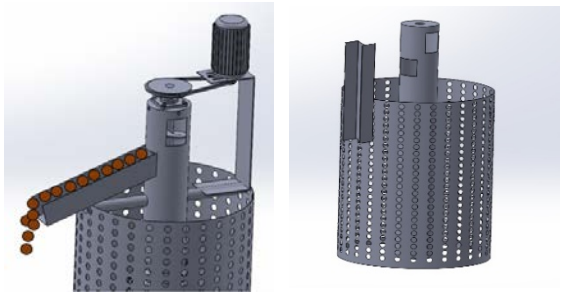


Fig. 10. Discharge channel

In the working position, in the drying phase, the tank emptying groove is in a vertical position so that the hazelnuts fall back freely into the tank. When emptying the tank, the emptying chute must be placed in the position shown in Figure 10 This is achieved by simply folding the groove using the hinge and resting it on the tube of the screw conveyor The length of the groove is calculated so that the chute does not "collapse" after leaning against the pipe.

Fig. 11. Tightening the belt by moving the electric motor

Figure 11 shows how to tighten the drive belt by simply moving the electric motor and tightening the screws. This solution is one of the easiest ways to tension the belt and is very commonly used in many operations. The figure also shows the way in which the transmission of power and motion is solved. Although the drive pulley, which is located on the shaft of the electric motor, and the shaft have a tight fit, the transmission of torque is guaranteed by a possible slippage of feather. Since the pulley can be easily mounted on the shaft of the electric motor, it is recommended to choose a tight fit, which is achieved by "light hammer blows" to avoid crimping, which is often inaccessible to presses. In the further part of the work, the recommended calculation of the tight fit is made.

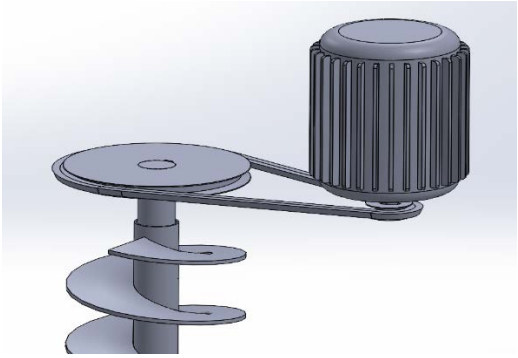


Fig. 12. Open belt transmission

A drive with a V-belt was chosen for the transmission of power and motion from the electric motor to the shaft of the screw conveyor. The drive pulley is located on the shaft of the electric motor, and the driven pulley is firmly seated on the conveyor shaft. The belt drive was chosen because of its simplicity and relatively low cost of manufacturing the transmission. Not only is the belt easy to maintain, but it also slips in the event of an overload, preventing major damage to the entire system. The screw conveyor can also be self-made, as all the necessary parts are available on the market.

Fig. 13. Conveyor auger available in the market

Fig. 14. Mounting the bearing and top plate on the shaft and the worm conveyor tube

In order to install the shaft with the screw conveyor in the Ø200 mm tube, at least one plate to which the bearing is attached must be removable. Figure 12. shows the sequence and method of mounting only the adjustable bearing attached to the top plate and the connection of the Ø196 * 20 plate to the conveying tube. All connections are bolted to make the work as simple as possible in case of repair or replacement of parts.

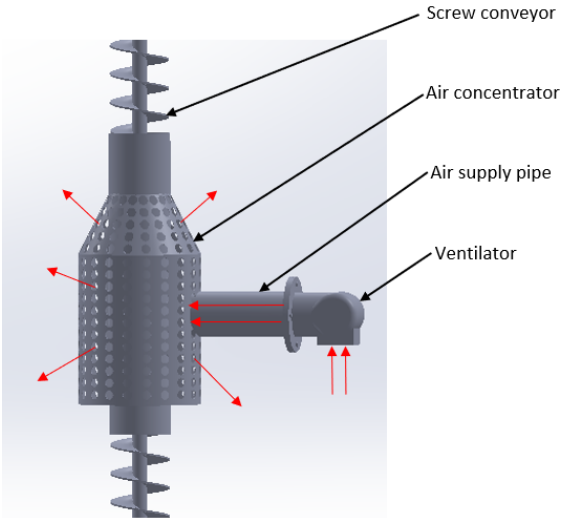


Fig. 13. Air concentrator

Figure 13 shows how the air concentrator is supplied with compressed air. The pressure blower draws air from the environment and forces it into the concentrator through the air supply tube. Since the concentrator is made of perforated plate with Ø6 mm holes, the compressed air flows freely through the holes and hits a 200 mm thick layer of hazelnuts which are located in the tank. As it flows through, the air absorbs some of the moisture from the hazelnuts and releases it into the environment. In this way, the moisture in the hazelnuts is gradually reduced so that the drying process takes place.

Fig. 14. Selected fan that meets the required conditions

Fig. 15. Self-aligning bearing UCF 208 SKF

It is recommended to install self-adjusting bearings. If the installation is done in a "home workshop", it is quite difficult to meet the requirement of parallelism of the upper and lower plates to which the bearings are attached. Self-adjusting bearings can withstand some shear on the axis of rotation, and these characteristics reduce the load on the shaft and vibration. For the screw conveyor in this system, the calculated maximum speed is up to 150 rpm. Since this is a relatively low speed and low loads, the selected bearing fully meets the required conditions.

The advantage of this bearing is that it is already in the housing, which avoids expensive turning operations in the manufacture of the hub, where the bearing would then have to be pressed into the hub. There are holes in the housing for tightening the bearings, which greatly simplifies installation.

The lubricator built into the housing allows lubrication, which extends the service life and reduces bearing noise.

On the inside of the bearing there are fixing screws with hexagon socket, which tighten the screw conveyor shaft and prevent its axial movement.

This type of bearing is available on the market at a very reasonable price, about 120 kn, which is very reasonable given the requirements it meets.

5. NECESSARY CALCULATION FOR THE CONSTRUCTION OF THE PLANT

Maximum speed of the worm conveyor

For each screw conveyor, it is necessary calculate the maximum allowable screw speed that must be maintained to prevent the device from breaking [5].

$$\boldsymbol{n_{max}} = \frac{\boldsymbol{E}}{\sqrt{\boldsymbol{D}}} \text{ rpm} \quad (1)$$

E coefficient as a function of the material to be transported

(for light, non-wearing material E = 65)

Screw conveyor D diameter (m) - a standard screw with a diameter of Ø190 mm was chosen

$$\boldsymbol{n_{max}} = \frac{\boldsymbol{65}}{\sqrt{\boldsymbol{0{,}190}}} = \boldsymbol{149{,}12\,\frac{r}{min} \approx 150\ \text{rpm}}$$

Gear ratio

To calculate the power of the electric motor that drives the schaft of the screw conveyor, it is necessary to calculate the transmission ratio between the driving and driven pulley. [4]

$$i_R = \frac{d_{R2}}{d_{R1}} \quad (2)$$

i_R - gear ratio

d_{R1} - drive pulley diameter (mm)

d_{R2} - driven pulley diameter (mm)

$$i_R = \frac{d_{R2}}{d_{R1}} = \frac{200}{50} = 4$$

Transport speed

When talking about the transport speed, it means the speed at which the hazelnuts pass through the screw conveyor. This calculation is necessary in order to eventually calculate the time needed to empty the bin. At the maximum permissible speed, it is possible to calculate how many times the total quantity of hazelnuts is mixed in one drying cycle and what the maximum capacity of the screw conveyor is [5].

$$v = \frac{s \times n}{60} \text{ m/s} \quad (3)$$

n - conveyor auger speed (rpm)

s - worm coil pitch (m)

v - transport speed (m / s)

TRANSPORT SPEED IN THE DRYING PHASE:

The recommended speed of the screw conveyor in the drying phase is about 50 rpm.

$$v = \frac{s \times n}{60} = \frac{0{,}1 \times 50}{60} = 0{,}083 \text{ m/s}$$

TRANSPORT SPEED WHEN TANK DISCHARGE:

The recommended speed of the screw conveyor when emptying the tank is the maximum allowed, for this conveyor it is up to 150 rpm.

$$v = \frac{s \times n}{60} = \frac{0{,}1 \times 150}{60} = 0{,}25\ m/s$$

At maximum speed, the tank emptying time is significantly reduced. Since this dryer is equipped with an adjustable speed electric-motor to start the screw conveyor, family farms that have their own device for separating the kernel from the shell can continue the "crunching" process directly from the dryer. In this case, the quantity of hazelnuts entering the "cruncher" hopper is adjusted to the capacity of the equipment by changing the speed of the electric motor.

Belt length calculation

The belt is tensioned by moving the electric motor along the grooves in the carrier. The length of the groove is limited and so is the movement of the electric motor. For this reason, it is necessary to calculate the length of the belt

in order to select a standard belt that can be properly tightened [4].

$$L = \beta \times \frac{D_1}{2} + (2\pi - \beta) \times \frac{D_2}{2} + 2a \times sin\frac{\beta}{2} \quad \text{mm} \quad (4)$$

$$cos\frac{\beta}{2} = \frac{D_2 - D_1}{2a} \quad (5)$$

L - belt length

β - coverage angle

D_1 - diameter small pulley

D_2 - diameter large pulley

a - pulley center distance

$$cos\ \frac{\beta}{2} = \frac{200 \times 50}{2 \times 300} = 0{,}25/\times\ cos^{-1}$$

$$\frac{\beta}{2} = arc\cos 0{,}25 = 75{,}522 = 75°\ 31'\ 21''/\times 2$$

$$\beta = 151{,}0449 = 151°\ 2'\ 42''$$

$$\beta = 151{,}045 \times \frac{\pi}{180} = 2{,}6362\ rad$$

$$L = 2{,}6362 \times \frac{50}{2} + (2\pi - 2{,}6362) \times \frac{200}{2} + 2 \times 300 \times sin\frac{2{,}66362}{2} = 1011{,}54 \text{ mm}$$

The first larger standard belt is selected, in this case a belt 17 × 1025 mm.

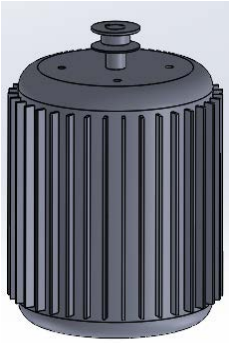
Tolerance of fit

In order to avoid pressing the bearing on the screw conveyor shaft as well as the pulley on the conveyor shaft and the electric motor shaft, and since the torque is achieved by the tongue, transitional and tight fits are chosen, which can be achieved by "light hammer blows", because the torque is achieved by feather. The manufacturing accuracy of the parts that make up the clamping joint, should be given by the tolerances of ISO in a system with a single bore [6].

For the connection of the bearing to the shaft of the screw conveyor, a transition fit was chosen for easier assembly.

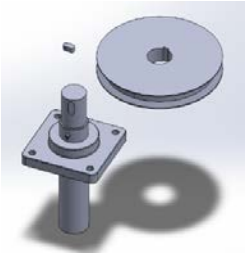
ISO tol. (mm)	
Ø40 H7	+ 0,035
	0
Ø40 j6	+ 0,013
	+0,009

A tight fit has been chosen for the connection between the motor shaft and the drive pulley Ø50 mm. The tolerance of a tight fit is such that the connection is achieved with "light hammer blows". With the selected seat, SJP, sufficient intimacy is achieved so that the pulley does not fall off the shaft during operation and torque transmission through the tongue is ensured.



ISO tol. (mm)	
Ø20 H7	+ 0,035
	0,0
Ø20 k6	+0,073
	+0,051

For the connection between the sleeve of the screw conveyor and the driven pulley Ø200 mm, a tight fit, SJP, was also chosen due to the ease of installation, achieved by "light hammer blows". Again, the transmission of the torque is ensured by the pin, and a tight fit is sufficient to prevent the pulley from falling off the sleeve during operation of the equipment.



ISO tol. (mm)	
Ø39 H7	+0,035
	0,0
Ø39 k6	+0,073
	+0,051

Calculation of the screw conveyor output

In order to be able to calculate the time in which the tank of the hazelnut dryer can be emptied and to find out how many times the total amount of hazelnuts has been mixed in one drying cycle, it is necessary to calculate the capacity of the screw conveyor [7].

The power calculation of the screw conveyor is calculated according to the following formula [7].

$$Q = 15 \times D^2 \times \pi \times n \times s \times \delta \times c \times \Psi \quad \text{t/h} \quad (6)$$

Where is: 6.

Q - action of the screw conveyor (t/h)
D - diameter of the screw conveyor (m)

- for this conveyor the standard dimension Ø190 mm was chosen
n - screw speed (rpm)
- for this calculation we take the number of revolutions in the drying phase, 50 rpm
s - screw pitch (m)
- the pitch of the coil is assumed to be 100 mm
δ - specific weight of the material (kg / m³)
- for hazelnuts δ = 650 kg / m³
ψ- filling coefficient of the conveyor
- depends on the type of material, for larger material it is 0.25 to 0.4
c - coefficient of power reduction due to gradient α - for α = 90° c = 0,40

Since all quantities are known, the power of the screw conveyor can be calculated.

Q=15×0,192×π×50×0,1×650×0,4×0,4 =
= 884,6 kg/h = 0,884 t/h

This is a calculation of the output of the screw conveyor in the drying phase, at 50 rpm. In the same way, the maximum effect can be calculated, that is, the time in which the dryer hopper can be emptied. The maximum permissible speed of the screw conveyor, 150 rpm, is included in the calculation.

Q=15×0.192×π×150×0.1×650×0.4×0.4=
=2653.8 kg/h =2.65 t/h

It follows that the maximum effect of this screw conveyor is 2.65 t / h of hazelnut transport.

Calculation of torque and power at the screw conveyor shaft

The torque of the screw conveyor is calculated according to the following formula: [7]

$$Mo = F \times r_o \text{ Nm} \quad (7)$$

$$r_o = (0.7\text{-}0.8) \times D/2 \text{ m} \quad (8)$$

Where is :

F - axial force acting on the screw conveyor (N)
- the conveyor is upright at a 90 °
r_o - radius of the coil on which the axial force acts
D - diameter of the cochlea (m)
0.7 - 0.8 -experience coefficients
Mo - Torque on the coil (Nm)

In order to calculate the torque, it was necessary to calculate the axial force acting on the screw of the conveyor, namely F = 611 N

$r_o = 0.8 \times 0.095 = 0.076$ m

Mo = 611 × 0.076=46.4 Nm

The power at the screw shaft is calculated using the following formula:

$$Mo = Po/\omega \text{ Nm} \quad (9)$$

$$\omega = (\pi \times n)/30 \text{ rad/s} \quad (10)$$

The power of the shaft can be calculated from the above expressions.

$$Po = Mo \times \omega \text{ W} \quad (11)$$

For the speed in the drying phase, 50 rpm, the power at the screw shaft is:

ω = (π×50)/30 =5.235 rad/s

Po = 46.4 × 5.235 = 249.9 W

For the number of revolutions in emptying the tank (150 rpm), the power at the worm shaft is:

ω = (π×150)/30 = 15.7 rad/s

Po = 46.4 × 15.7 = 728.48 W

6. CONCLUSION

Due to the growing need for structurally acceptable solutions, leading to increased efforts by the profession to provide simple, flexible and, above all, financially but also technologically efficient solutions to a given problem, we come across a certain number of acceptable options for product design and construction. In this task, we will deal with only one variant of manufacturing a hazelnut dryer.

As for the technical aspect of the design of a hazelnut dryer, it was focused on technology, efficiency, economy, and ease of manufacture and installation. The use of a blower without heating the air needed for drying significantly reduces operating costs. The feedback from the owner of this equipment, referring to economy, is that for a mass of 350 kg of hazelnuts with 21% moisture, the moisture drops to 12% in 3 hours, which is enough to separate the kernel from the shell, with a total cost of about 10 kn for the electricity that drives a fan and an electric motor to drive the screw conveyor.

This work has shown that it is possible to build a functional and economical plant for drying hazelnuts that is simple and safe to use. And above all, such a plant can be afforded by any small business, and that was the aim of this work.

7. REFERENCES

[1] I. Krpina, Voćarstvo; Zagreb, 2004.

[2] G. Mitar, Diplomski rad-Kemijski sastav lješnjaka različitih sorti u Hrvatskoj; Zagreb, rujan, 2016.

[3] S. Šimunić ; I. Lacković, Računalom podržano modeliranje prostornih modela, Veleučilište u Slavonskom Brodu, 2014.

[4] K-H Decker, Elementi strojeva; Tehnička knjiga, 2006.

[5] Z. Novak, Predavanja; Prekrcajna sredstva; Veleučilište u rijeci, Rijeka, 2008.

[6] B. Kraut, Strojarski priručnik; Tehnička kjiga , Zagreb, 2010.

[7] M. Kršulja, Transporteri, strugači i pužni transporteri; Veleučilište u rijeci; Prometni odjel

The Laboratory Facility for the Research of Forced Convection of Nanofluids - Validation of Hydraulic Parameters

S. Laloš[a], M. Bukurov[b], M. Vraneš[c], S. Papović[c], D.Knežević[a], S. Bikić[b]

[a] University of Banja Luka, Faculty of Mechanical Engineering, Vojvode Stepe Stepanovića 71, Banja Luka 78000, Bosnia and Herzegovina, sasa.lalos@mf.unibl.org, darko.knezevic@mf.unibl.org

[b] University of Novi Sad, Faculty of Technical Sciences, Trg Dositeja Obradovića 6, 21000 Novi Sad, Serbia, mbukurov@uns.ac.rs, bika@uns.ac.rs

[c] University of Novi Sad, Faculty of Sciences Trg Dositeja Obradovića 3, 21000 Novi Sad, Serbia, milan.vranes@dh.uns.ac.rs, snezana.papovic@dh.uns.ac.rs

Abstract

This paper deals with a laboratory facility for testing the forced convection of nanofluids through circular cross-section pipes. The aim of this paper was to verify the hydraulic parameters of the laboratory facility. The parameters considered were pressure drop and friction factor. The paper presents a technical solution for the part of the laboratory facility related to the measurement of hydraulic parameters and the results of its validation. The facility parameters were verified with distilled water, and the measured data were compared with the results obtained from the well-known Darcy–Weisbach, Poiseuille, and Blasius equations. It has been shown that the measured data match theoretical data very well. The maximum relative deviation of the experimental and theoretical pressure drop is 4,8%, while the average value of the relative deviation is 1,15%.

Keywords: Nanofluid; Pressure drop; Friction factor; Forced convection.

1. INTRODUCTION

The first research on nanofluids was done by Masuda et al. [1]. The authors suspended Al_2O_3, SiO_2, and TiO_2 particles in water as a base fluid. They found that an increase in the concentration of Al_2O_3 and TiO_2 particles leads to a rise in nanofluid thermal conductivity. After that, intensive development of nanofluids followed, where numerous researchers worldwide were engaged in the research of thermophysical properties of nanofluids [2]. Today, it is considered that nanofluids (NFs) are advanced colloids obtained by dispersing 1–100 nm nanoparticles (NPs) in a base liquid [2]. Water, ethylene glycol, oil, and ionic liquids are used as base fluids. Different material particles are suspended in base fluids: metals, oxides, carbides, nitrides, and carbon nanotubes. In the future, nanofluids could be used as heat transfer fluids for heat exchangers, so researchers are now intensively dealing with the forced convection of nanofluids.

Adding nanoparticles to the liquid can increase its thermal conductivity and intensify heat transfer in heat exchangers. Intensification of heat transfer does not automatically mean a benefit from the considered nanofluid. The suspension of nanoparticles can increase fluid viscosity, which affects the increase in the pressure drop. As a result, more energy is needed to pump the fluid through the system.

It is crucial to examine the nanoparticle impact on the heat exchange process related to the power required to achieve the desired flow regime and to determine whether it makes sense to use such a nanofluid in practical applications. The criterion representing the ratio of transferred thermal to required mechanical energy [3–8] is used for validation purposes. This ratio can be defined in a few ways, and

literature gives a few different names, like performance index and thermal performance factor. If the energy ratio is greater than 1, nanoparticles provide more benefits regarding heat conduction than drawbacks regarding pumping power. In that case, the nanofluid could be used in practical applications. Therefore, in many papers related to nanoparticles-induced thermal conductivity and convection coefficient improvement, pressure drop and friction factor studies are performed. Measured data have been compared with the theoretical data obtained by the Darcy–Weisbach, Poiseuille, and Blasius equations [3–22]. In some papers, various empirical formulas for the prediction of nanofluid friction factors have been proposed [3,5,14,16]. They differ significantly due to different nanoparticle materials, sizes, and methods needed to obtain them. A large amount of experimental data is necessary to develop a new mathematical model for calculating a nanofluid's viscous friction factor or pressure drop. Various technical solutions for test facilities were proposed. All facilities were first tested using a base fluid. The results obtained were verified using theoretical values.

Mojarrad [3] et al. studied heat transfer enhancement of alumina/water and alumina/water–ethylene glycol nanofluids with nanoparticles volume concentrations up to 0,7%. A laminar flow regime was observed. Validation of the facility was carried out using water. The result showed that the pure water maximum deviation between experimental and theoretical pressure drop values was 4%. A comparison of the energy ratio was also performed, and it was shown that this ratio increases both by increasing the Reynolds number and by increasing the concentration of nanoparticles. Razi et al. [4] used a CuO/base oil nanofluid under a turbulent flow regime with nanoparticle concentrations from 0,2 to 2 wt%. Validation of the facility was performed with pure base oil. The maximum pressure drop deviation for pure oil was less than 16%. The energy ratio showed that only nanofluid with higher concentrations could be used in practical applications. Iyahraja et al. [5] researched convective heat transfer and friction factor of silver–water nanofluid under laminar flow, with particle concentrations of 0,01, 0,05, and 0,1 vol%. After facility validation, the maximum deviation of the friction factor was 2,37%, and the average deviation was 1,19%. Validation of the facility was performed with pure water. New correlations for predicting the Nusselt number and friction factor were proposed. Energy analysis showed that the energy ratio was greater than one for all concentrations. Emad et al. [7] investigated forced convection using graphene nanoplatelet-distilled water nanofluid under a turbulent flow regime at particle concentrations of 0,025, 0,05, 0,075, and 0,1 wt %. The facility validation was carried out with water. The measured and theoretical friction factor deviation was less than 10%. Hussein [9] performed an investigation of forced convection under laminar flow. Nanofluid was the mixture of aluminium nitride nanoparticles into ethylene glycol with a volume fraction of 1 to 4%. Validation of the facility was carried out with water. During validation, friction factor deviation was less than 3%. Hwang et al. [10] performed Al_2O_3/water nanofluids tests in a fully developed laminar flow regime, with particle concentrations from 0,01 to 0,3 vol%. The validation was carried out using water flowing through a pipe with a small diameter of 1,812 mm, so the measured pressure drop was relatively significant for the laminar flow regime. The pressure drop deviation was less than 1%. Almohammadi et al. [11] used the same type of nanofluid in the laminar flow regime. Validation was performed using pure water. The deviation of the friction factor was less than 5%. Rea et al. [12] studied the heat transfer and viscous pressure loss of alumina/water (20 wt%.) and zirconia/water (12,8 wt%) nanofluids under laminar flow. The pressure drop was measured, and the results were compared with the Darcy–Weisbach equation. Validation was performed with distilled water. The pressure drop deviation of the measured and theoretical values was less than 20%. It has been shown that the pressure drop of the selected nanofluids depends only on the viscosity. Minakov et al. [13] studied the heat transfer coefficient of a CuO/water nanofluid with several nanoparticle concentrations between 0,25 and 2 vol%. Laminar and transitional flow regimes were investigated. The Poiseuille and the Blasius correlations were used to compare the friction factor. Validation of the facility was performed with pure water. The pressure drop deviation was less than 5%. Syam et al. [14] explored heat transfer and friction factors under laminar flow. MWCNT–Fe_3O_4/water hybrid nanofluids with

0,1 and 0,3 vol% nanoparticles concentration were used. The facility validation was carried out with water, and the maximum friction factor deviation was within the limits of ±3%. New correlations for the Nusselt number and friction factor calculation were proposed. Everts and Meyer [15] studied water convection at constant heat flux under a laminar flow regime. The experimental facility was verified, and the average friction factor deviation reported was 2,5%. The Poiseuille correlation was used to calculate the theoretical friction factor. Teng et al. [16] studied pressure drop of TiO_2/water nanofluid with different fractions (0,5, 1, and 1,5 wt%) for laminar and turbulent flows at different temperatures. It was found that at concentrations between 0 and 1,55 wt% and temperatures between 10 and 40 °C, the pressure drop increased from 25 to 63,3% for laminar and 5,7 to 15,3% for turbulent flow. Deviations of the measured values compared to the theoretical ones for laminar flow ranged from 0,01 to -52,36%, and below 20% for turbulent flow. A new empirical formula for friction factor calculation was introduced, which gave better results.

Arani et al. [17] explored Ag/oil nanofluid in concentrations of 0,011, 0,044, and 0,171 vol% in the laminar flow regime. The experimental facility was validated with pure oil, and the measurement results coincided with the theoretical values. The most significant increase in pressure drop was observed at the highest concentration of nanoparticles and was about 3% compared to pure oil. There was no significant change in the nanofluid friction factor compared to pure oil. Naddaf et al. [18] explored heat transfer performance and pressure drop under laminar flow. Nonfluid was a mixture of graphene/multi-walled carbon nanotubes and diesel oil in concentrations of 0,05, 0,1, 0,2, and 0,5 wt%. It was shown that the viscosity increased with consentration, and accordingly, the pressure drop increased as well, but the pressure increase was not significant, between 0,012 and 6,3%. The energy ratio showed that the benefit from thermal conductivity growth was greater than the disadvantages due to the increase in pressure drop. Heyhat et al. [19] experimented with Al_2O_3 nanoparticles dispersed in distilled water with concentrations between 0,1 and 2 vol%. They studied convective heat transfer and pressure drop under laminar flow. The experimental facility was first verified with distilled water and then used to measure the pressure drop of nanofluids of different concentrations. For smaller particle concentrations, the measured pressure drop coincides with the theoretical one. However, pressure drop deviation is significant for higher concentrations, so the same expression cannot be used for pressure prediction as for pure water. Kayhan et al. [20] observed Al_2O_3 nanoparticles suspended in distilled water at concentrations from 0,1 to 2 vol% in a turbulent flow regime. Facility validation was successfully performed with distilled water. The measured pressure drop was in good agreement with that obtained theoretically. The nanofluid friction factor differed slightly from pure water for the same Reynolds numbers. Zarringhalam et al. [21] investigated CuO/water nanofluid concentrations between 0,0625 and 2 vol% in a turbulent flow regime. An analysis of the benefits of adding nanoparticles was performed. It was shown that for some concentrations at specific Reynolds numbers, the energy ratio was less than 1, and for some, it was greater than 1. It was also shown that the theoretical model could be used for friction factor calculation but that measured value deviations were more significant at lower Re numbers. Hemmat et al. [22] experimented with carbon nanotubes/water nanofluid with concentrations between 0,05 and 1 vol%, at Reynolds numbers from 5000 to 27000. It was shown that with an increase in the concentration of nanoparticles, the energy ratio at all values of Reynolds numbers increased, although there was an increase in pressure drop. Thus, it is justified to use this type of nanofluid with a higher concentration of nanoparticles from an energy efficiency standpoint.

The paper presents a developed technical solution for the part of the laboratory facility for testing the forced convection of nanofluids through tubes of circular cross-section. It is a specific laboratory facility with a small volume because the nanofluid price is still very high. Due to the small volume, developing a laboratory facility to investigate nanofluid forced convection is very challenging. This is precisely why experimentally obtained hydraulic and heat transfer parameters must be verified. The research aims to validate the hydraulic parameters of the laboratory facility. The validation was done using distilled water for laminar and turbulent flow regimes for the

following two hydraulic parameters: pressure drop and friction factor. The experimentally obtained hydraulic parameters were compared with the values obtained from the Darcy–Weisbach, Poiseuille, and Blasius equations. The research hypothesis was that the deviation of experimental and theoretical results follows the data from the literature.

2. MATERIAL AND METHOD

2.1. Experimental Setup

A schematic of the laboratory facility is given in Figure 1. The main parts of the facility are the tank, pump, test section, control valves, heat exchanger, temperature, flow and pressure sensors, data acquisition device, and thermal bath.

A centrifugal magnetic pump A01VP-12VDC-5,0L, 12 VDC (Rotek Handels GmbH, Austria) with a maximum flow of 5 L/min and a pressure of 0,54 bar was used for forced flow realization. Flow regulation can be done via two needle valves and/or by changing the number of revolutions, i.e., by changing the electric voltage of the pump. The pump takes water from the 1,5 L stainless-steel tank and sends it through the needle valve to the test section assembly. The needle valve is used for flow regulation and fluid mixing intensification to achieve uniform fluid temperature over the pipe cross-section.

The test section assembly consisted of several parts. At the beginning and the end of the test section, there were specially designed couplings made of polyamide, in which PT1000 temperature probes were placed to measure the mean temperature of the fluid at the entrance and exit of the test section. The temperature probes were calibrated with an accuracy of ±0,1 °C. The fluid first entered the 800 mm long flow development section to ensure full hydrodynamic flow. The flow development section and the pressure drop measurement section comprised a smooth, seamless tube made of stainless steel EN 1.4301, with a calibrated inner diameter of 5,6 mm, a wall thickness of 0,2 mm, and absolute roughness of 0,0015 mm.

The length of the pressure drop measuring section was 1490 mm. At the beginning and the end of the pressure measuring section, specially designed couplings made of polyamide were placed.

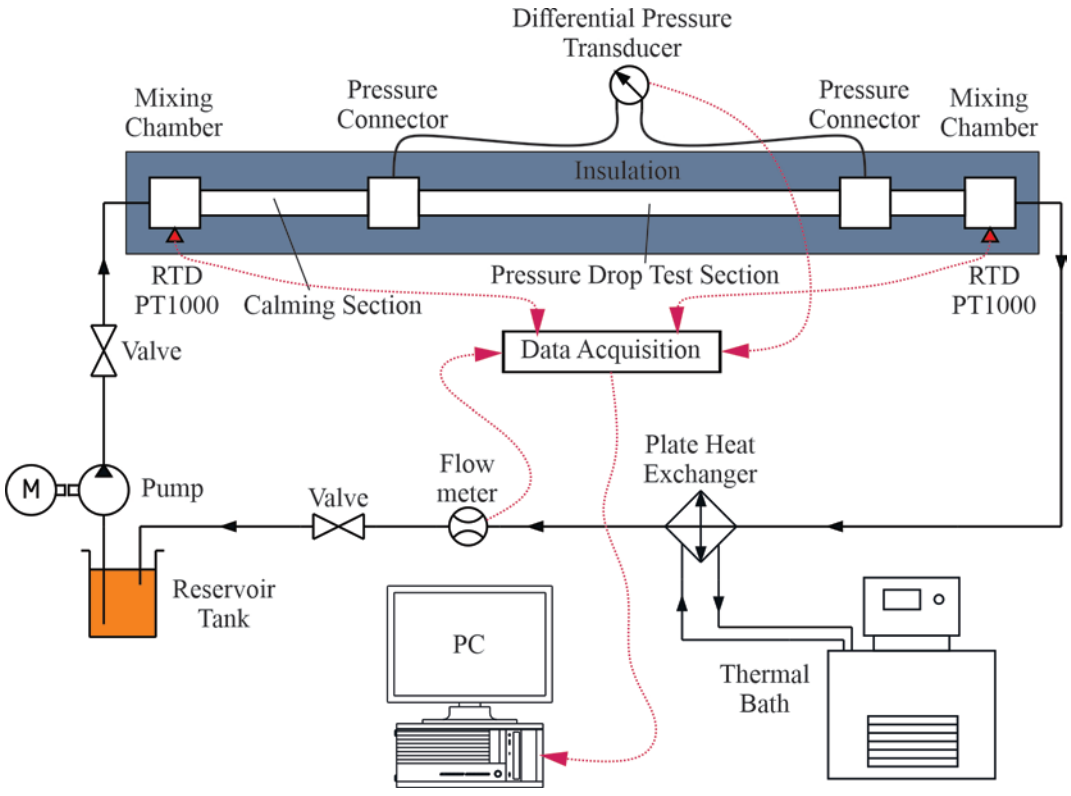


Fig. 1. Schematic of the laboratory facility

The couplings had fittings for connection with a differential pressure gauge. A differential pressure gauge EJA110A (Yokogawa Electric Corporation, Japan) was used for pressure drop measurement.

After leaving the test section, the fluid passed through the primary side of the plate heat exchanger, then through the Coriolis flow meter R025/2700 (Emerson Electric, USA), and returned to the tank. The secondary side of the heat exchanger was connected to a MaXircu CR-P30 thermal bath (Witeg Labortechnik GmbH, Germany) with a maximum power of 800 W and temperature accuracy of ±0,1 °C. The heat exchanger and the thermal bath achieved and maintained the desired fluid temperature. The fluid flow through the secondary side of the exchanger was achieved with a pump installed in the thermal bath. The adjustment of the thermal power was made by adjusting the fluid flow and temperature in the secondary line of the heat exchanger. The remaining pipes were flexible hoses with an outer diameter of 8 mm, which additionally thermally isolated the system in the axial direction and prevented the transmission of vibrations.

All sensors and gauges were connected to the CompactDAQ data acquisition system (National Instruments, USA) with modules NI 9219 for temperature measurement and NI 9923 for current signal measurement, i.e., for measuring volumetric flow rate (Q) and pressure drop (Δp_M). Data acquisition was connected to a computer where all data were displayed in real-time and stored. The data sampling rate was 1 Hz.

The test section had to be insulated to prevent uncontrolled cooling or heating of the fluid. The entire test section was thermally insulated with an 8 cm thick layer of mineral fibers insulation and additionally placed in an armour made of 5 cm thick firm polyurethane foam. The market price of nanoparticles is relatively high. Therefore, during the design of the laboratory facility, special care was taken to ensure that the volume of fluid required for testing was as small as possible. The minimum volume of liquid required for conducting the test was 0,7 L. The experimental setup is shown in Figure 2.

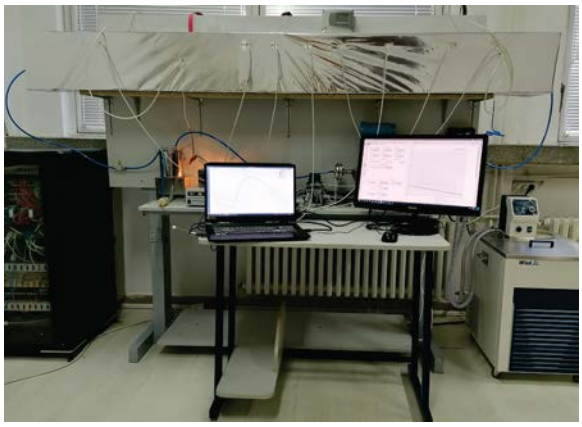


Fig. 2. Experimental setup

2.2. Data Analysis

The experimental facility is intended for pressure drop measurement in laminar (Re<2300) and turbulent (4000<Re<10^5) flow regimes. In order to verify the hydraulic parameters of the facility, the measured data had to be compared with the theoretical data. The well-known Darcy–Weisbach equation (1) is used to calculate the pressure drop at all flow regimes:

$$\Delta p_C = \frac{1}{2}\rho v^2 \cdot f \frac{L}{d} \tag{1}$$

where ρ is the density [kg/m^3], v is the velocity [m/s], f is the friction factor [-], L is the test section length [m], and d is the inner diameter [m].

For a fully developed laminar flow, the friction factor is calculated with the Poiseuille equation (2):

$$f = \frac{64}{\mathrm{Re}} \tag{2}$$

where Re is the Reynolds number and is calculated using the well-known equation:

$$\mathrm{Re} = \frac{v \cdot d}{\upsilon} \tag{3}$$

where υ is kinematic viscosity [m^2/s].

To calculate the friction factor in turbulent flow, for smooth pipes and for Re≤10^5, the Blasius equation (4) is used [24]:

$$f = \frac{0{,}316}{\mathrm{Re}^{0{,}25}} \tag{4}$$

All thermophysical properties of water are obtained at the bulk temperature (T_B).

3. RESULTS AND DISCUSSION

Validation of the laboratory facility was performed using distilled water. Measurements were made for three different temperature regimes. The value of the Reynolds number ranged from 300 to 5040, and Table 1. shows the measurement results. The test procedure starts with the adjustment of the thermal bath fluid temperature. After reaching the desired bath temperature, the laboratory facility pump is turned on, and the maximum flow is set. When the thermal equilibrium is established, the desired flow rate is adjusted. When the new steady state of inlet and outlet temperature, pressure, and flow is reached, the data recording starts. All measured values are displayed in real-time via the computer monitor. Setting up and reaching the stationary state takes about 50 minutes. The measured values were recorded once per second, and the recording time was at least 5 minutes. The analysis of the saved data was performed, and all of the measured values were averaged. Those averaged values were used for comparison with theoretical values.

The experimental values were compared with the theoretical data to evaluate the accuracy of the hydraulic parameters. Data presentation was done graphically, in a form established in papers dealing with forced convection of nanofluids [3–5,8,10–14].

Table 1. Measurement results

Q [L/min]	T_B [°C]	Re [-]	f [-]	Δp_M [Pa]	Δp_C [Pa]	Δp deviation %
0,863	40,8	5040,3	0,0375	1699,2	1698,7	0,04
0,804	40,8	4697,2	0,0382	1500,6	1503,7	0,21
0,751	40,7	4380,0	0,0389	1326,5	1332,9	0,48
0,704	40,7	4104,8	0,0395	1188,0	1192,0	0,34
0,349	40,1	2009,4	0,0319	236,7	235,4	0,57
0,299	39,7	1712,2	0,0374	203,7	203,1	0,29
0,200	39,1	1131,0	0,0566	138,6	137,5	0,78
0,100	37,9	554,3	0,1155	72,7	70,7	2,86
0,406	24,4	1697,2	0,0377	384,4	380,2	1,10
0,297	24,5	1243,0	0,0515	282,9	277,1	2,07
0,199	24,6	838,4	0,0763	190,6	185,6	2,67
0,101	24,9	429,2	0,1491	98,2	93,6	4,83
0,604	14,9	2003,7	0,0319	720,5	714,8	0,79
0,541	14,9	1793,9	0,0357	633,4	639,1	0,89
0,500	15,0	1665,5	0,0384	584,3	589,3	0,86
0,399	15,3	1338,6	0,0478	462,6	467,4	1,03
0,297	15,7	1002,9	0,0638	340,1	344,0	1,14
0,198	16,1	677,5	0,0945	225,2	227,9	1,19
0,104	16,2	357,7	0,1789	118,7	119,4	0,59

According to the data in Table 1., the maximum deviation of pressure drop is 4,8% for only one measurement, while for other measurements, the deviation is less than 3%. The average value of the deviation is 1,15%, which follows the values from the literature. Therefore, we can conclude that the measured values agree well with the theoretical values. This matching is also visible in Figure 3., where a comparison of experimental and theoretical pressure drop values is shown.

Figure 4. shows a pressure drop comparison for different values of Re and three different temperature intervals in laminar, and Figure 5. in a turbulent flow.

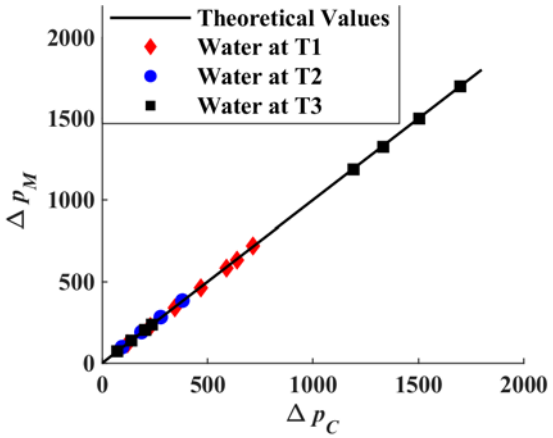


Fig. 3. Comparison of the theoretical and measured pressure drop in the laminar flow

As expected, it is visible that the pressure drop decreases with the increase in temperature, and with the increase in Re, in both flow regimes, the pressure drop increases.

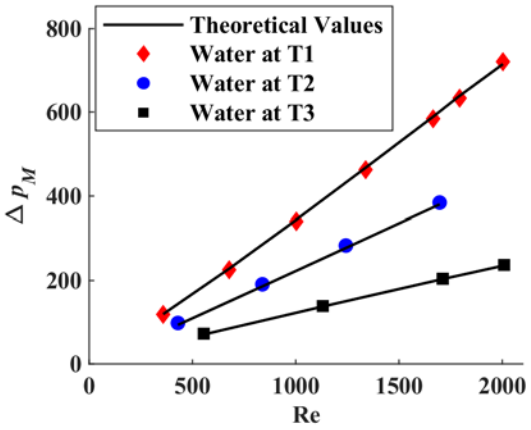


Figure 4. Pressure drop comparison in the laminar flow against Re

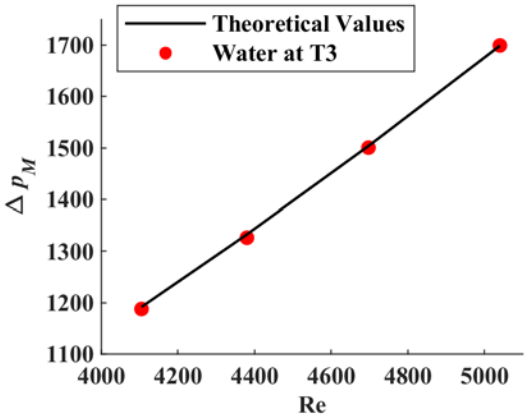


Figure 5. Pressure drop comparison in the turbulent flow against Re

Figure 6. illustrates the change in the viscous friction factor with the change in Re and the comparison of measured and calculated values for laminar and Figure 7. for turbulent flow. It can be observed that the viscous friction factor for both flow regimes decreases by increasing Re, which is in line with expectations.

Figure 8. shows the relationship between the measured friction factor and its theoretical value for all measurements. The friction factor and the pressure drop are correlated by formula (1) and are directly proportional. Therefore, the deviation of the pressure drop is identical to the deviation of the friction factor. It can be seen from Figure 8. that the maximum deviation of the friction factor is less than 5% and that most of the measured values are very close to the theoretical values.

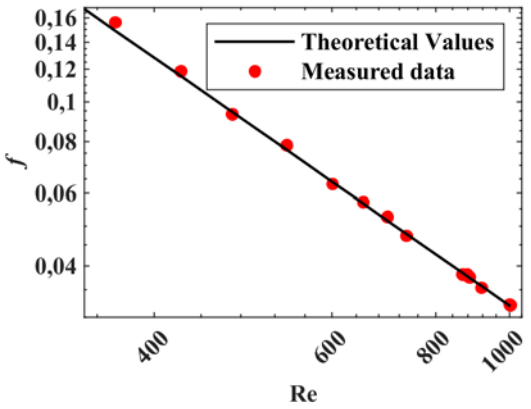


Figure 6. Comparison of the viscous friction factor against Re in the laminar flow

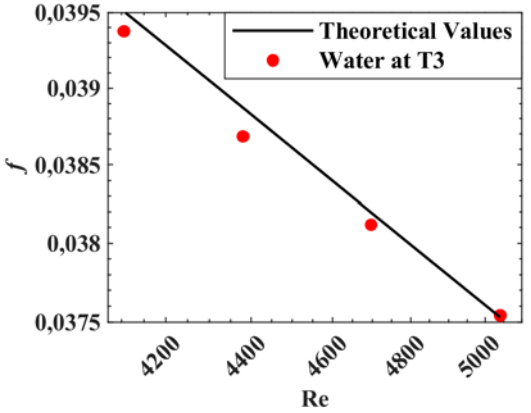


Figure 7. Comparison of the viscous friction factor against Re in the turbulent flow

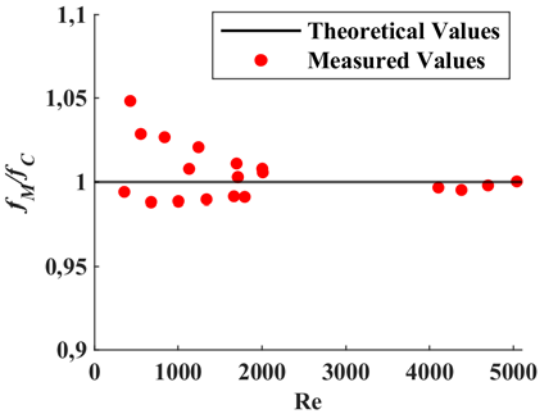


Figure 8. The ratio of the measured and theoretical friction factor against the theoretical ratio

4. CONCLUSIONS

The paper presents the technical solution for one part of the experimental facility for the forced convection investigation of nanofluids through tubes of circular cross-section. The part of the facility related to measuring hydraulic

parameters is shown. It is a facility where the fluid volume, due to the high price of nanofluids, is small and amounts to only 0,7 L. The paper also presents the validation results of the measured hydraulic parameters (pressure drop and friction factor). The validation was done with distilled water by comparing the measured hydraulic parameters with the parameters obtained by applying the Darcy-Weisbach, Poiseuille, and Blasius equation. The maximum pressure drop deviation of the experimental and theoretical values is 4,8%, while the average value of the deviation is 1,15%. This deviation is consistent with data from the literature.

Based on the obtained data, it can be concluded that the experimental data agree well with the theoretical values. In this way, the parameters of the laboratory plant were successfully verified in relation to hydraulics. Therefore, the presented technical solution of the laboratory facility related to hydraulics can be reliably used in future research on nanofluid forced convection. The authors plan to verify the heat transfer parameters obtained at the laboratory facility. The following two heat transfer parameters, the Nusselt number and heat transfer coefficient, should be taken into account. Verification of heat transfer parameters is to be done with distilled water for laminar and turbulent flow regimes.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

[1] H. Masuda; A. Ebata; K. Teramae, Alteration of thermal conductivity and viscosity of liquid by dispersing ultra-fine particles Dispersion of Al_2O_3, SiO_2 and TiO_2 ultra-fine particles. Netsu Bussei 7 (1993), pp. 227-233

[2] L. Qiu; N. Zhu; Y. Feng; E.E. Michaelides; G. Żyła; D. Jing; X. Zhang; P.M. Norris; C.N. Markides; O. Mahian, A review of recent advances in thermophysical properties at the nanoscale: From solid state to colloids. Physics Reports 843 (2020), pp.1–81

[3] M.S. Mojarrad; A. Keshavarz; M. Ziabasharhagh; M.M. Raznahan, Experimental investigation on heat transfer enhancement of alumina/water and alumina/water-ethylene glycol nanofluids in thermally developing laminar flow. Experimental Thermal and Fluid Science 53 (2014), pp.111–118

[4] P. Razi; M.A. Akhavan-Behabadi; M. Saeedinia, Pressure drop and thermal characteristics of CuO-base oil nanofluid laminar flow in flattened tubes under constant heat flux. International Communications in Heat and Mass Transfer 38 (2011), pp.964–971

[5] S. Iyahraja; J. Selwin Rajadurai; B. Siva Subramanian; S. Siva Subramanian; P. Sivasankar; S. Subash, Investigation on convective heat transfer and friction factor of silver–water nanofluid under laminar flow – an experimental study. Heat and Mass Transfer / Waerme- Und Stoffue-bertragung 55 (2019), pp.3029–3039

[6] M. Mehrali; E. Sadeghinezhad; M.A. Rosen; A.R. Akhiani; S. Tahan Latibari; M. Mehrali; H.S.C. Metselaar, Experimental investigation of thermophysical properties, entropy generation and convective heat transfer for a nitrogen-doped graphene nanofluid in a laminar flow regime. Advanced Powder Technology 27 (2016), pp.717–727

[7] E. Sadeghinezhad; M. Mehrali; S. Tahan Latibari; M. Mehrali; S.N. Kazi; C.S. Oon; H.S.C. Metselaar, Experimental investigation of convective heat transfer using graphene nanoplatelet based nanofluids under turbulent flow conditions. Industrial and Engineering Chemistry Research 53 (2014), pp.12455–12465

[8] C.J. Ho; C.Y. Chang; W.M. Yan, An experimental study of forced convection effectiveness of Al_2O_3-water nanofluid flowing in circular tubes. International Communications in Heat and Mass Transfer 83 (2017), pp.23–29

[9] A.M. Hussein, Thermal performance and thermal properties of hybrid nanofluid laminar flow in a double pipe heat

exchanger. Experimental Thermal and Fluid Science 88 (2017), pp.37–45

[10] K.S. Hwang; S.P. Jang; S.U.S. Choi, Flow and convective heat transfer characteristics of water-based Al_2O_3 nanofluids in fully developed laminar flow regime. International Journal of Heat and Mass Transfer 52 (2009), pp.193–199

[11] H. Almohammadi; S.N. Vatan; E. Esmaeilzadeh; A. Motezaker; A. Nokhosteen, Experimental investigation of convective heat transfer and pressure drop of Al_2O_3/water nanofluid in laminar flow regime inside a circular tube. International Journal of Mechanical and Mechatronics Engineering 6 (2012), pp.1750–1755

[12] U. Rea; T. McKrell; L. wen Hu; J. Buongiorno, Laminar convective heat transfer and viscous pressure loss of alumina-water and zirconia-water nanofluids. International Journal of Heat and Mass Transfer 52 (2009), pp.2042–2048

[13] A. V. Minakov; V.Y. Rudyak; D. V. Guzei; A.S. Lobasov, Measurement of the heat transfer coefficient of a nanofluid based on water and copper oxide particles in a cylindrical channel. High Temperature 53 (2015), pp.246–253

[14] L.S. Sundar; M.K. Singh; A.C.M. Sousa, Enhanced heat transfer and friction factor of MWCNT-Fe_3O_4/water hybrid nanofluids. International Communications in Heat and Mass Transfer 52 (2014), pp.73–83

[15] M. Everts; J.P. Meyer, Laminar hydrodynamic and thermal entrance lengths for simultaneously hydrodynamically and thermally developing forced and mixed convective flows in horizontal tubes. Experimental Thermal and Fluid Science 118 (2020), pp. 110–153

[16] T.P. Teng; Y.H. Hung; C.S. Jwo; C.C. Chen; L.Y. Jeng, Pressure drop of TiO_2 nanofluid in circular pipes. Particuology 9 (2011), pp.486–491

[17] A.A. Abbasian Arani; H. Aberoumand; S. Aberoumand; A. Jafari Moghaddam; M. Dastanian, An empirical investigation on thermal characteristics and pressure drop of Ag-oil nanofluid in concentric annular tube. Heat and Mass Transfer/Waerme- Und Stoffuebertragung 52 (2016), pp.1693–1706

[18] A. Naddaf; S. Zeinali Heris; B. Pouladi, An experimental study on heat transfer performance and pressure drop of nanofluids using graphene and multi-walled carbon nanotubes based on diesel oil. Powder Technology 352 (2019), pp.369–380

[19] M.M. Heyhat; F. Kowsary; A.M. Rashidi; M.H. Momenpour; A. Amrollahi, Experimental investigation of laminar convective heat transfer and pressure drop of water-based Al_2O_3 nanofluids in fully developed flow regime. Experimental Thermal and Fluid Science 44 (2013), pp.483–489

[20] M.H. Kayhani; M. Nazari; H. Soltanzadeh; M.M. Heyhat; F. Kowsary, Experimental analysis of turbulent convective heat transfer and pressure drop of Al_2O_3/water nanofluid in horizontal tube. Micro and Nano Letters 7 (2012), pp.223–227

[21] M. Zarringhalam; A. Karimipour; D. Toghraie, Experimental study of the effect of solid volume fraction and Reynolds number on heat transfer coefficient and pressure drop of CuO-Water nanofluid. Experimental Thermal and Fluid Science 76 (2016), pp.342–351

[22] M. Hemmat Esfe; S. Saedodin; O. Mahian; S. Wongwises, Thermophysical properties, heat transfer and pressure drop of COOH-functionalized multi walled carbon nanotubes/water nanofluids. International Communications in Heat and Mass Transfer 58 (2014), pp.176–183

[23] R.W. Fox; A.T. McDonald; J.W. Mitchell, Fox and McDonald's introduction to fluid mechanics, John Wiley & Sons, 2020, pp. 361

Design features and analytical calculation of a continuous variable transmission

J. Marijić [a], M. Vilić [a], P. Črnjević [a], I. Grgić [a], M. Karakašić [a]

a University of Slavonski Brod, Mechanical Engineering Faculty in Slavonski Brod, Trg I. B. Mažuranić 2, 35000 Slavonski Brod, Croatia, jmarijic@unisb.hr

Abstract

With the development of CVT (Continuously Variable Transmission) technology, transmissions are regularly used in industrial plants. At the end of the 20th century, CVT transmissions were increasingly used in agricultural machinery, off-road vehicles, snowmobiles and cars. Nowadays, as more and more attention are paid to environmental awareness, i.e. pollution, the use of CVT transmissions in cars is a normal phenomenon. Continuously variable transmissions are suitable for applications where precise control of the gear ratio or output speed and torque is required and where the power flow in the transmission must not be interrupted. Due to their design, i.e. the operating principle, these transmissions are suitable for automatic control of the transmission ratio with prior knowledge of the characteristics of the input and output sides. The aim of this research is to analyse the existing performance of gearbox structures and to show the efficiency of the design and parts of the analytical calculation for the chosen design. The chosen design solution for the analytical calculation and design elaboration is a continuously variable belt transmission with manual adjustment of the transmission ratio. The design of the machine system for changing the transmission ratio is presented in detail. The SolidWorks 2021 software package is used for the design, while the data from the available catalogues of standard elements are used for the analytical calculations. The principle of operation of the change of transmission ratio, belt CVT transmission, is based on the axial movement of the two halves of the conical pulleys or the change of the distance between them. The change of the transmission ratio is achieved by means of a lever, which achieves the given axial displacement of the two halves of the pulleys through a connection of machine elements. The result of this work was to show the way to calculate the CVT transmission and to present the construction process of the same.

Keywords: Design features, Analytical calculation, Continuous variable transmission, Belt transmission, Developing

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1. INTRODUCTION

Today's requirements for electric motors are such that the output power is maximised with optimal and efficient operation. Since the specified power is achieved at high speeds, i.e. at speeds far above the optimum speeds for the operation of the machine, transmissions are used that achieve the specified power via gear ratio at lower speeds in the optimum operating mode. When a speed ratio change is only occasionally required, a pair of meshing gears may be removed from the train and replaced with a pair having a different ratio. For rapid and frequent speed ratio changes, pairs of gears having different ratios are engaged by shifting the location of the gears and employing bands and clutches in the transmission. A continuously variable (step less) transmission is a different type of transmission that employs belts, chains and friction drives [1].

A Continuously Variable Transmission (CVT) is a device which has a continuous range of transmission ratios that can, up to device-dependent physical limits, be selected independently on the transmitted torque [2]. Most CVTs transfer power through friction. Because of this they are often referred to as traction or friction drives. In its simplest form, a traction drive is just two smooth unequal sized wheels in driving contact. Traction drives can be constructed to give a single fixed ratio, as in a gearbox, or a speed ratio that can be continuously varied [3]. A traction drive is a device that transmits power by means of tractive contact between multiple rotating bodies. Variable ratio power transmission is achieved by varying the system geometry so that the point of action of the tractive force is varied. When this is done in a continuous manner, we get a continuously variable traction drive variator [3]. Rubber-belt continuously-variable transmissions (CVT) are used in a wide variety of off-road and on-road recreational vehicles such as: all-terrain vehicles (ATVs), snowmobiles and motorcycles. They consist of a rubber belt wrapped around two variable diameter pulleys [4]. For better performances, instead of centrifugal mechanisms, electromechanical control systems can be implemented [5,6]. The aim of this paper is to present the design features and explain how this transmission works. Parts of the analytical calculations are also presented later in the paper.

2. CONTINUOUSLY VARIABLE BELT TRANSMISSION

Belt CVT transmissions are the most common or widely used type of CVT transmission. They have been used for many years in industry as well as in low-powered motor vehicles such as mopeds, snowmobiles, four-wheeled engines and agricultural machinery. In recent decades, their use has also expanded to private vehicles in the so-called "push belt" configuration. The belt CVT transmission consists of conical pulleys and a V-belt with a special profile designed for use in this type of transmission. The principle of operation of the belt CVT transmission is based on the axial movement of the two halves of the conical pulleys, i.e. changing the distance between them. The operating principle of belt CVT transmissions is shown in Figure 1 and explained in more detail in Chapter 3.

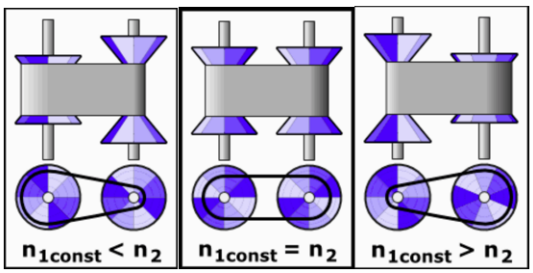

Fig. 1. Operation principle [7]

Advantages of this transmission: simple construction, quiet operation, good belt drive efficiency (0.96-0.98), easy maintenance, light weight, less stress on shafts and bearings compared to friction transmission. Disadvantages of this transmission: the possibility to change the transmission ratio is limited by the geometry of the belt, requires a special tool to control the tension of the belt.

Figure 2 shows the characteristics of a continuously variable transmission where, for the same constant input speed $n_2 = n$, we can theoretically achieve an infinite number of output speeds between n_{2min} and n_{2max}, limited by the minimum i_{min} and the maximum transmission ratio i_{max} set by design. In other words, we can theoretically achieve infinitely many transmission ratios in the construction of a certain interval from i_{min} to i_{max}. The transmission ratio is changed continuously without jumps and without interrupting the power flow.

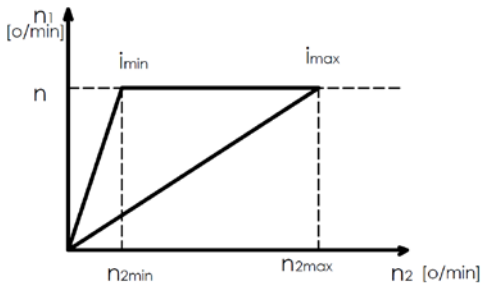

Fig. 2. Characteristics of a CVT transmission [7]

2.1. Design features of a continuously variable belt transmission

An essential part of our own problem-solving method involves step-by-step analysis and synthesis. In it we proceed from the qualitative to the quantitative, each new step being more concrete than the last [8]. Guided by this idea, a continuously variable belt transmission is chosen for the analytical calculation and the elaboration of the design. Figure 3 shows the whole transmission, while Figure 4 shows the transmission without the top cover.

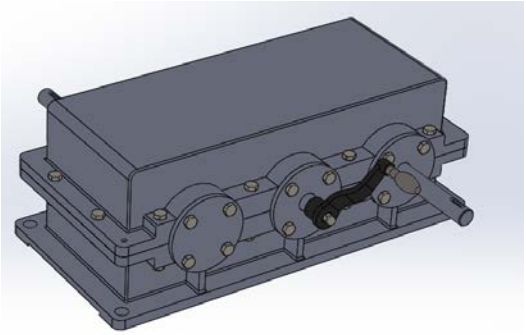

Fig. 3. 3D model of transmission

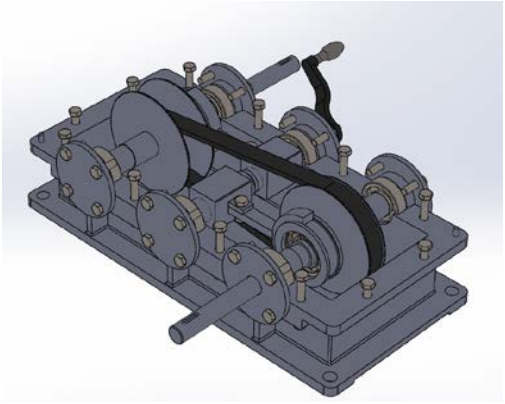

Fig. 4. Transmission without the top cover

This type of belt CVT transmission uses a special profile of the V-belt prescribed by the standard ISO 1604, which prescribes the shapes of endless belts for industrial CVT transmissions and the corresponding pulleys for them. The taper angles on the pulley are between 24° and 28°, depending on the belt profile, while the taper angles of the belt for the corresponding pulley are slightly larger. The analytical calculation in relation to the input data determines the required belt profile and the corresponding pulley geometry for this profile, which will be shown later in this paper.

In this chosen design solution, the pulley itself consists of two separate halves or two concentrically arranged conical plates, one of which is fixed and connected to the shaft by a pin, while the other is movable and its axial movement changes the transmission ratio, as shown in Figure 5. The axial movement on the shaft is made possible by the involute splines, which are fitted both on the shaft and on the movable pulley.

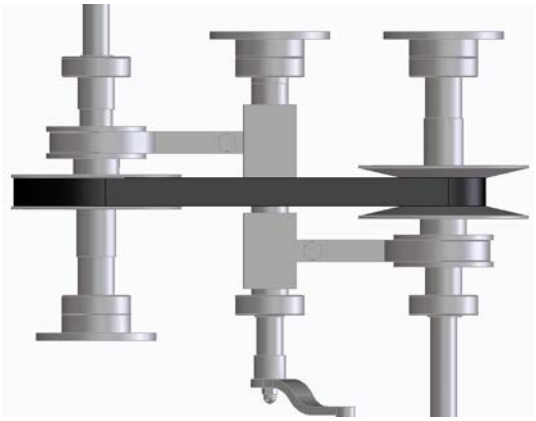

Fig. 5. 3D model of the operation principle

The force required to move the moving part of the pulley is realised by means of a trapezoidal threaded spindle and nuts, which transmit the force via the fork assembly and the moving hub, which presses the pulley over the ball bearing. Since the required transmission characteristic is not set, no automatic adjustments can be made. The spindle is driven by turning the lever, i.e. the transmission ratio is set manually. This can be seen in Figure 6. The axial movement of the pulleys causes the V-belt to move along the pitch, i.e. along the taper of the pulley, which changes the kinematic diameter of the pulley itself. At the same time, but in the opposite direction to the fixed part of the pulley, the moving parts of the pulley move on both the driving and driven sides. This movement causes a change in the ratio between these two diameters, i.e. a change in the transmission ratio.

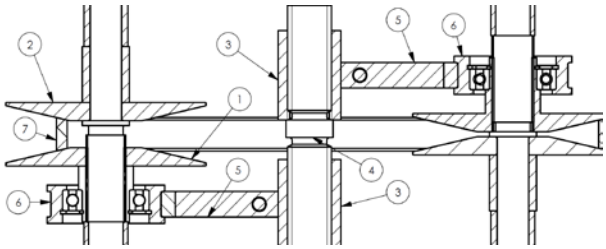

Fig. 6. Transmissions parts

(1-Movable pulley, 2-Immovable pulley, 3-Nut, 4-Trapezoidal thread spindles, 5–Fork, 6-Moving hub, 7–Belt)

Figure 6 shows how the distance between the movable and immovable parts of the pulley affects the kinematic diameter of the pulley itself, or how it affects the diameter at which the belt is located. It can also be seen that the possibility of changing the transmission ratio is limited by the geometry of the belt profile or its width.

As can be seen in Figure 7, the transmission housing consists of an upper and a lower part. It is produced in a cast version and the housing material is SL 25. The dimensions of the housing are determined using empirical values for cast gearbox housings.

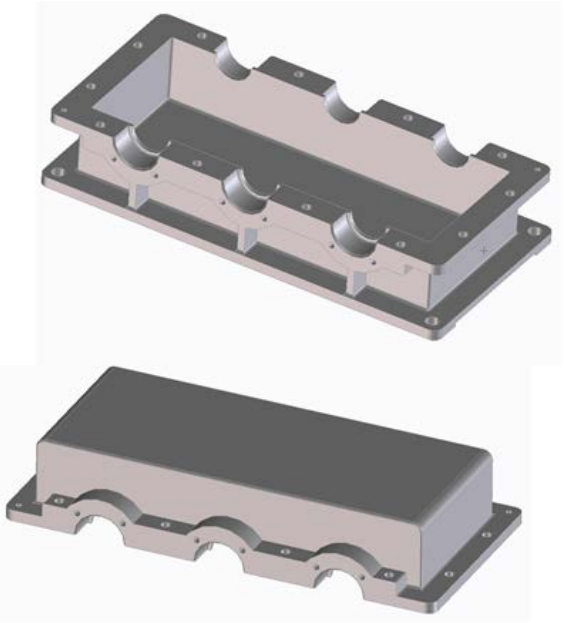

Fig. 7. Transmission housing

3. ANALYTICAL CALCULATION OF A CONTINUOUSLY VARIABLE BELT TRANSMISSION

The paper presents a calculation for the selection of electric motors based on input data, determines the diameters of pulleys and the requested transmission ration, shows the calculation and selection of belt profiles and finally the required number of lever turns to achieve the desired transmission ration. Since the aim of the paper is to present parts of the analytical calculation of the belt CVT transmission, the input parameters are defined. This transmission will drive a working machine in an industrial plant, which must have the following characteristics:

Power of working machine: $P_{RS} = 5\,\text{kW}$

Minimum speed of rotation of the working machine: $n_{2\min} = 1500\,\text{min}^{-1}$

Maximum speed of rotation of the working machine: $n_{2\max} = 6000\,\text{min}^{-1}$

3.1. Izbor pogonskog motora

The required power of the electric motor is calculated according to expression (1), while the required total efficiency of the transmission (2):

$$P_{EM} = \frac{P_{RS}}{\eta_p} \cdot c = \frac{5}{0,922} \cdot 1,2 = 6,51\,\text{kW} \tag{1}$$

$$\eta_p = \eta_r \cdot \eta_L^4 = 0,96 \cdot 0,99^4 = 0,922 \tag{2}$$

η_p - Total efficiency of the transmission

$\eta_r = 0,99$ - Bering efficiency

$\eta_L = 0,96$ - Efficiency of the belt drive

$c = 1.2$ -Impact factor comprising masses of the rotating part.

For the conversion, a three-phase asynchronous motor with the designation 5AZ 132SB-2 from the Končar catalogue [9] was chosen, which has the following characteristics:

$n_{EM} = 3000\,\text{min}^{-1}$ - Speed of rotation of the electric motor

$P_{EM} = 7,5\,\text{kW}$ - Selected power of the electric motor

3.2. Pulley diameters and required transmission ration

The next step is to determine the pulley diameter, which can be determined on the basis of the previous data.

The required maximum and minimum transmission ration are determined according to expressions (3) and (4):

$$i_{\max} = \frac{\eta_{EM}}{\eta_{2\min}} = \frac{3000}{1500} = 2 \quad (3)$$

$$i_{\min} = \frac{\eta_{EM}}{\eta_{2\max}} = \frac{3000}{6000} = 0,5 \quad (4)$$

As determined, the transmission ratio range of this transmission is from 0.5 to 2. Based on the data obtained and the operating principle of the transmission, the initial diameters of the pulleys must be assumed, which give the range of transmission ratios.

The following dimensions of the pulleys are assumed:

$d_{1\min} = 60\,\text{mm}$ - minimum diameter of the drive pulley

$d_{1\max} = 120\,\text{mm}$ - maximum diameter of the drive pulley

$d_{2\min} = 60\,\text{mm}$ - minimum diameter of the driven pulley

$d_{2\max} = 120\,\text{mm}$ - maximum diameter of the driven pulley

3.3. Calculation and selection of belt profiles

The calculation and selection of profiles will be done according to the Optibelt catalogue [10].

The required belt speeds are calculated according to expressions (5) and (6).

Minimum belt speed:

$$v_{REM\,\min} = \frac{d_{1\min} \cdot \eta_{EM} \cdot \pi}{60} = \frac{60 \cdot 3000 \cdot \pi}{60} = 9,42\,\text{m/s} \quad (5)$$

Maximum belt speed:

$$v_{REM\,\max} = \frac{d_{1\max} \cdot \eta_{EM} \cdot \pi}{60} = \frac{120 \cdot 3000 \cdot \pi}{60} = 18,9\,\text{m/s} \quad (6)$$

According to [10], the value of 30 m/s is given as the maximum permissible value for the speed of the V-belt profile, and we can conclude that the belt of this transmission is within the permissible working range.

As already mentioned, this type of transmission uses a special W-belt profile prescribed by ISO 1604, which differs from the normal V-belt profile in its dimensions or greater width with the same belt thickness and the smaller V-angle. Another very important difference from the normal profile is that this belt design is reinforced with transverse fibres that reinforce the belt to reduce deformation due to forces when changing gear ratios.

Belt power is calculated according to the following expression (7):

$$P_{EM} = \frac{P_{RS}}{\eta_r \cdot \eta_L^2} \cdot c = \frac{5}{0,96 \cdot 0,99^2} \cdot 1,2 = 6,38\,\text{kW} \quad (7)$$

3.4. Profile selection

The selection of the profile is made according to Figure 8 depending on the force transmitted by the belt and the speed of rotation of the smaller pulley.

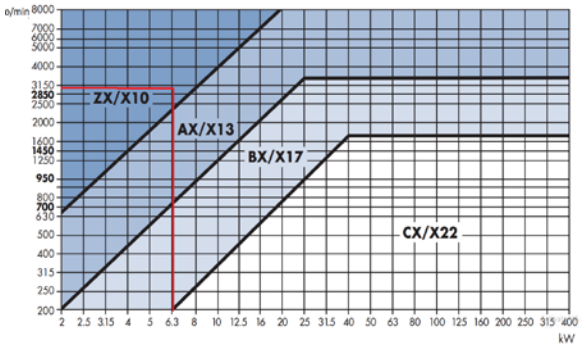

Fig. 8. Diagram for choosing the profile of a normal V-belt with transverse grooves [10]

The ZX belt profile is selected by reading the diagram for the specified input data. The geometry of the ZX profile would correspond to the W16 profile of the V-belt, but since no information is available on the load capacity of the belt itself and in order to ensure the required safety of the belt, the first larger W20 profile is

selected for this application. The dimensions of the specified belt are shown in Figure 9

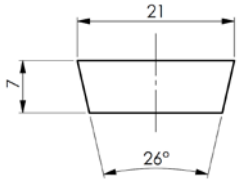

Fig. 9. Dimensions of W20 belt profile [10]

3.5. Pulley shift

The required displacement of the nuts x, i.e. the displacement of the pulleys, is determined via the SolidWorks 2018 software package and for the change of the transmission ratio in a certain interval, i.e. for the change of the pulley diameter in the amount of $\Delta d = 60\text{mm}$, and for the selected belt profile W20 is 13.85mm.

In order to achieve this movement, the spindle must be rotated (8) by:

$$n = \frac{x}{P_h} \cdot c = \frac{13,85}{5} = 2,77\,\text{turn} \tag{8}$$

4. CONCLUSION

Driven by the global development of mechanical engineering, especially the automotive industry, the need for transmissions is inevitable. Guided by this need, the paper presents the design features, parts of the analytical calculation and describes the operating principle of the chosen design of the continuously variable belt transmission. The aim of the paper was to present the design features and to clarify the principle of the transmission. Therefore, the design of the transmission change as the main structural unit within the transmission is presented in detail. The calculation of the belt CVT transmission with the possibility of changing the transmission ratio from i_{min}=0.5 to i_{max}=2 was carried out. Choosing a larger belt profile than required due to lack of data leads to oversizing of the structure, as all dimensions of the transmission come from the belt itself. Furthermore, if this transmission is to be designed for an industrial application or production, an analysis of the manufacturability and an optimisation of the design itself would have to be carried out, which is beyond the scope of this work.

5. REFERENCE

[1] C.E. Wilson, J. Peter Saddler, W.J. Michels, Kinematics and Dynamics of Machinery, Harper & Row Publishers, New York, (1983).

[2] J. Kim, F.C. Park, Y. Park, Design and analysis of a spherical continuously variable transmission, Journal of Mechanical Design 124 (2002), pp.21–29

[3] H.A. Rothbart, Mechanical Design and Systems Handbook, Second Edition, Mc Graw-Hill Book Company, New York, (1985).

[4] G.Julió, J.S.Plante, An experimentally-validated model rubber-belt CVT mechanics, Mechanism and Machine Theory 46 (2011), pp.1037-1053

[5] M. Asumi, H. Ishikawa, K. Mori, N. Matsudaira, Development of electronically controlled belt-type CVT for motorcycles, SAE Technical Papers (2005), pp. 1-7

[6] X. Yang, C. Naishi, L. Zhaohui, Electro-mechanical control devices for continuously variable transmission of vehic le, SAE Technical Papers (2008), pp. 1-7

[7] W. Rebel. Continuously variable transmission, https://en.wikipedia.org/wiki/Continuously_variable_ transmission, last accessed 03/06/2022.

[8] Pohl G., Beitz W., Feldhusen J., Grote K. H.,: Engineering Design A Systematic Approach. Springer, London, 2007

[9] Three-phase asynchronous motor with cage rotor, Končar motori i električni sustavi, https://koncar-mes.hr/hr/, last access 03/06/2022

[10] Technical manual V-belt drives, Optibelt, https://www.optibelt.com/fileadmin/pdf/produkte/keilriemen/Optibelt-TM-v-belt-drives.pdf, last access 03/06/202

Structural Analysis of AISI 316LSi Multilayer Joint Made by Wire Arc Additive Manufacturing

M. Marônek[a], K. Bártová[b], J. Bárta[c], J. Urminský[d], F. Šugra[e]

[a] Slovak University of Technology, Faculty of Materials Science and Technology, Jána Bottu 25, 917 24 Trnava, Slovakia, milan.maronek@stuba.sk

[b] Slovak University of Technology, Faculty of Materials Science and Technology, Jána Bottu 25, 917 24 Trnava, Slovakia, katarina.bartova@stuba.sk

[c] Slovak University of Technology, Faculty of Materials Science and Technology, Jána Bottu 25, 917 24 Trnava, Slovakia, jozef.barta@stuba.sk

[d] Slovak University of Technology, Faculty of Materials Science and Technology, Jána Bottu 25, 917 24 Trnava, Slovakia, jan.urminsky@stuba.sk

[e] Slovak University of Technology, Faculty of Materials Science and Technology, Jána Bottu 25, 917 24 Trnava, Slovakia, filip.sugra@stuba.sk

Abstract

The enormously rising prices of raw materials and energy are currently making it possible to apply AM technologies to an even greater extent. These technologies include WAAM. However, the gradual deposition of layers creates different structures compared to standard materials intended for machining, which results in a change in mechanical properties and corrosion resistance. The multilayer joint of AISI 316LSi was made by the technology of additive manufacturing WAAM. The macroscopic analysis revealed a geometric asymmetry of the joint and a decreasing depth of penetration of the initial layers welded to the base material. The weld metal microstructure had a dendritic morphology. The dendrites were formed by austenite and the interdendritic space contained δ-ferrite. Microscopic analysis revealed imperfections at the edges of the wall as well as areas with different oxide concentrations. The phases present in the weld metal were identified by TEM using electron diffraction. Precipitates of various morphology were observed at the austenite – δ-ferrite interface. The presence of a σ-phase and occasionally carbide $M_{23}C_6$ was found. The structure also contained globular oxides, which were identified by diffraction spectra as SiO_2 oxides. TEM overview images showed that more than a third of the oxides had a size of 400-499 nm.

Keywords: AISI 316LSi, WAAM, MIG welding, X-Ray diffraction analysis

1. INTRODUCTION

With regard to saving investment costs, nowadays the wire arc additive manufacturing (WAAM) is widely used because of productivity benefits. The WAAM method uses metallic wire as the feed material and an arc as the heat source. In comparison to laser and electron beam wire feed AM's low energy efficiency, WAAM offers a greater energy performance of up to 90% [1, 2]. This technology can also be used to create complex components from the AISI 316LSi material, which is commonly supplied as a welding wire.

Material AISI 316LSi is commonly used for applications in the marine and nuclear industry thanks to its high toughness and corrosion

resistance. Sudhakar et al. was testing application of Selective Laser Melting technology with AISI 316L as a biomedical material for production of various components. His research was oriented into lowering the porosity and lack of fusion as well as poor surface quality. These characteristics were critical, especially in biomedical applications that need good mechanical properties, ductility and corrosion resistance [3]. WAAM is providing much higher energy input and reducing the problems with lack of fusion.

Duraisamy et al., same as Wanwan et al. analysed the structural properties and behaviour of WAAM plates where they concluded that produced layers of materials showed anisotropic properties in terms of tensile strength and microstructure [4, 5]. Bharath Kumar et al. studied the wire feed velocity is the most essential of entirely the input factors for weld bead distance, weld velocity, and voltage flow rate. By selecting and optimizing the parameters, a surface's waviness, porosity, weld cracks, and weld bead discontinuity can be decreased [6].

Xiong et al. was studying the welding parameters influence on roughness of the surface. They confirmed that, increasing the travel speed will increase the consistency of the surface. A lower wire feed speed combined with a lower travel speed can improve the surface quality. These findings could be important especially for small applications and saving the material during final machining [7, 8]. Ravikumar et al. in his research confirmed that AISI 316L which is low carbon version of AISI 316 Grade prevents the formation of dangerous carbides to form during welding process [9].

Zhang et al. used EDS analysis that revealed the ellipsoid phase composed of a small amount of low-melting eutectic and a small number of oxidized inclusions [10]. Due to the small diameter of welding nozzles used in the WAAM process and protection of the large weld pool from the surrounding atmosphere, it is problematic to avoid oxidation of the material. Moreover, by creating multi-layer deposits, the individual layers are repeatedly thermally affected. This can result into precipitation of undesired secondary phases, negatively affecting the mechanical properties as well as the corrosion resistance of the produced components.

For this reason, a comprehensive evaluation of the structure of the produced component is necessary, which will reveal production defects and also offer procedures to optimize the process and thus expand the usability portfolio of austenitic stainless steels.

2. EXPERIMENTAL SETUP

The material used for the production of the multilayer joint was austenitic stainless steel AISI 316LSi in the form of wire with a diameter of Ø 1.2 mm (ESAB OK Autrod 316LSi). It is a material with a reduced carbon content and an increased silicon content in order to reduce the formation of undesired secondary phases. The chemical composition of wire is given in Tab. 1.

The Fronius TPS 600i welding source was used for WAAM. The torch was mounted on the arm of a universal semi-automatic welding machine. The parameters of the welding process are given in Tab. 2.

Tab. 1 Chemical composition of austenitic stainless steel AISI 316LSi

Material	Chemical element content [wt.%]						
AISI 316LSi	C	Si	Mn	Cu	Mo	Cr	Ni
	0.010	0.90	1.80	0.12	2.60	18.40	12.20

Tab. 2 Parameters of the WAAM process

Current [A]	195
Voltage [V]	23.2
Feed rate [m/min]	11.7
Wire stick out [mm]	16
Gas flow rate [l/min]	15
Welding speed [mm/s]	10

The multilayer joint consisted of 20 layers 150 mm long. The base of the joint consisted of 4 parallel layers on a base plate with a thickness of 10 mm. Subsequently, 16 layers were formed vertically on the base. The same process parameters were used for each layer, with the opposite direction of movement being used to form each subsequent layer. The transition temperature during the formation of the

new layer was monitored by a thermocouple and did not exceed 100 ° C. 99.996% argon was used as the protective atmosphere. Fig. 1 documents 3D model of a multilayer joint.

Fig. 1 Multilayer joint 3D model using the WAAM method

For macroscopic and microscopic analysis, cross-sections of the multilayer joint were made. Electrolytic etching in 10% oxalic acid (100 ml H_2O + 10 g $C_2H_2O_4$) at 10 V for 25 s was used to highlight the macrostructure of AISI 316LSi steel. Macroscopic analysis was performed on a Zeiss Stemi 2000 light microscope. A solution composed of 50 ml HCl + 50 ml HNO_3 + 25 ml H_2O was used to reveal the microstructure. The etching time was 25 s. The microstructure was observed on a Zeiss Neophot 32 light microscope. To observe the structure by TEM, thin metal foils were formed from the cross section of the joint by consecutive wet grinding to a thickness of 150 μm and final electrolytic thinning using a Tenupol 5 equipment. The foils were sprayed on both sides with electrolyte (300 ml HNO_3 + 700 ml CH_3OH) at - 31 ° C and 15 V voltage. A JEOL 200 CX transmission electron microscope was used to verify the presence of secondary phases and oxides in the microstructure.

3. RESULTS AND DISCUSSION

3.1 Macroscopic analysis

The microstructure of the weld metal (WM) in the joint axis is documented in Fig. 2. Since the phase change associated with the change in crystal structure did not occure here, WM had a dendritic morphology. Dendrites were formed by austenite, with δ-ferrite in the interdendritic space. Significant etching of the interdendritic space may have indicated the presence of secondary phases. Globular oxides can be observed in the microstructure, the presence of which is typical for WM. From a detailed analysis of the purity of WM in the polished state, it can be concluded that there were areas with different concentrations of oxides. Increased oxide content was visible especially in the lower parts of multilayer joint and at its edges. The reason for increased amount of oxides in WM was probably caused by the remelting of the previous layer, the surface of which was covered with oxides due to insufficient coverage by the protective atmosphere.

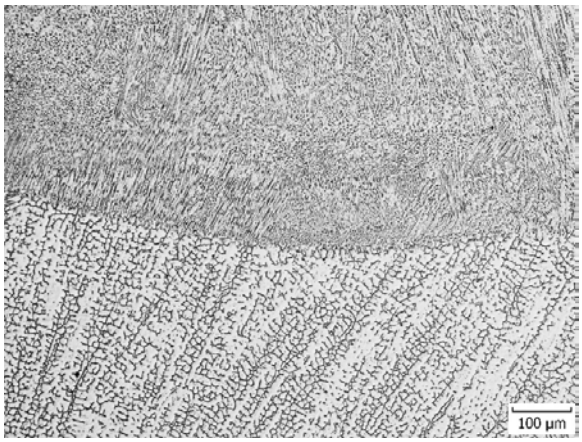

Fig. 2 Microstructure of weld metal - transition between layers

3.2 Transmission electron microscopy analysis

Fig. 3 documents detail on the structure of WM in both bright and dark fields. The structure is formed by an austenitic matrix in which δ-ferrite is located in the interdendritic space, which was also confirmed by the diffraction pattern (Fig. 4).

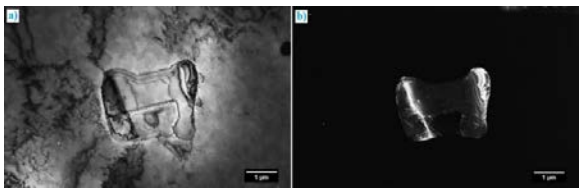

Fig. 3 Detail of austenitic matrix and interdendritic space, a) bright field image, b) dark field image

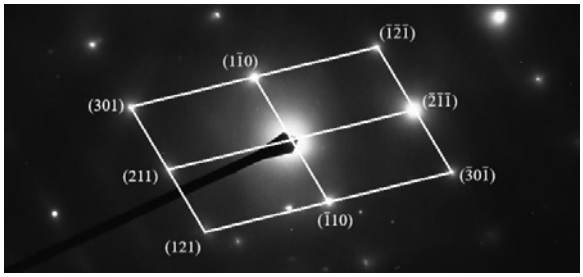

Fig. 4 Diffraction pattern generated from Fig. 3

The detail of the WM structure at the austenite-δ-ferrite interface (Fig. 5a) revealed the presence of an elongated precipitate, which was highlighted in the

dark field (Fig. 5b). The diffraction pattern (Fig. 6) confirmed it as a σ-phase.

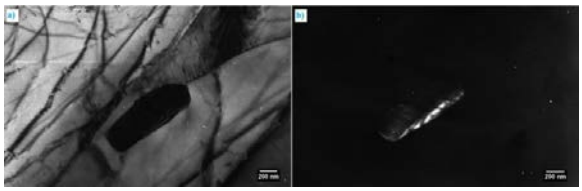

Fig. 5 Detail of the precipitate deposited at the austenite–δ-ferrite interface, a) bright field image, b) dark field image

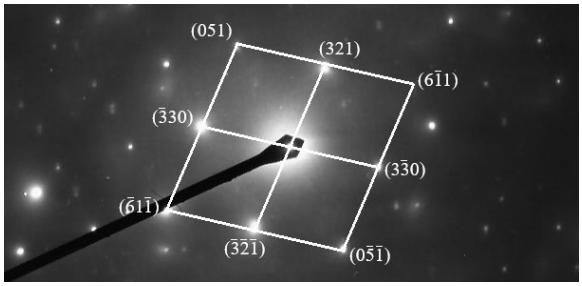

Fig. 6 Diffraction pattern generated from Fig. 5

Fig. 7 shows a detail of the structure in which the oval precipitates are located at the δ-ferrite-austenite interface. The diffraction pattern (Fig. 8) confirmed that it as an $M_{23}C_6$ precipitate (blue colour) in austenite dendrite (white colour).

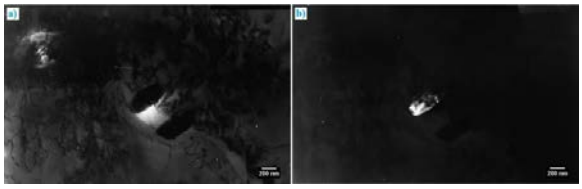

Fig. 7 Detail of the precipitate precipitated at the interface, a) bright field image, b) dark field image

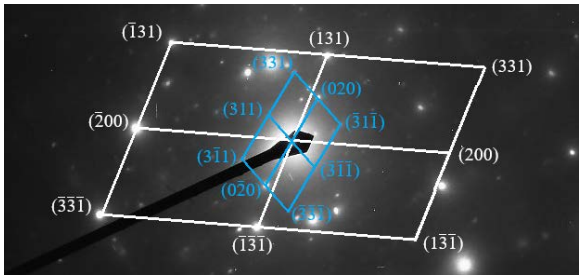

Fig. 8 Diffraction pattern generated from Fig. 7

The identification of oxides using diffraction patterns was complicated by the fact that there were complex oxides in the structure, which may contain several elements. For this reason, identification was complicated due to the high number of possible compounds. Fig. 9 shows a detail of the structure of WM in which the globular oxide highlighted in the dark field is located. Diffraction patttern (Fig. 10) revealed the presence of SiO_2 compound.

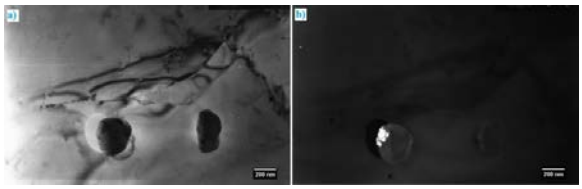

Fig. 9 Detail on globular oxide, a) bright field image, b) dark field image

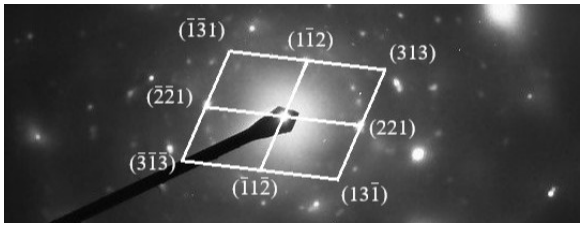

Fig. 10 Diffraction pattern generated from Fig. 9

4. CONCLUSIONS

The microstructure of the WM multilayer joint had a dendritic morphology in its whole volume. In WM, a significant difference in the orientation of dendrites was observed in the transition areas between the individual layers. Diffraction pattern confirmed the presence of austenitic matrix and δ-ferrite in the interdendritic region. In WM, a single precipitation of secondary phases was observed by TEM, which precipitated at the austenite-δ-ferrite interface. Preferably, precipitation of the elongated σ-phase, which was rich in iron and chromium, occurred, while a rare occurrence of $M_{23}C_6$ carbide was also noted at the austenite-δ-ferrite interface. Globular oxides were found in the structure of WM, the size of which was predominantly 200 - 499 nm. Diffraction pattern confirmed SiO_2 type of oxides.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

[1] C. Zhang, Y. Li, M. Gao, X. Zeng: Wire arc additive manufacturing of Al-6Mg alloy using variable polarity cold metal transfer arc as power source; *Materials Science and Engineering.*, A, 10 (711) (2018), pp. 415-423, 10.1016/j.msea.2017.11.084

[2] V. Vinoth, S. Sathiyamurthy, U. Natarajan, D. Venkatkumar, J. Prabhakaran, K. Sanjeevi Prakash: Examination of microstructure properties of AISI 316L stainless steel fabricated by wire arc additive manufacturing; *Materials Today*:

Proceedings, 2022, ISSN 2214-7853, https://doi.org/10.1016/j.matpr. 2022.04.011

[3] K.V. Sudhakar, P. Rawn, R. Coguill, S. Coguill, T. Winsor, B. Madigan: Mechanical properties and microstructure evaluation of biomaterial grade 316L stainless steel produced by additive manufacturing; *European Journal of Advances in Engineering and Technology*, 5 (2) (2018), pp. 106-112

[4] R. Duraisamy, S. Mohan Kumar, A. Rajesh Kannan, N. Siva Shanmugam, K. Sankaranarayanasamy: Reliability and sustainability of wire arc additive manufactured plates using ER 347 wire-mechanical and metallurgical perspectives; *Proc. Instit. Mech. Engineers, Part C: J. Mech. Eng. Sci.*, 235 (10) (2021), pp. 1860-1871, 10.1177/0954406219861136

[5] W. Jin, C. Zhang, S. Jin, Y. Tian, D. Wellmann, W. Liu: Wire arc additive manufacturing of stainless steels: a review, *Applied Sci*ence, 10 (5) (2020), p. 1563, 10.3390/app10051563

[6] C.B. Kumar, V. Anandakrishnan: Experimental investigations on the effect of wire arc additive manufacturing process parameters on the layer geometry of Inconel 825; *Materials Today*: Proceedings 1 (21) (2020), pp. 622-627, 10.1016/j.matpr.2019.06.727

[7] J. Xiong, Y.J. Li, Z.Q. Yin, H. Chen: Determination of surface roughness in wire and arc additive manufacturing based on laser vision sensing; *Chinese Journal of Mechanical Engineering*, 31 (1) (2018), pp. 1-7, 10.1186/s10033-018-0276-8

[8] J. Xiong, Y. Li, R. Li, Z. Yin: Influences of process parameters on surface roughness of multi-layer single-pass thin-walled parts in GMAW-based additive manufacturing; *Journal of Materials Processing Technology*, 1 (252) (2018), pp. 128-136, 10.1016/j.jmatprotec.2017.09.020

[9] P. Ravikumar, E. Bharathiraja, V. Tharani, R. Yamuna, T. Yamunarani: Design and analysis of coronary stent; *Int. J. Healthcare Technol. Manage.*, 12 (5–6) (2011), pp. 447-456, 10.1504/IJHTM.2011.042374

[10] Zhaodong Zhang, Zongyu Li, Yajing He, Gang Song, Liming Liu; The effect of low-power laser on micro-forming of 316 stainless steel additive manufacturing part; *Journal of Manufacturing Processes*, Volume 68, Part A, 2021, Pages 583-601, ISSN 1526-6125, https://doi.org/10.1016/j.jmapro.2021. 05.060.

Evaluation of the arc welding power source regimes with regard to additive manufacturing

M. Marônek[a], K. Bártová[b], J. Bárta[c], J. Urminský[d], F. Šugra[e]

[a] Slovak University of Technology, Faculty of Materials Science and Technology, Jána Bottu 25, 917 24 Trnava, Slovakia, milan.maronek@stuba.sk

[b] Slovak University of Technology, Faculty of Materials Science and Technology, Jána Bottu 25, 917 24 Trnava, Slovakia, katarina.bartova@stuba.sk

[c] Slovak University of Technology, Faculty of Materials Science and Technology, Jána Bottu 25, 917 24 Trnava, Slovakia, jozef.barta@stuba.sk

[d] Slovak University of Technology, Faculty of Materials Science and Technology, Jána Bottu 25, 917 24 Trnava, Slovakia, jan.urminsky@stuba.sk

[e] Slovak University of Technology, Faculty of Materials Science and Technology, Jána Bottu 25, 917 24 Trnava, Slovakia, filip.sugra@stuba.sk

Abstract

Modern arc welding power sources allow the choice of several welding modes, which differ from each other in the time course of welding parameters. With the constantly growing importance of additive manufacturing and the possibility of using arc welding methods in the production of components by e. g. WAAM method, it is therefore important to choose a suitable welding power source regime. The paper evaluates the influence of the welding regime on the selected geometric characteristics of the produced overlay weld beads (overlay weld bead width, height and angle). Despite the constant set of wire feed rate and welding speed, the results confirmed a statistically significant difference between the individual welding modes in terms of the geometry of the overlay weld beads and the linear dependence of the geometry of the welds on the welding regime, or the heat input. The highest heat input exhibited PMC regime, followed by LSC, standard pulse and CMT regimes. The height of the overlay weld bead created in the CMT regime was 47% higher compared to the PMC regime, which can represent a significant time saving when creating multilayer components. The lower heating input of the CMT regime makes also possible to reduce the thermal influence of the previously produced layers and to improve the mechanical properties of the created components.

Keywords: welding regimes, WAAM, additive manufacturing, weld bead geometry

1. INTRODUCTION

Additive manufacturing is nowadays a huge topic for the industry due to material savings. Talking about additive manufacturing the plastics, metals as well as composite materials can be used to build up desired components. Different AM technologies have different advantages and can be applied based on required precision of the end product, its dimensions or material. For large components that are made of metals mostly welding technologies are used for production. Additive manufacturing is based on a

cladding principle where components are built from scratch layer by layer. There are several technologies to melt the metals effectively, however best productivity would be achieved by laser metal deposition using metal powder or arc welding technologies using filler wires. Present paper is focused on arc welding, which is a common technology used in production nowadays. Leading companies producing modern welding equipment offer different setup for pulse welding to influence the amount of heat applied to the material [1]–[4].

Arc welding is a dynamic and fast process in which the electrical welding parameters change very quickly during welding even if they are set to a constant level by the operator of the welding power source due to immediate fluctuations of the welding process. Real-time control of welding parameters was not possible in the past due to the slow feedback to the change of welding parameters. Advances in electronics and the deployment of microprocessor control have enabled modern welding sources to monitor all important welding process variables (welding current, welding voltage, arc length, wire feed speed) and actively change them during the welding process. This approach made it possible to reduce spatter of weld metal during short-circuit welding modes, reduce the formation of craters at the end of the welding process, and limit heat input [5]–[9].

In order to simplify the operation of power sources for welders, manufacturers developed synergic regimes of controlling the welding parameters. Synergic MIG/MAG (GMAW) welding is a variant of pulsed MIG/MAG welding. A synergic welding set provides unit current pulses to detach identical molten droplets of predetermined volume from the electrode wire, combined with the other parametric relationships necessary for stable wire burn off. Different manufacturers offer different sets of parameters for particular base materials, filler materials, shielding atmospheres, etc. These sets of parameters are stored in a power source database as well as in database provided via mobile applications which can remotely set the parameters to the power source. Synergic regime automatically controls pulse parameters, pulse frequency and duration related to wire feed rate, moreover it ensures uniform penetration and weld bead profile. Basically the databases and “one knob” operation of power machines are powerful tools that make welders life easier. Power sources without predefined sets of parameters are not as “welder friendly” since all parameters need to be adjusted manually by welder which can be difficult for beginners [10].

Four different pulse methods from FRONIUS Company were compared in this paper in order to see the influence on weld bead dimensions. First to compare was Pulse Synergic mode, which is a pulsed-arc process with controlled metal transfer (Figure 1). In the base current phase, the energy supply is reduced to such an extent that the arc is only just stable and the surface of the workpiece is preheated. In the pulsing current phase, a precise current pulse ensures the targeted detachment of a droplet of welding material. This principle guarantees a low-spatter weld and precise working across the entire power range. Pulse Multi Control (PMC) is a pulsed arc welding process with high-speed data processing, precise recording of the process status and improved droplet detachment (Figure 3). Faster welding possible with a stable arc and even fusion penetration. Low Spatter Control (LSC) is a low-spatter dip transfer arc process with a pulse shape provided in Figure 2. The current is reduced before breaking the short-circuit bridge; re-ignition takes place at significantly lower welding current values. The reversing wire movement in the cold metal transfer (CMT) process results in a droplet detachment with improved dip transfer arc properties (Figure 4). The advantages of the CMT process are low heat input, less spattering, reduced emissions and high process stability [11].

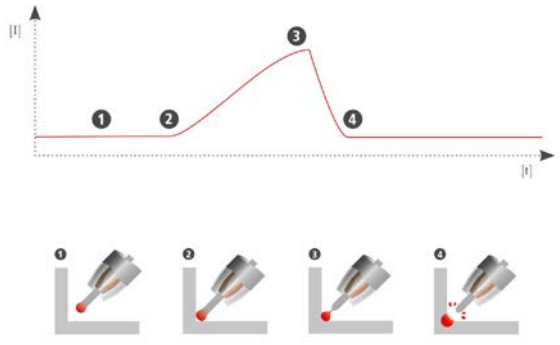

Fig. 1 Characteristics of standard process [12]

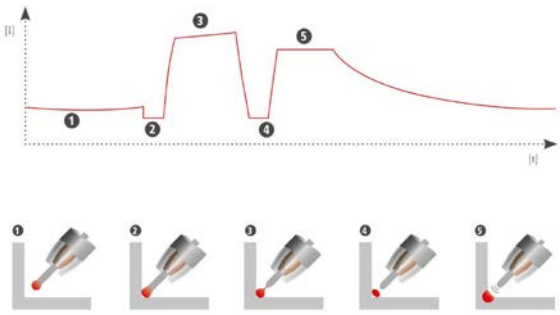

Fig. 2 Characteristics of LSC process [12]

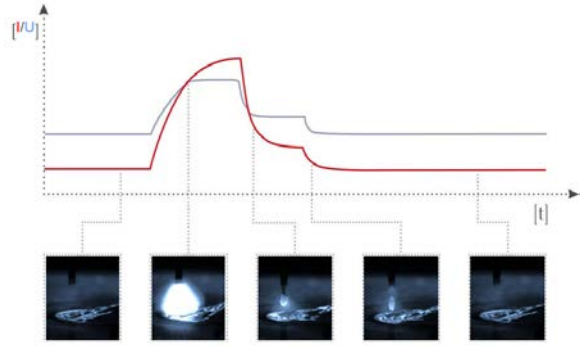

Fig. 3 Characteristics of PMC process [12]

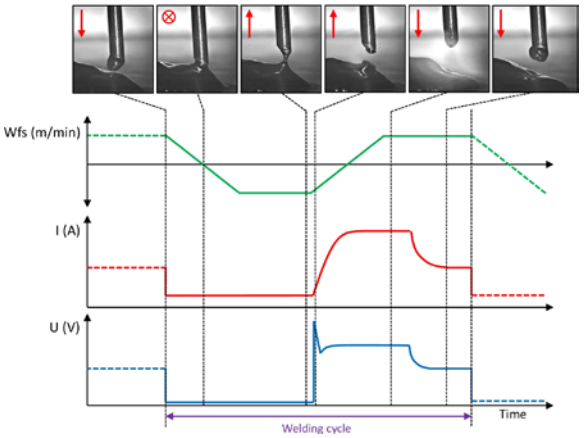

Fig. 4 Characteristics of CMT process [13]

2. MATERIALS AND METHODS

S235 carbon steel with dimensions of 170×30×20 mm was used as the parent material. The reason is the cost saving, as in additive manufacturing, the parent material is usually removed at the end. The WAAM method is cost-effective for thin-wall large scale components made of expensive alloys. Therefore, Inconel 718 alloy in the form of wire NiCro 718 MIG with a diameter of 1.2 mm was chosen as overlay metal. The chemical composition of the filler wire is provided in Table 1.

Tab. 1 Chemical composition of austenitic stainless steel AISI 316LSi

C	Mn	Si	S	P	Cr	Ni	Mo
0.07	0.1	0.15	0.001	0.008	17.5	52	3
Al	Ti	Co	Cu	Nb+ Ta	B	Fe	
0.4	0.9	0.05	0.05	5	0.005	Rem	

Fronius TPS600i and Fronius TransPuls Synergic 3200 CMT welding power sources as well as portal First Welding Company Inc. Muliweld equipment controlling the movement of the welding torch were used to produce overlay welded joints. With the Fronius TPS600i power source, overlay welds were made in Pulse synergic, LSC and PMC modes. The overlay weld in CMT mode was made with a Fronius TransPuls Synergic 3200 CMT power source. All welds had a constant length of 100 mm, the welding speed of 5 mm/s and the wire feed rate of 8 m/min. Argon with a purity of 99.996% and a flow rate of 16 l/min was used as a protective gas. The parent material was weighed 3 times before and after overlay welding, and the average weight of the weld bead was determined from the difference in weight.

Fig. 5-8 show the appearance of particular overlay weld beads. They had a regular surface look and minimal spatter. Visual inspection realised according to ISO 17637 did not reveal any imperfections.

Fig. 5 Weld bead appearance of standard pulse

Fig. 6 Weld bead appearance of LSC regime

Fig. 7 Weld bead appearance of PMC regime

Fig. 8 Weld bead appearance CMT regime

The weld bead geometry was analysed by optical 3D scanning using a GOM ATOS II TripleScan scanner. Ten virtual cuts were made on each of the overlay weld beads, where the width, height and the angle of the overlay weld bead were determined (Fig. 9, Fig. 10). Scan results were evaluated using the GraphPad Prism 8 statistical program.

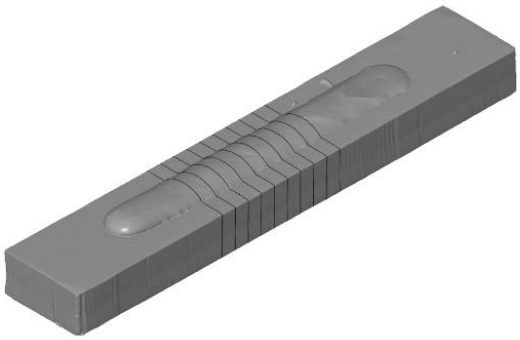

Fig. 9 Virtual cross-sections positions

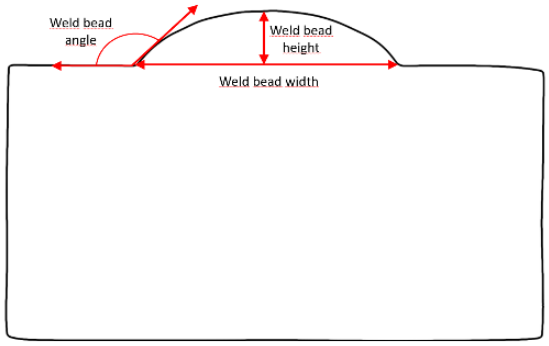

Fig. 10 Measured weld bead parameters

3. RESULTS AND DISCUSSION

Welding parameters and welding regimes are listed in Tab. 2.

Tab. 2 Parameters of welding regimes

Welding parameters	Welding regime			
	Pulse	LSC	PMC	CMT
RMS welding current [A]	237.37	226.7	239.82	209.57
RMS welding voltage [V]	17.1	18.19	19.25	13.68
Welding speed [mm/s]	5	5	5	5
Wire feed rate [m/min]	8	8	8	8
Heat input [J/mm]	811.81	824.73	923.31	573.38
Short circuit frequency [Hz]	150.58	95.00	136.98	73.24
Part of short circ. [%]	52.58	33.33	54.72	48.37

This table shows that the lowest heat input and short-circuit frequency were achieved in the CMT mode, as expected. The heat inputs in the pulse and LSC regimes were similar, but these regimes differed in the frequency of short circuits and the relative duration of short circuits during welding.

The average values of the width, height and angle of the overlay weld beads as well as their mass are given in Table 3. The mass of individual weld beads when setting a constant wire feed rate were approximately the same. Minor differences can be explained by fluctuations in wire feed rate and weld metal spatter. The largest width and smallest height of the overlay weld bead was achieved in the PMC mode, which can be justified by the largest heat input during welding. Regarding additive manufacturing point of view, this mode is disadvantageous as it takes the longest time to create a component of a defined height. The most suitable welding mode appears to be CMT, which, compared to the PMC mode, achieves up to 47% more weld height at the same welding speed and wire feed rate. In the case of production of components with a thicker wall, it is more advantageous to use the standard pulse mode, which allows to increase the width of the overlay weld bead compared to the CMT regime by 83%, while the height of the overlay weld bead is smaller by 29%.

Tab. 3 Evaluated weld bead geometries

Sample	Pulse	LSC	PMC	CMT
Avg. weld bead width [mm]	12	13.82	14.99	6.55
Avg. weld bead height [mm]	3.42	3.26	3	4.4
Avg. weld bead angle [°]	139.85	150.78	156.87	101.32
Mass of weld bead [g]	25.42	26.76	26.59	25.99

Fig. 11 shows the dependence of the width, height and angle of the weld bead on the heat input, which is characteristic for the selected welding regime, wire feed rate and welding speed. The overlay weld bead width and angle increase in direct proportion with increasing heat input, while the height of the overlay weld bead decreases linearly.

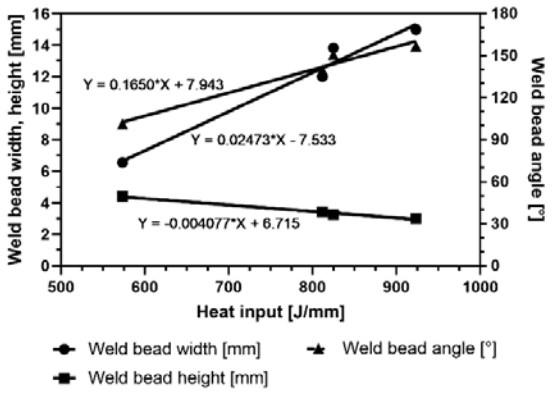

Fig. 11 Dependence of weld bead width, height and angle on heat input

Detailed records of welding current and voltage for individual regimes are shown in figures 12 to 15. Welding in the standard pulse regime is characterised by the largest number of short circuits and the largest fluctuation of welding voltage (Tab. 3, Fig.9). This regime also achieves the highest pulse current values (506 A). From the point of heat input view , the root mean square value of the welding parameters is important for additive manufacturing, which, in addition to the value of voltage and current, also depends on the duration of the pulses. For this reason, the PMC and LSC regimes achieve a higher heat input. Figure 12 shows a typical course of the CMT welding regime with the regulation of the welding current and voltage during the duration of the pulse and the subsequent reduction of the heat input.

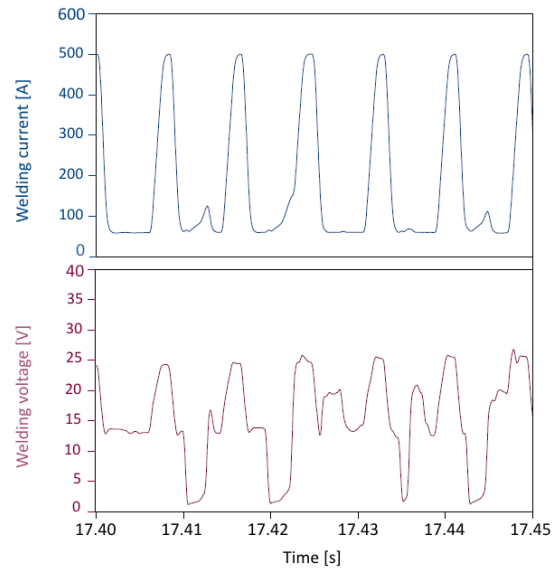

Fig. 12 Time based record of welding parameters in pulse welding regime

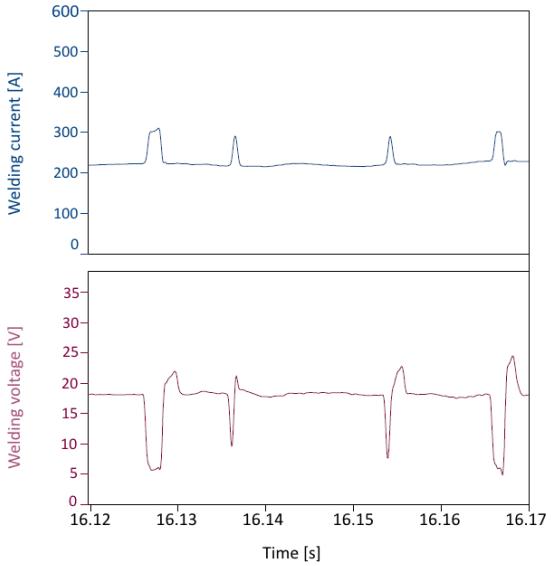

Fig. 13 Time based record of welding parameters in LSC welding regime

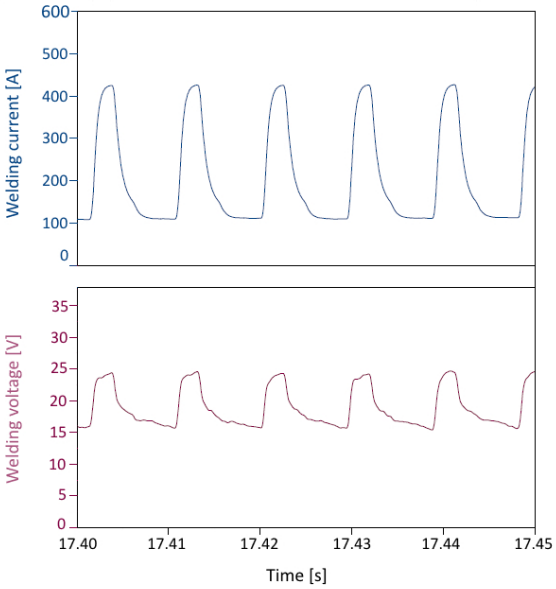

Fig. 14 Time based record of welding parameters in PMC welding regime

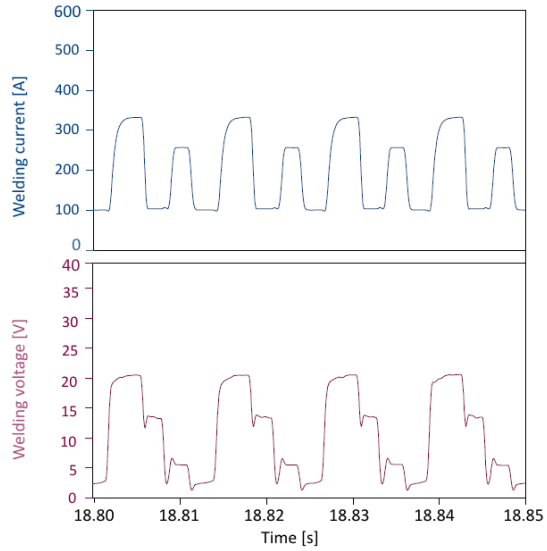

Fig. 15 Time based record of welding parameters in CMT welding regime

All data related to the geometry of overlay weld beads showed a normal distribution. ANOVA statistical analysis confirmed the significance between the individual welding regimes in terms of width and height of the overlay weld bead (Fig. 16, 17).

From the point of view of the overlay weld bead angle evaluation, statistical analysis did not confirm the significance between the LSC and PMC welding regimes, as the average values and the variance of the measured data were very close (Fig. 18). The statistical significance among other welding regimes were confirmed.

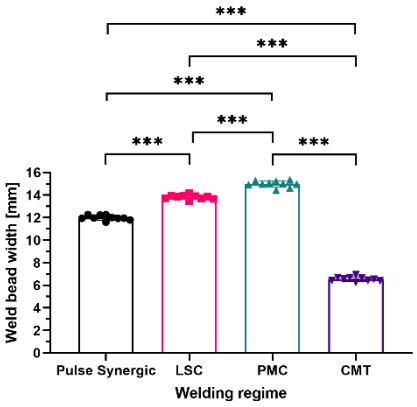

Fig. 16 Weld bead width analysis with regard to welding regime

**** $p \leq 0.001$, ** $p \in (0.001; 0.01>$*

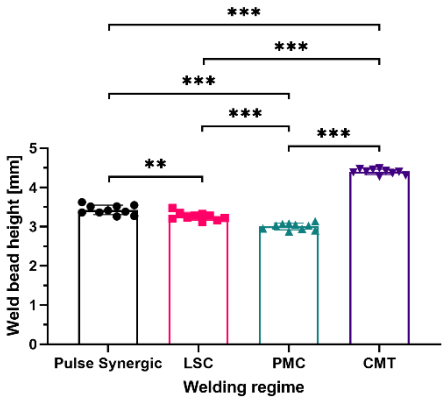

Fig. 17 Weld bead height analysis with regard to welding regime

**** $p \leq 0.001$, ** $p \in (0.001; 0.01>$*

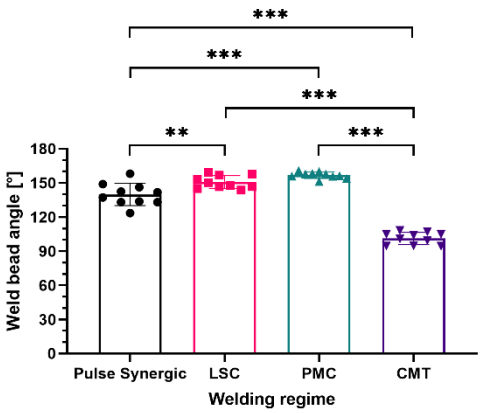

Fig. 18 Weld bead angle analysis with regard to welding regime

**** $p \leq 0.001$, ** $p \in (0.001; 0.01>$*

4. CONCLUSIONS

Despite the constant wire feed rate and welding speed, individual regimes exhibited differences in welding parameters. The greatest heat input was achieved by the Fronius TPS600i device in the PMC welding regime. This regime was also characterised by the highest short circuit frequency. In terms of short circuit frequency, the LSC mode achieved the lowest value, apart from the CMT regime. The manufacturer recommends this regime to reduce spatter, while the short circuit frequency in regimes without reverse wire feed control can have an impact on the formation of spatter. In terms of heat input reduction, the dominance of the CMT regime was confirmed, where there was a decrease of 48% compared to the PMC regime with the highest heat input.

The differences in individual welding regimes in terms of the achieved width and height of the overlay weld bead as well as the angle of the overlay weld

bead were statistically significant. As the heat input increased, the width of the overlay weld bead also increased. The increase in heat input from the CMT regime to the PMC regime (48%) caused an increase of the overlay weld bead width by 129%. On the other hand, the same increase in heat output caused a decrease in the overlay weld bead height by 42%. The narrowest overlay weld bead widths at constant welding speed and wire feed rate were achieved in CMT regime.

The height of one overlay weld bead ultimately affects the production time of a component consisting of a large number of overlay weld beads. Even a minor increase in the height of the individual overlay weld bead can significantly shorten the total welding time. From this point of view, for additive manufacturing using the WAAM method, regimes that enable higher overlay weld bead heights to be achieved with relatively low heat input are an advantage. With standard methods, it is possible to achieve higher overlay weld bead heights by using a higher wire feeding rate and thus a higher welding current, which in the case of multi-layer components represents a significant thermal influence of the previous overlay weld beads by the overlay weld bead currently being made. The CMT regime thus represents a suitable alternative in the production of components using the WAAM method.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

[1] A. E. Medvedev, T. Maconachie, M. Leary, M. Qian, and M. Brandt, “Perspectives on additive manufacturing for dynamic impact applications,” Mater. Des., vol. 221, p. 110963, Sep. 2022.

[2] N. Kumar et al., “Wire Arc Additive Manufacturing – A revolutionary method in additive manufacturing,” Mater. Chem. Phys., vol. 285, Jun. 2022.

[3] J. Rupesh Kumar, K. Mayandi, S. Joe Patrick Gnanaraj, K. Chandrasekar, and P. Sethu Ramalingam, “A critical review of an additive manufacturing role in Covid-19 epidemic,” Mater. Today Proc., Jul. 2022.

[4] A. K. Malaga, R. Agrawal, and V. A. Wankhede, “Material selection for metal additive manufacturing process,” Mater. Today Proc., 2022.

[5] J. Xu, Y. Ma, L. Wang, Y. Zhang, and X. Lu, “Numerical investigation on the influence of current waveform on droplet transfer in pulsed gas metal arc welding,” Vacuum, vol. 203, Sep. 2022.

[6] X. Lv, Z. Qu, H. Su, L. Xu, and H. Jing, “Study on arc characteristics of different defects in pulsed micro-plasma arc welding,” J. Mater. Process. Technol., vol. 302, Apr. 2022.

[7] D. V. Sahane, P. M. Ghate, and A. N. Paithane, “Design of a low-cost welding machine controller with a novel control algorithm for an enhanced HF TIG welding process,” Eng. Res. Express, vol. 4, no. 2, Jun. 2022.

[8] G. A. Bestard, R. C. Sampaio, J. A. R. Vargas, and S. C. A. Alfaro, “Sensor fusion to estimate the depth and width of the weld bead in real time in GMAW processes,” Sensors (Switzerland), vol. 18, no. 4, Apr. 2018.

[9] R. Hamzeh, L. Thomas, J. Polzer, X. W. Xu, and H. Heinzel, “A sensor based monitoring system for real-time quality control: Semi-automatic arc welding case study,” in Procedia Manufacturing, 2020, vol. 51, pp. 201–206.

[10] “What is Synergic MIG/MAG welding and what are its advantages? - TWI.” [Online]. Available: https://www.twi-global.com/technical-knowledge/faqs/faq-what-is-synergic-mig-mag-welding-and-what-are-its-advantages. [Accessed: 27-Jul-2022].

[11] Operating Instructions TPS 320i / 400i / 500i / 600i TPS 400i LSC ADV. Pettenbach: Fronius International GmbH.

[12] “LSC” [Online]. Available: https://www.fronius.com/en/welding-technology/world-of-welding/fronius-welding-processes/lsc. [Accessed: 27-Jul-2022].

[13] D. Galeazzi, R. H. G. e. Silva, I. O. Pigozzo, A. F. da Rosa, A. S. Pereira, and C. Marques, “Analysis of current pulse during short-circuit phase in CMT version of GMAW process under a view of additive manufacturing,” Weld. World, vol. 66, no. 7, pp. 1369–1380, 2022.

Impact of injection point in tool design on costs of injection tools production

A. Maslo[a], A. Ćoralić[a], A. Vučina[a], M. Manjgo[b]

[a] Sveuciliste u Mostaru, Fakultet strojarstva, racunarstva i elektrotehnike, Matice hrvatske b.b, 88000 Mostar, Bosnia and Herzegovina, a.maslo@emka.ba, amir.coralic@student.fsre.ba, adisa.vucina@fsre.sum.ba

[b] Univerzitet „Dzemal Bijedic" Mostar, Masinski fakultet, Sjeverni logor b.b. 88104 Mostar, Bosnia and Herzegovina, mersida.manjgo@unmo.ba

Abstract

Today, there is a big request for plastic products on the market. In the case of plastic injection moulding, the need for designing and making appropriate tools for production has increased. The costs of making tools are in a large percentage of the total costs of making plastic products. Because of this, the efficiency of the production of plastic products is mostly determined by the quality of the tool design.

The complexity of tools for plastic injection moulding, and the requirements for the minimum design time of the optimal tool for a specific product, require a systematic approach in design and the use of different software.

Defining the injection point is a very important step in the design process of plastic injection moulding tools. The expected results of the simulation are the analysis of injection cycle times and injection point locations. Determining the optimal gate location, in the tool for injection moulding with the aim of achieving the optimal cost of making the tool itself.

Keywords: injection moulding, tool design, injection point, mouldflow analysis.

1. INTRODUCTION

The position of the injection point in an injection moulding tool is one of the most important variables in the complete tool design. The quality of the product is largely caused by the position of the injection point, because it affects the way the plastic flows into the cavity of the injection tool. Some defects on the working part can be effectively controlled only by injection point and optimising its geometry. Position of the injection point depends on the geometry of the part and must be taken in consideration that the injection point is not placed on the visible surface, due to injection marks [1]. Improper injection point location can cause high shear stress, poor weld lines and deformation. Reducing the deformation of the injection moulded part is critical to the quality of the injection moulded part. The primary cause of warping is variation in partial shrinkage. Part shrinkage can be thought of as a geometric reduction in part size. If a part shrinks uniformly, it simply gets smaller. If regions of the part shrink unequally, stresses are created within the part, which, depending on the stiffness of the part, will cause it to deform and warp [2]. Also, the design of the injection point aims to achieve a balanced flow inside the cavity to reduce bending. The polymer flow is balanced when all ends of the mould, fill at the same time. Lam and coworkers [3] proposed using the concept of flow paths (standard deviation of flow path length or filling time, or length of filling time) as a measure of balanced flow. They found that the length of charging time is primary.

On the basis of the above, it can be considered that: in order to obtain an acceptable injection moulded part, it is necessary to search for the optimal location of the injection point. The application of mouldflow simulation in the optimisation of the injection moulding process improves the analysis of plastic processing as well as the quality of the injected part itself.

2. MOULDFLOW SIMULATION

The injection moulding process is directed towards the development of tools with high requirements in terms of dimensional accuracy, high strength and demanding characteristics. The initial stage of the injection moulding process is to create a model in order to obtain a quality injected parts. The key factors influencing errors during injection moulding are unbalanced filling of the tool cavity and non-uniform cooling [4] . CADMOULD software is mainly used in the area of numerical simulation of the injection process. This software enables simulation of the injection process as well as modifications based on the obtained results.

Simulation using CADMOULD enables the simulation of various phases of the injected parts, all with the goal of predicting the behaviour of injected plastic parts as well as obtaining high-quality production. Plastic injection simulation software enables experimentation with different "What if" scenarios, where different materials are tested, part geometry changes, production conditions, before defining the final product. The possibility of analysing different scenarios throughout the entire production process results in a higher quality product.

3. EXPERIMENT

The position of the injection point can have a direct impact on the performance, appearance and cost of the parts and tool. The position of the injection point determines the filling method and the maximum length of the material flow. Ideally, the injection point would be positioned to balance the filling and minimise the flow length, usually near the middle of the part or at strategic intervals for parts with multiple injection points. Often these best injection point locations are unacceptable, e.g. they can result in unsightly marks at the position of the injection points or welding lines, or increase costs of production injection moulding tools. The best position of the injection point is often a compromise between ease and efficiency of moulding, performance and appearance of parts, and feasibility in tool design. [6]

Part drawing for analysed part is shown on Fig. 1.

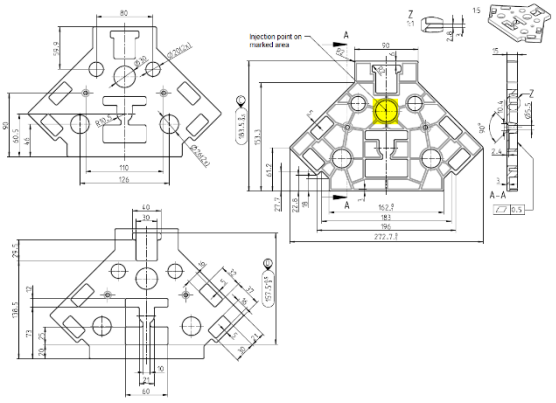


Fig 1. Part drawing

Due to the complex geometry of the working part, the injection simulation with one, two and three injection points is presented. By analysing the variants, the optimal variant of the position of the injection point will be chosen from the aspect of the deformation of the working part, the time of filling the working part and the impact on the tool manufacturing costs.

Simulation for one point, V1, Fig. 2.

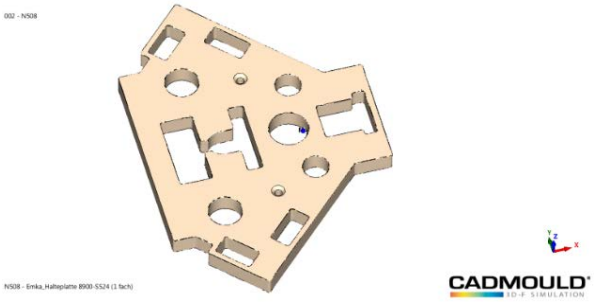


Fig. 2. Working part with one injection point, V1

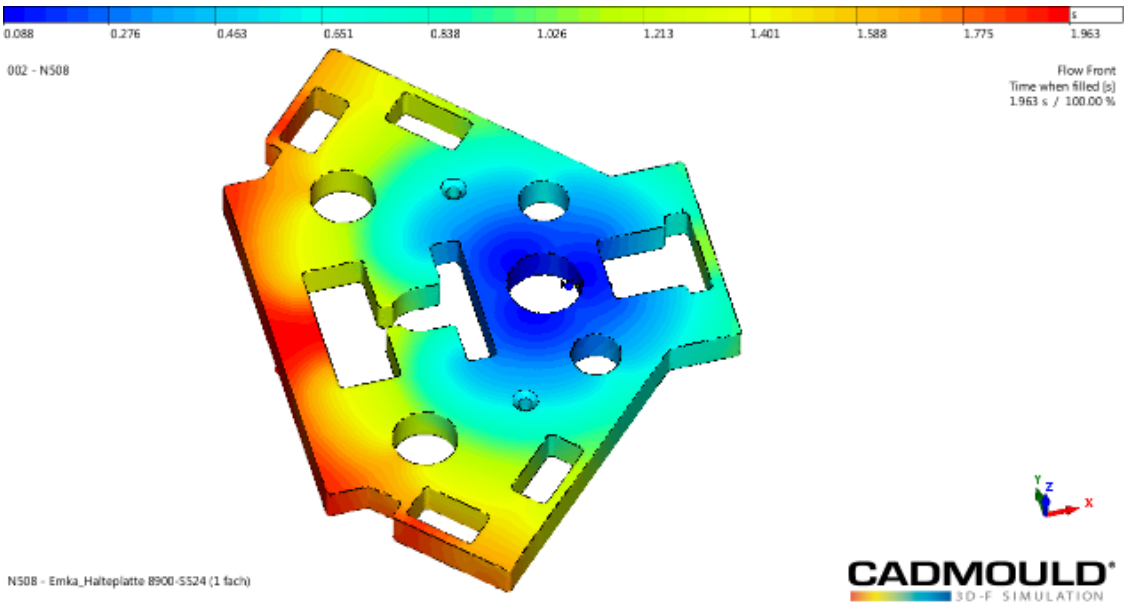


Fig. 3. Filling time t=1.963 s, V1

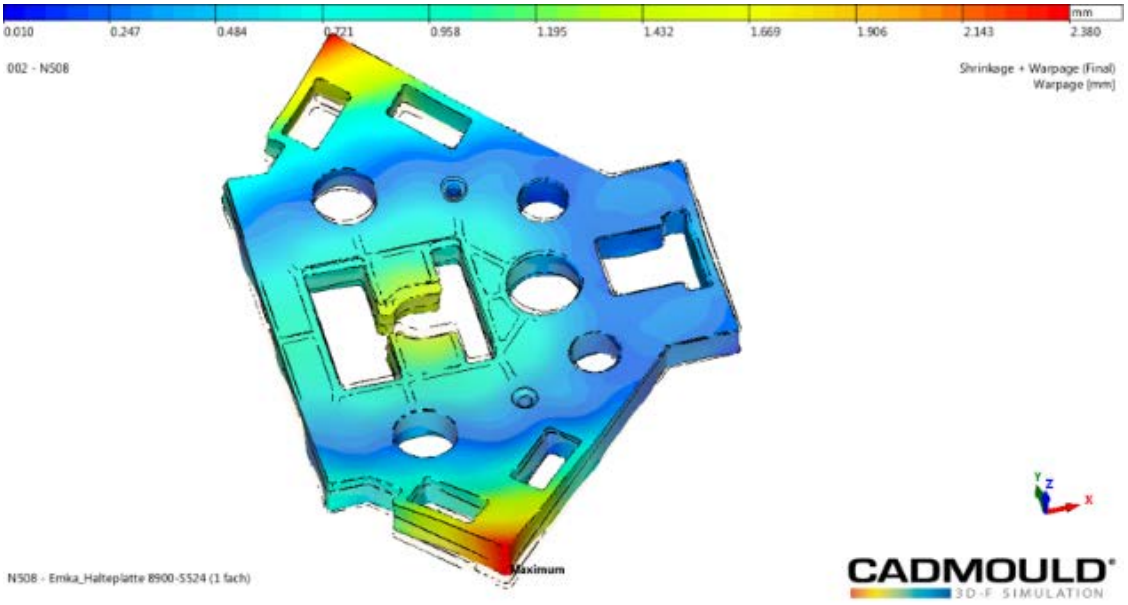


Fig. 4. Shrinkage and deformation for working part for POM material , 2.38 mm

By positioning the injection point at position V1, no additional costs are required for tool production.

Simulation for two points, V2, Fig. 5.

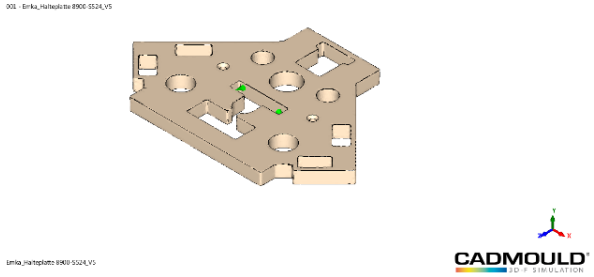


Fig. 5. Working part with two injection points, V2

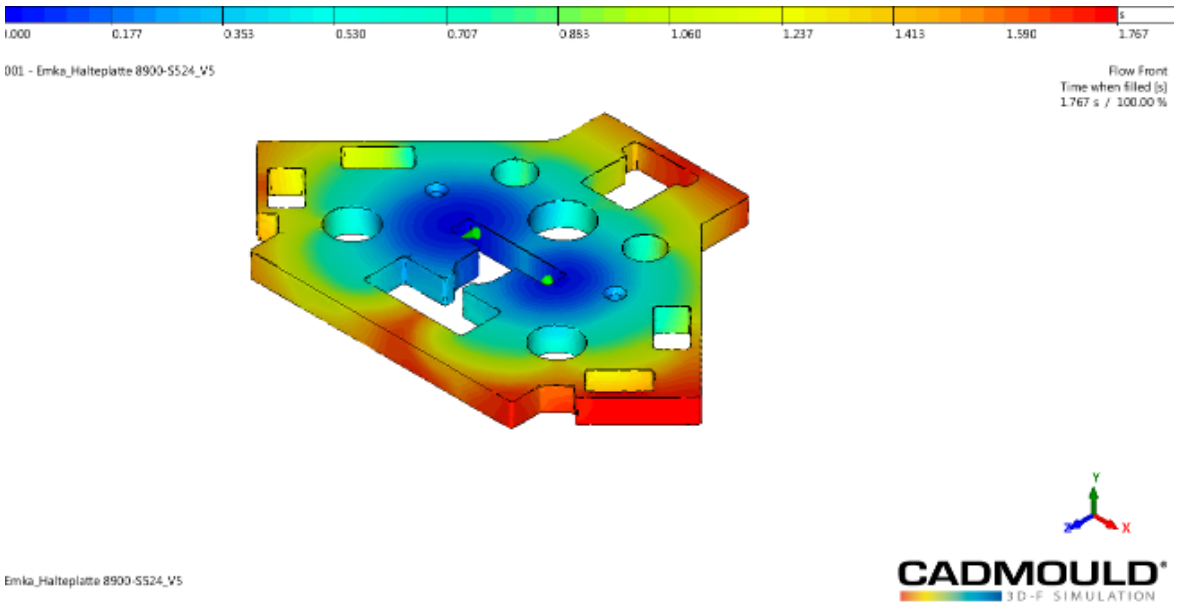


Fig. 6. Filling time t=1.767 s, V2

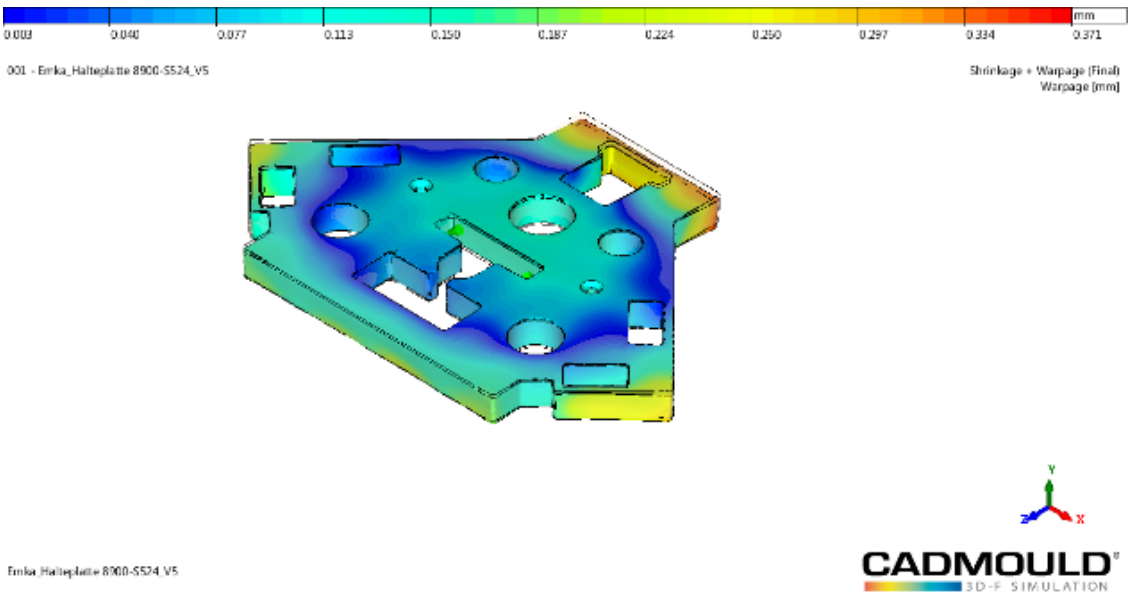


Fig. 7. Shrinkage and deformation for working part for POM material, 0.371 mm.

By positioning the injection point at position V2, no additional costs are required for tool production.

Simulation for 3 points, V3, Fig. 8.

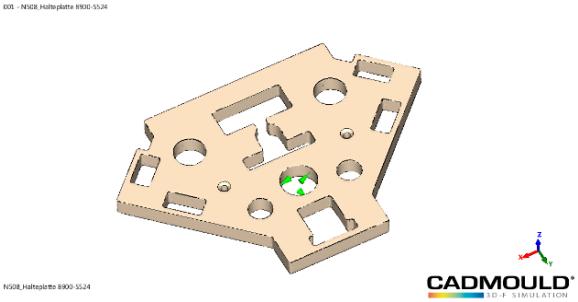


Fig. 8. Working part with three injection points, V3

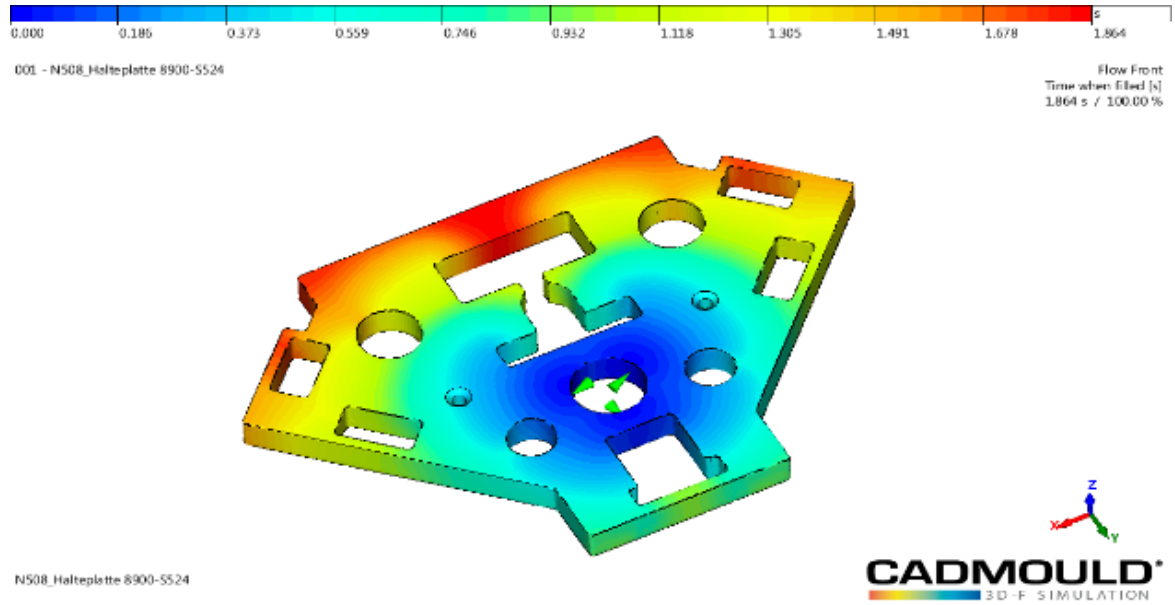


Fig. 9. Filling time t=1.864 s, V3

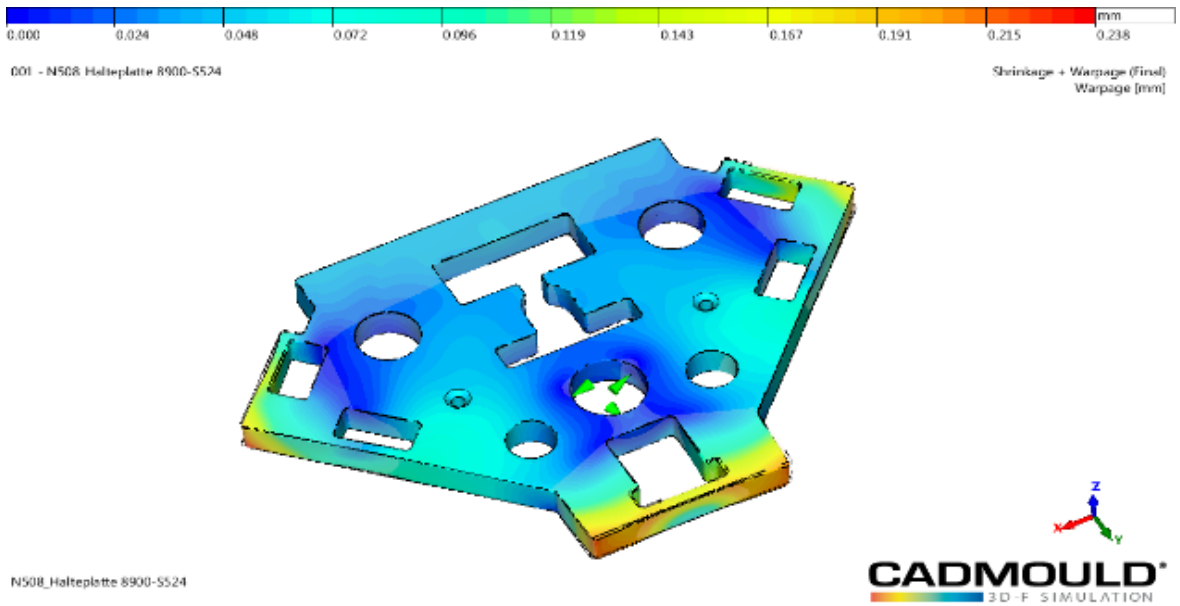


Fig. 10. Shrinkage and deformation for working part for POM material 0.238 mm

By positioning the injection point at position V3, no additional costs are required for tool production.

Simulation for 3 points, V4, fig. 11.

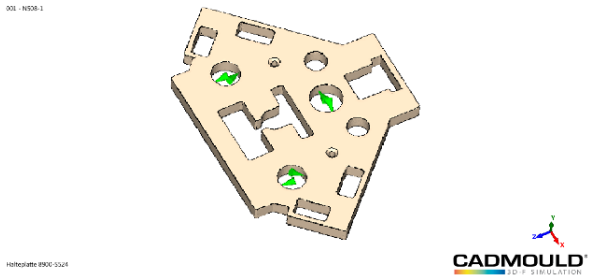


Fig. 11. Working part with three locations and 2 injection points

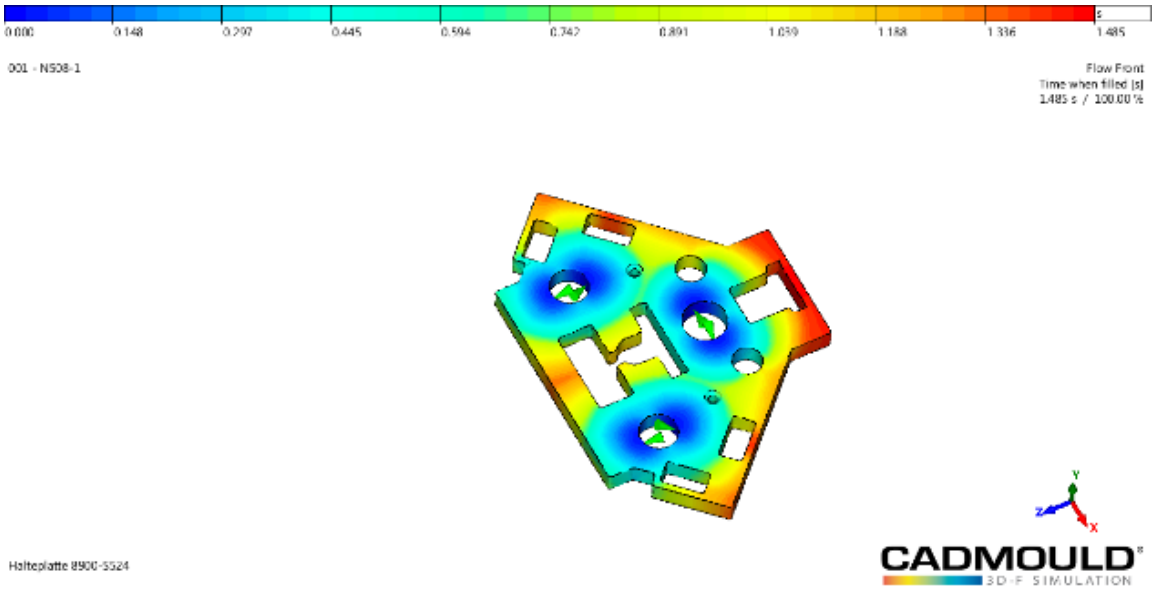


Fig. 12. Filling time t=1.485 s, V4

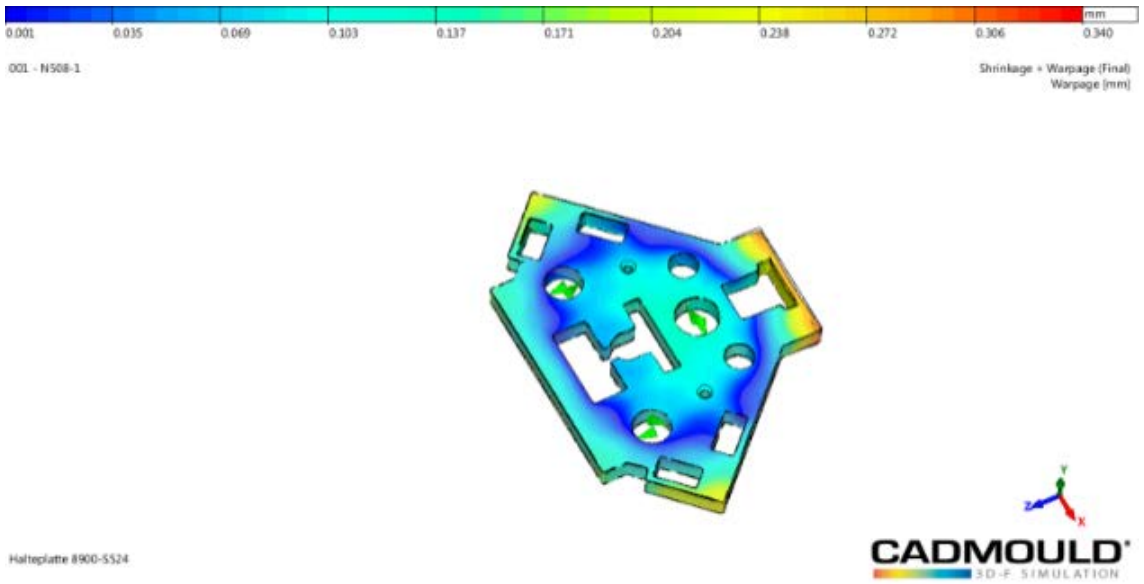


Fig. 13. Shrinkage and deformation for working part for POM material 0.34 mm

By positioning the injection point at position V3, additional costs are required for tool production since in this case it has to be implemented hot runner manifold with three nozzles to achieve gate locations as presented on Fig. 11.

3.1. Selection of the optimal variant

Costs criteria were selected by price of hot runner system (single nozzle or hot runner system with several nozzles). According to results, best filling time is in variant 4 (V4), but deformations are big, as costs of production, so this variant falls out as optimal. In variant 3 there are lowest deformations, costs of production are minimal and this variant is taken as an optimal. Customer request is accepted for injection point location.

Table 1. Selection of the optimal variant

Criteria	Variants			
	1	2	3	4
Filling time, s	1.963	1.767	1.864	1.485
Deformation, mm	2.38	0.371	0.238	0.34
Costs, €	Low	High	Low	Low

4. CONCLUSIONS

Based on results, it can be concluded:

The analysis of the selection of the injection location is used in order to find an adequate injection point on the model. The place of the injection point depends on the geometry of the part and must be considered that the injection point is not located on a visible place, due to injection marks.

By choosing the optimal variant of the injection point, we obtained minimal deformation of the injected part. Also, this analysis prevents additional exposure to costs that may arise as a result of an incorrectly chosen injection point.

Results of mouldflow simulation confirmed that the selected point is appropriate and that there will be no problems in the injection moulding process.

The efficiency and productivity of tool shops does not depend only on the machine park and human potential. It is evident that the use of various software contributes to better efficiency and productivity, since proces of tool optimisation is reduced selecting good injection point and avoiding sink marks, reducing welding lines,... It is very risky that if there is not enough experience in the production of tools, there may be a situation where instead of profit, a loss will be realised, which is a consequence of ignorance, poor planning or poor assessment.

5. REFERENCES

[1] M.Vračević, Prerada plastičnih masa brizganjem, Novi Sad, 1997.

[2] Ming Zhai, Y.C. Lam,* C.K. Au, and D.S. Liu, Automated Selection of Gate Location for Plastic Injection Molding Processing, Polymer-Plastics Technology and Engineering, 44: 229–242, 2005. ISSN: 0360-2559 print/1525-6111 online DOI: 10.1081/PTE-200048523

[3] Lam, Y.C.; Jin, S. Optimization of gate location for plastic injection molding. J. Inject. Mold. Tech. 2001, 5 (3), 180–192.

[4] Damir Godec, Doprinos sustavnosnom razvoju kalupa za injekcijsko prešanje plastomera , Magistarski rad Sveučilište u Zagrebu, Fakultet strojarstva i brodogradnje, ZAGREB, 2000.

[6] Part and mold design guide, Bayer Design Engineering Services Group

Usage of single sign on service in the healthcare via MS ADFS

M. Mazurek[a], Z. Janeš[b], M. Bašić[c], D. Nadih[d]

[a] University of Slavonski Brod, Ivane Brlić Mažuranić 2, HR-35000 Slavonski Brod, Croatia, mmazurek@unisb.hr

[b] General Hospital "Dr. Josip Benčević" Slavonski Brod, Andrije Štampara 42, HR-35000 Slavonski Brod, Croatia, Zdravko.janes@gmail.com

[c] Croatian Health Insurance Fund, Tome Skalice 4, HR-35000 Slavonski Brod, Croatia, Marijan.baso@gmail.com

[d] Elementary School "Antun Mihanović", Mihanovićeva 35, HR-35000 Slavonski Brod, Croatia, dinko.nadih@gmail.com

Abstract

Healthcare institutions are required to apply various security standards and procedures such as encryption, pseudonymization, redundancy and intrusion detection mechanisms to ensure that patient data is not compromised. Hospitals should and must exchange information with other health entities for the better treatment of patients. The main reason why healthcare IT teams are considering implementing a Single Sign-on (SSO) solution is to increase the protection of their IT environments. The goal of the project presented in this paper was to enable external users to access the multimedia platform for education and collaboration using SSO. An active directory federation service was implemented with the aim of authentication and authorization of external users of the platform through the local identity and access management system.

Keywords: SSO, healthcare, Microsoft AD.

1. INTRODUCTION

With the development of modern treatment methods and modern IT technology in the health service, the scope and diversity of medical data is increasing. Electronic patient health records contain a number of sensitive information about the medical history of patients whose transparent and dynamic exchange makes it easier for physicians and other health care professionals to perform their daily activities. Medical documentation, whose aim is a more efficient care and treatment of patients, is exchanged between different types of health care institutions. Due to the sensitive and confidential nature of medical records, and the fact that healthcare professionals must comply with the rules of privacy and security defined by the GDPR (The General Data Protection Regulations [1], it is imperative to adequately store, dispose and secure data and their exchange in accordance with relevant legal regulations. Kumar Venkatesiah points out that it is mandatory for healthcare providers to apply adequate security, encryption, pseudonymization, redundancy and intrusion detection mechanisms to ensure that patient data is not compromised in any way [2].

The paradox of sharing medical data is that they simultaneously make patients safer and at the same time put them at risk. The larger a healthcare network's information network, the better it is at providing quality medical care, but its data becomes more accessible and vulnerable to cyber threats. According to a group of authors, cyber threats in healthcare are a big problem for several reasons: [3]:

- In addition to a patient's medical records, medical provider networks can contain valuable financial information.
- Since very few people do not use health services, almost everyone's personal information is available in some form.
- Interconnected healthcare facilities mean that hackers have access to data collected over the years under the names of patients. Sharing patient information is an integral part of providing the best possible treatment to patients, but that same sharing also makes networks extremely valuable targets.

Since the healthcare institution should and must exchange information with other entities in order to treat patients better, IT professionals should protect this exchange from cyber threats.

In his podcast, Ray Madril emphasizes that the negative impact of data breaches and the need to implement stronger data security has spurred a rise in adopting single sign-on (SSO) technology in healthcare [4]. Once some user logs in to an application that's part of the single sign-on system, they can access any other application supported by single sign-on without signing in again.

Also, in his blog, John Trader quotes a recent statement from the American Association for Health Information Management (AHIMA) that the overarching goal of health information exchanges is to allow authorized users to quickly and accurately exchange health information to enhance patient safety and improve efficiency [5]. However, as healthcare organizations move more and more services to the cloud, it is equally important to have an SSO option that seamlessly integrates into their local and legacy systems. Therefore, increasing the protection of their IT environments is a major reason for healthcare IT teams to consider implementing SSO solutions.

According to Emily McKeown, Single sign-on (SSO) is an authentication process that allows users to securely access multiple related applications or systems by using just one set of credentials [6]. SSO works based on a trust relationship established between the party that holds the identity information and can authenticate the user, called the identity provider, and the service or application the user wants to access, called the service provider. Users will log in to the Identity and Access Management system (IAM) [7] through the SSO, which takes responsibility for verifying the rights and roles of the user. Any resource or service that a user tries to use will trust the IAM when it says that the user is authenticated. In short, Identity and Access Management (IAM) is the process of defining and managing all the roles and access privileges of all users of some network. Federated Services provides the process of connecting multiple organizations or applications in such a way that authorization is transferred from one application to another where the validation process allows users to share their authorization attributes between applications and networks so that they can access them with only one login (SSO). Microsoft Active Directory Federation Services (ADFS) is an optional software component service that runs on Windows Server operating systems and provides users with access to single sign-on (SSO) systems and applications located across multiple organizations and services. According to Brenna Lee, it allows organizations to create a „trust relationship" between one another across the internet, complementing AD by extending identities in on-prem setups to cloud-based environments. It operates much like any web application-based SSO service that uses the Secure Assertion Markup Language (SAML) protocol. ADFS can also use cookies and other token standards such as JSON web tokens (JWT) to provide authentication services (Figure 1) [8]. In the continuation of the paper, the process of implementing the SSO access and establishing federal trust in order to connect external users to the educational platform in the local computer network of the health institution will be presented.

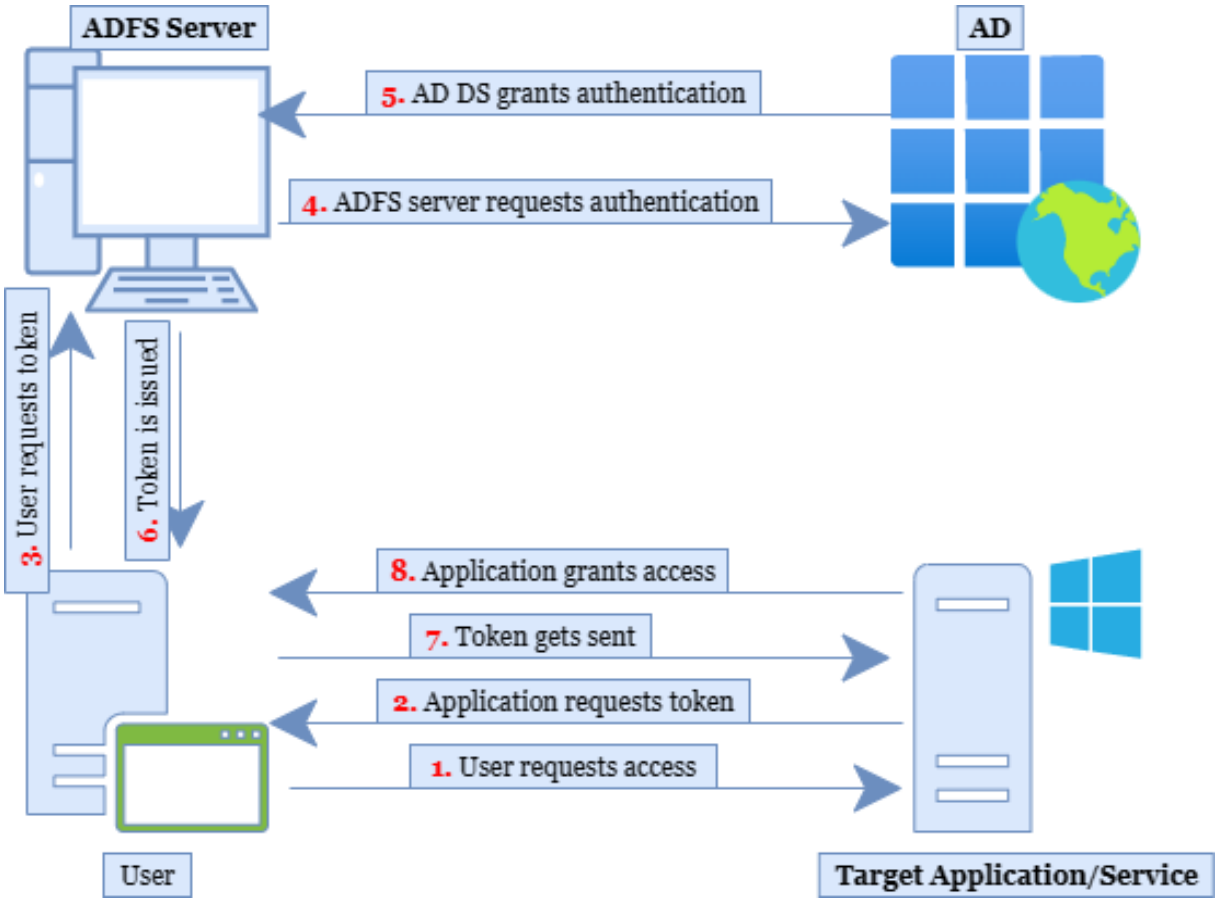


Figure 1. The workflow for ADFS-based systems. (Source: https://jumpcloud.com/blog/what-is-adfs)

2. PROCESS OF IMPLEMENTING

The goal of this project was to provide external users with access to the multimedia platform for education and collaboration installed in the hospital's operating tract. It is a system that allows two-way real-time video and audio streaming communication with surgical teams in two or more hospitals, or between mentor surgeons and students during operations. There are numerous advantages of implementing such a system in healthcare. Bruns and others point out that 1-2 days simulation courses are probably inadequate for teaching a new technique. It is often unrealistic for a practicing surgeon to leave his or her practice for an extended period of time, and therefore surgical telementoring may be a solution by allowing an expert to support a trained surgeon through the learning curve of a new procedure while overcoming geographic distance [9]. The platform is a clinical virtual presence platform which allows physicians to communicate virtually – reducing, for example, the need for personal contact. The software provides access to real-time clinical video, such as live feed of endoscopic images and related patient health information, on a private and secure cloud-based platform, allowing experts to collaborate on treatment virtually – as if they were in the same room.

Since the educational platform is located in the cloud, it was decided to provide access to it through the security mechanisms of the local hospital domain managed by Microsoft Active Directory which stores information about network objects and resources, making them easy to find and use by other authorized users and devices on the same network. In order to provide external users with access to the

platform, as long as their authentication and authorization in the domain are successful, it is decided to implement Microsoft Active Directory Federation Services, since it is a fully incorporated service in the Windows Server operating system.

It is important to note that in the remainder of this paper, it is assumed that readers already possess a certain level of system knowledge and knowledge of Microsoft Windows Server and Active Directory technology. A detailed explanation of each step of the ADFS implementation course would go much further than the scope of this article.

First of all, ADFS was installed on a virtual machine running Windows Server 2019 version 1809 with all updates installed. Hardware requirements are as common as 8GB of RAM and a minimum of 100GB of hard drive. Other prerequisites are [11]:

- Federation Services DNS name – Each ADFS uses an SSL certificate to service HTTPS federation service requests. The SSL certificate must be publicly trusted, so it is best for the production environment to obtain one of the commercial issuers.
- Public (or external) IP address - A public IP address is an IP address that can be accessed directly over the internet and is assigned to ones network device by ones internet service provider [10]. Server that hosts ADFS must have one network interface card configured with public IP address.
- Service Account or Group Managed Service Account (gMSA) – ADFS Server must be joined to an Active Directory domain. Group Managed service accounts require at least one domain controller running Windows Server 2012 or higher. The gMSA must live under the default 'CN=Managed Service Accounts' container.
- Domain Admin Permissions – The user who installs and administers ADFS must be a member of the Domain Administrator security group.
- Create Kds Root key using PowerShell on Domain Controller:

  PS C:\Users> Add-KdsRootKey -EffectiveImmediately)

  Domain Controllers (DC) require a root key to begin generating gMSA passwords. The DCs will wait up to 10 hours from time of creation to allow all domain controllers to converge their AD replication before allowing the creation of a gMSA. The 10 hours is a safety measure to prevent password generation from occurring before all DCs in the environment are capable of answering gMSA requests. [13]
- Using AD Users & Computers console create a security group named gmsa1Group
- Create gMSA Account using PowerShell on Domain Controller:
- PS C:\Users> New-ADServiceAccount "gmsa1" -DNSHostName "ADFS DNS FQDN" –PrincipalsAllowedToRetrieveManagedPassword "gmsa1Group"

The first step is to activate the ADFS role, which is usually done via the Server Manager console (graphical interface) or using the Powershell command line interface [12]. As Figure 2 shows, open PowerShell as administrator and run the following command:

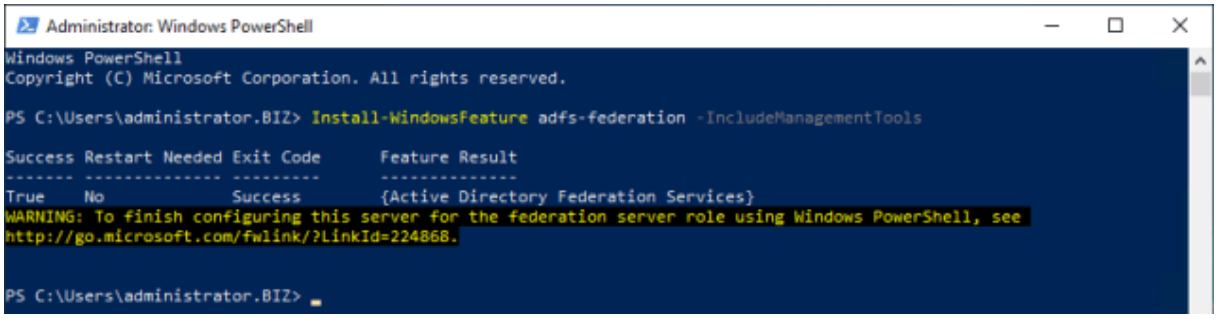


Figure 2. Screenshot of executing Powershell command for installation of ADFS

After successful installation, within Server Manager Console, at the top right corner, navigate to the Flag icon, click and select Configure the federation service on this server. Select the Create the first federation server in a federation server farm option and click Next. After specifying the account with AD domain administrator permissions it was continued with selecting SSL certificate (Figure 3).[14] The certificate and its private key must be available and the subject name and subject alternative name must contain full DNS federation service name, such as xyz.domain.hr.

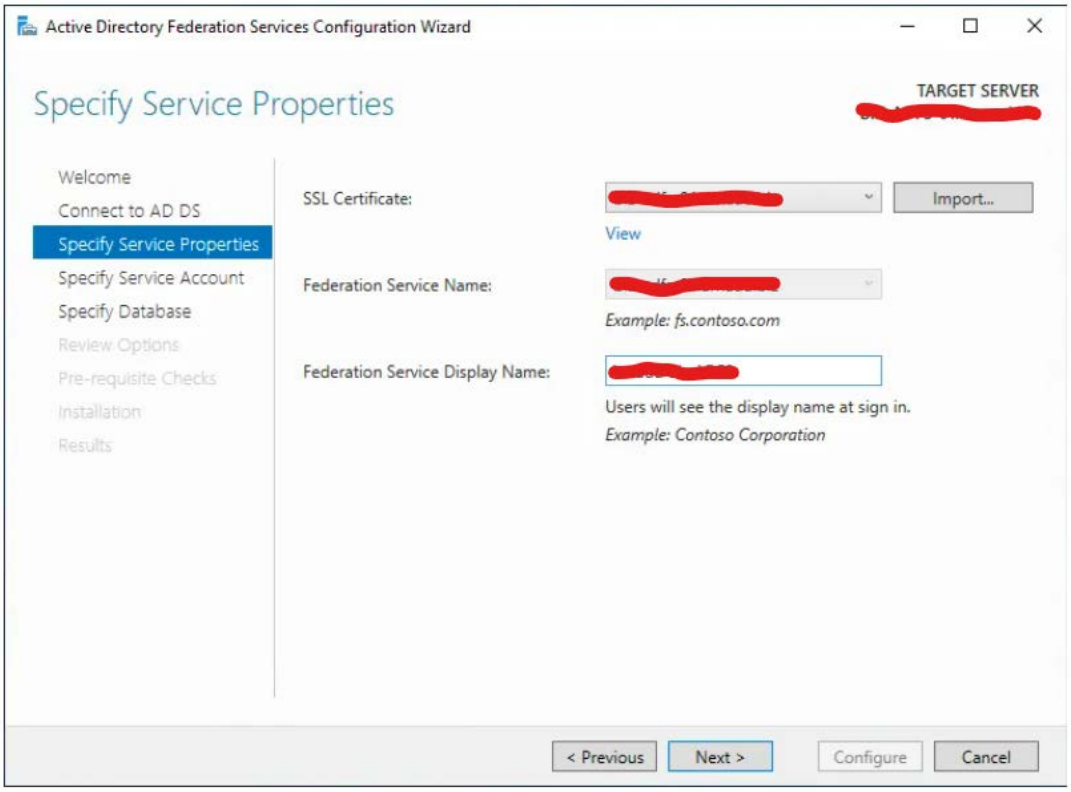


Figure 3. Screenshoot of one of the ADFS Configuration screens.

After specifying the group managed service account and configuration database, the server must be restarted for the ADFS installation to be complete.

Figure 4. Display of XML with the ADFS description.

3. AUTHENTICATION TESTING

To test the single sign-on functionality, the home page must be activated to log in to ADFS. The simplest way to do that is through PowerShell interface:

PS C:\Users> Set-AdfsProperties -EnableIdPInitiatedSignonPage $true

Then Browse to the ADFS sign-in page: https://federationservicename/adfs/ls/idpinitiated signon and test authentication (Figure 5).

In order to provide external service access to the resources, it is necessary to create the so-called Relying Party Trust through ADFS management. ADFS allows federation which comprises two sides, Claims Provider - the owner of the identity repository, which in this case is Active Directory, and the Relying Party, which is another service or application that wishes to authenticate to the Identity Management System or Identity repository. In this case, the website that allows users to access educational multimedia platform relies on ADFS to verify their identity. In ADFS, you configure a trusted party to tell ADFS where to expect claims from. It will trust the reliable party so that once the user is checked, it can be redirected back to that web site.

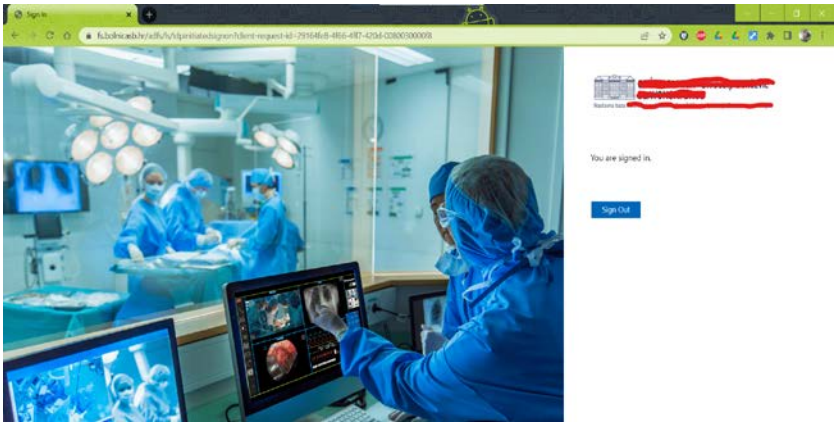


Figure 5. Display of succesfull login to the Federation service.

The procedure for setting up a Relying Party Trust is quite simple using Relying Trust Party Wizard. Values for each relying party trust can be imported, which is published online, or on a local network or it can be created manually.

First, the name of the Relying Party Trust is set on the Specify Display Name page. Then Enable support needs to be selected for the WS-Federation Passive protocol check box. The relying party trust URL address needs to be typed under Relying party WS-Federation Passive protocol URL. On the Configure Identifiers page, specify one or more identifiers for this relying party. On the Choose Access Control Policy, select Allow a specific group policy and add an AD security group whose members need to gain access to the resources. Finally, the relying party trust information is saved and the access to federated applications using Active Directory Federation Services (ADFS) can be tested. Figure 6 shows ADFS console with already configured Relying Party Trust used in this project.

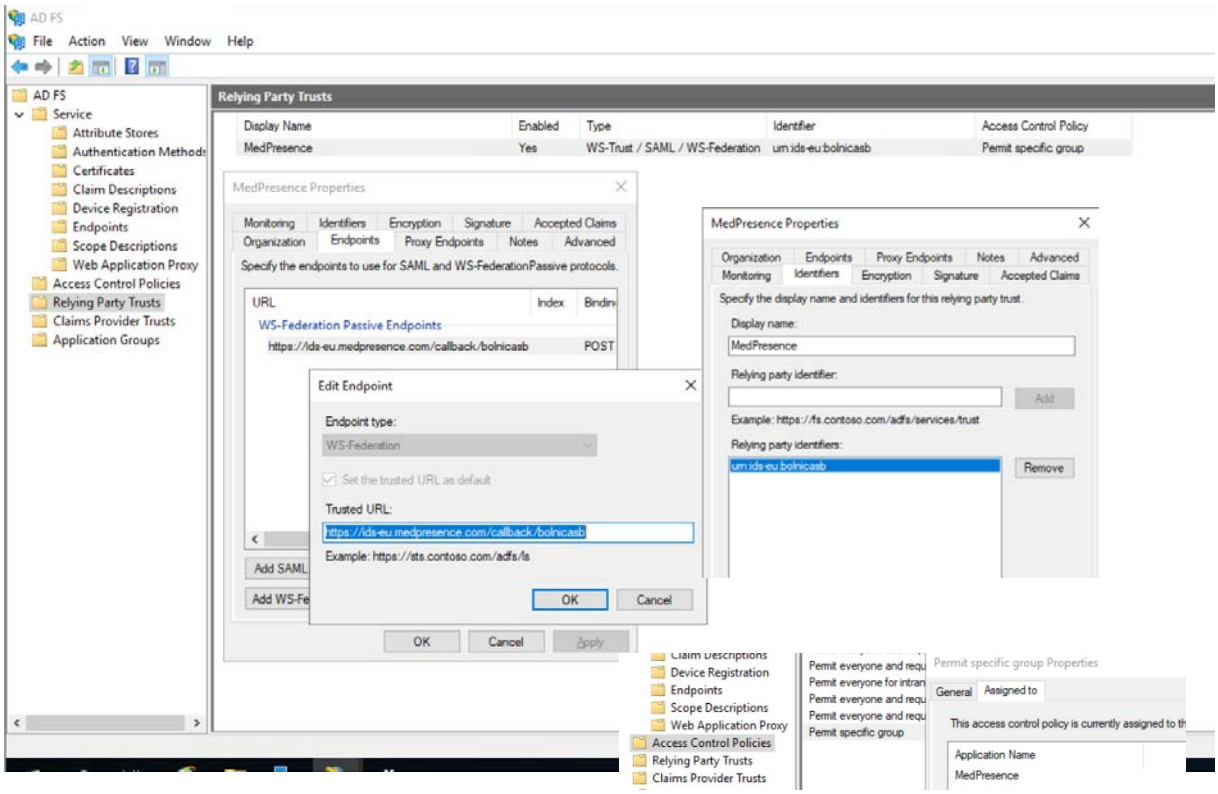


Figure 6. Screenshoot of ADFS management console.

In order to test the configuration, cloud-based education platform was accessed and then followed instant redirection to the ADFS authentication page. Basically, the education platform page requires an authentication token, which the test user then requests from ADFS. The federation service requests authentication from the Active Directory server and then issues a token containing the test user's claim set. The test user passes the token to the website of the educational platform, which gives him/her authorization access (Figure 7). After successful authentication, the user was enabled to use the educational platform and the test was successfully completed (Figure 8).

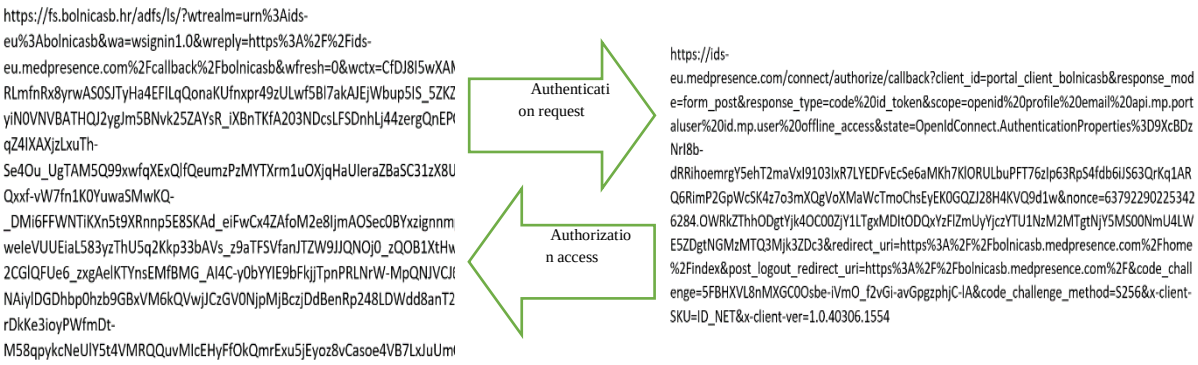


Figure 7. A simplified representation of token exchange during the authentication process

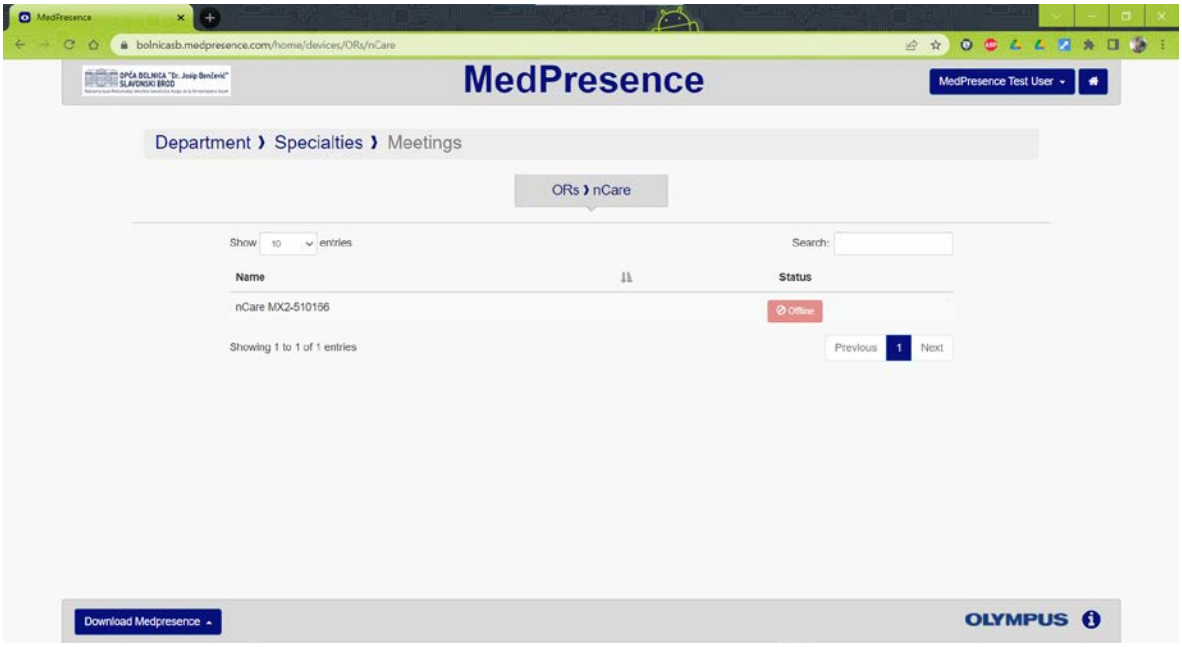


Figure 8. Screenshot of a successfully completed session on the website of the educational platform

4. CONCLUSIONS

Healthcare IT departments need an identity and access management solution that can address cloud and on-premises authentication needs while increasing security and productivity for healthcare users. By implementing SSO technology, IT departments can more easily and quickly implement security policies, manage users, and monitor all subscriptions that users have associated with their specific cloud accounts, all from one place. In this paper, it was shown that Active Directory Federation Service represents a fast ad-hoc, cost-effective solution that uses a locally installed Identity Access Management system for authentication and authorization of external users and devices that want to access local IT resources. Microsoft Active Directory stores information about network objects and resources, user and computer accounts, making them easier to find and use by other authorized users and devices, whether from a local computer network or somewhere in the "cloud". Active Directory Federation Services enables organizations to extend user Single Sign-on access to resources across organizational boundaries. It provides organizations with the flexibility needed to simplify the end-user experience while improving IT administrators' control over user accounts in proprietary and third-party applications.

5. REFERENCES

[1] GDPR - User-Friendly Guide to General Data Protection Regulation. GDPR EU 2022. https://www.gdpreu.org/. Accessed on 10/06/2022

[2] K. Venkatesiah, GDPR Vs. HIPAA — Noting The Differences. VertMarkets, Inc, Cranberry, PA, United States, (2017) https://www.healthitoutcomes.com/doc/gdpr-vs-hipaa-noting-the-differences-0001. Accessed on 10/06/2022

[3] Security Threats in HealthCare Systems. Consolidated Technologies, New York, NY, United States, (2019) https://consoltech.com/blog/security-threats-healthcare-systems/. Accessed on 10/06/2022

[4] R. Madril, PodCast: Implementing Single Sign-On (SSO) in Healthcare. RightPatient, Atlanta, GA, United States, (2015) https://www.rightpatient.com/implementing-single-sign-on-sso-in-healthcare/. Accessed on 10/06/2022

[5] J. Trader, Uniting Accurate Patient Identification with Secure Single Sign-On (SSO) to Improve Data Integrity in Healthcare. RightPatient, Atlanta, GA, United States, (2015) https://www.rightpatient.com/blog/uniting-accurate-patient-identification-with-secure-single-sign-on-sso-to-improve-data-integrity-in-healthcare/. Accessed on 10/06/2022

[6] E. McKeown, Benefits of Single Sign-on. Ping Identity, Denver, CO, United States, (2021) https://www.pingidentity.com/en/resources/blog/post/top-benefits-sso.html. Accessed o 10/06/2022

[7] L. Rosencrance, C. Mathias, Identity management. TechTarget, Newton, MA, United States, (2021) https://www.techtarget.com/searchsecurity/definition/identity-management-ID-management. Accessed o 10/06/2022

[8] B. Lee, What Is ADFS?. JumpCloud, Louisville, CO, United States, 2021. https://jumpcloud.com/blog/what-is-adfs. Accessed o 15/06/2022

[9] N. E. Bruns, S. Irtan, S. S. Rothenberg, E. M. Bogen, Trans-Atlantic Telementoring with Pediatric Surgeons: Technical Considerations and Lessons Learned. Journal of laparoendoscopic. (2016) Part A, 26(1), 75–78. https://doi.org/10.1089/lap.2015.0131. Accessed o 15/06/2022

[10] E. Farrier, Public vs. Private IP Addresses: What's the Difference? Avast Software s.r.o., Prague, Czech Republic, 2021. https://www.avast.com/c-ip-address-public-vs-private. Accessed o 16/06/2022

[11] Group of authors. Active Directory Federation Services - ADFS Requirements. Microsoft, Redmond, WA, United States, (2022) https://docs.microsoft.com/en-us/windows-server/identity/ad-fs/overview/ad-fs-requirements. Accessed o 16/06/2022

[12] F. Malaeb, What is PowerShell and Why Use It? Adam The Automator, Evansville, IN, United States, 2021. https://adamtheautomator.com/what-is-powershell/. Accessed o 16/06/2022

[13] Group of authors. Create the Key Distribution Services KDS Root Key. Microsoft, Redmond, WA, United States, (2022) https://docs.microsoft.com/en-us/windows-server/security/group-managed-service-accounts/create-the-key-distribution-services-kds-root-key. Accessed o 15/06/2022

[14] B. Math, Configure a Federation Server. Microsoft, Redmond, WA, United States, 2021. https://docs.microsoft.com/en-us/windows-server/identity/ad-fs/deployment/configure-a-federation-server. Accessed o 17/06/2022

Digital rotary incremental encoder for educational purposes

J. Morosavljević [a], D. Kozak [b], I. Morosavljević [c], I. Raguž [d]

[a] Mechanical Engineering Faculty in Slavonski Brod, University of Slavonski Brod, Trg Ivane Brlić Mažuranić 2, 35000 Slavonski Brod, Croatia, jmorosavljevic@unisb.hr

[b] Mechanical Engineering Faculty in Slavonski Brod, University of Slavonski Brod, Trg Ivane Brlić Mažuranić 2, 35000 Slavonski Brod, Croatia, dkozak@unisb.hr

[c] Mechanical Engineering Faculty in Slavonski Brod, University of Slavonski Brod, Trg Ivane Brlić Mažuranić 2, 35000 Slavonski Brod, Croatia, imorosavljevic@unisb.hr

[d] Polymer Competence Center Leoben GmbH, Roseggerstrasse 12, 8700 Leoben, Austria, iraguz@pccl.at

Abstract

Ordinary electric motors provide machines with the necessary power and torque, but as such, they cannot determine their current position or how much they have rotated. One of the devices that made CNC machines and robots work in the first place is a digital encoder. The digital encoder gives feedback to the electric motor controller about its position and how much movement it has made. To control machines this way, it is necessary to describe a motor with a universal language, which is the G code, where to move, how fast to move, and what path to follow. Therefore, by programming the G code and uploading it to a CNC machine, it is possible to move each axis of the machine for the programmed value. In order to understand how the digital incremental rotary encoder works and its operating logic, the electrical parts of the device are explained. Also, for educational purposes, an experimental model has been made and described. Affordable components were used in the production of the encoder which enables everyone who wants to learn to produce one.

Keywords: Production Engineering, Encoder, Arduino, CNC machine

1. INTRODUCTION

The transition from universal milling machines and lathes to CNC (computer numerical control) machines enabled much higher productivity, processing quality and high accuracy of dimensions.

In universal machines, machine operators and auxiliary devices are the ones that determine the displacement values. Ordinary electric motors provide machines with the necessary power and torque, but as such, they cannot determine their current position or how much they have rotated. One of the devices that made CNC machines and robots work in the first place is the encoder that gives feedback to the electric motor controller about its position and how much movement it has made.

To give a command to a CNC machine where to move, how fast to move, and what path to follow, a universal language for the CNC machines is used which is called the G code. Therefore, by programming the G code and uploading it to the CNC machine, it is possible to move each axis of the machine for the programmed value. After the movement, the signal from the encoder is sent to the controller which decides did the motor made a programmed value. [1]

The basic division of digital encoders is incremental and absolute. Regarding the type of displacement, they can be linear or rotary.

Absolute encoders are called absolute because each position has its unique code. Absolute encoders output the binary code of the current position. An absolute encoder remembers the last position it stopped at versus an incremental one. For example, if the device rotated 45˚ and stayed there performing some specific function, it remembers that it rotated 45˚. If the device rotates another 45˚, it is currently in a position 90˚ from the reference position. The main advantage of absolute encoders is that there is no need to set a reference point.

Incremental optical encoders are most often used in places where mechanical displacement needs to be converted into a digital signal. They are used where it is necessary to precisely determine the speed, distance, position, or direction of rotation of an axle or shaft.

The incremental encoder gives information about the displacement relative to the reference point, and if the electricity failure occurs, the information about the position relative to the reference point is lost. So, in order to measure movement again, it is necessary to find the reference point again.

For example, when an incremental encoder is mounted with an electric motor on one axis of a CNC milling machine, and after finishing the operation of the milling machine, the axis stops in a certain position. After restarting the milling machine, the machine will not know in which position the axis remained after switching off. [2]

The main reason for using incremental encoders is their price. They are cheaper in comparison with absolute encoders, and if there is no need for remembering the reference point, most often they are recommended to use.

2. DIGITAL INCREMENTAL ROTARY ENCODERS WITH PHOTOTRANSISTORS

Like every electro-mechanical device, the digital incremental encoder consists of electronic and mechanical parts. To understand how the digital incremental rotary encoder works, it is necessary to know which electronic parts are used and their working principle.

2.1. Electronic parts of the incremental encoder

Besides a LED, used as a light source, and cable connections, a phototransistor is the main electronic part of the incremental encoder. A phototransistor is a transistor whose collector current changes under the influence of light falling on it. The main mechanical part is a disc with circularly arranged holes/slots. Every slot represents an opening that enables the LED's light to activate/deactivate the phototransistor and thus create a pulse. Pulses are being recognized by a microcontroller. The microcontroller counts pulses and determines the position of the disc by the relative angle of rotation in relation to the initial point, according to the algorithm specified by the program code.

With only one phototransistor, it is possible to determine only the absolute movement, regardless of the movement direction. With two or more phototransistors, also the direction of the rotation can be determined. Figure 1 shows the schematic of the electronic parts of the encoder with the previously mentioned elements.

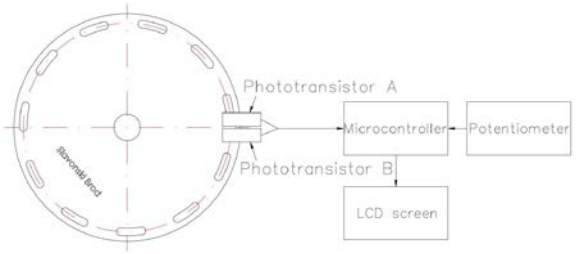


Fig. 1. The schematic of the electronic parts of the encoder

Phototransistors A and B, which are shown in Figure 1, are connected to the microcontroller. A DC motor is connected to the disc and is used to rotate the disc. The DC motor is used only to provide the movement since the encoder was not installed in the real machine. The potentiometer is connected to the microcontroller and serves to regulate the disc rotation speed by changing the voltage of the motor. The LCD screen will display the current angle of the disc rotation. [3] [4]

2.2. Working principle of electronic parts

Determining the direction of rotation of the disc is based on observing which phototransistor will change the first digital pulse ("low" or "high") from the current position of the disc. Depending on which phototransistor changed the pulse first, a positive or negative turn angle will be assumed. Figure 2 shows the reading of the phototransistor in the case when both receive the same signal.

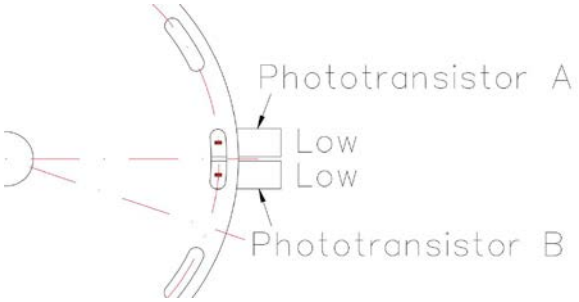


Fig. 2. The schematic of phototransistors in the case when both receive the same signal

If the pulse from phototransistor A changes first, while the pulse from the phototransistor B remains the same, this means that the disc will rotate clockwise. It is assumed to be a positive rotation angle. Figure 3 shows such a case. [4]

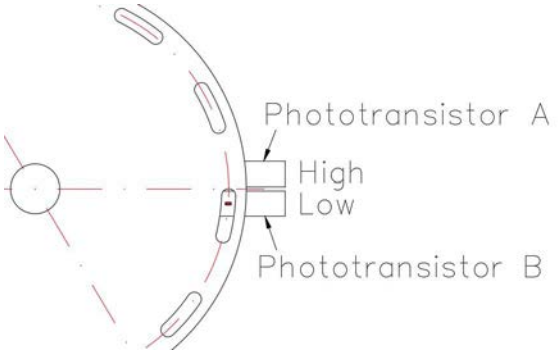


Fig. 3. The schematic of phototransistors in the case when one of them receives the different signal

The microcontroller adds or subtracts the changes of the digital signals read from the phototransistors, thus determining the number of changes it made from the initial position of the disc. Depending on the number of "holes" (slots) on the disc, it is possible to calculate the angle of rotation in degrees.

By dividing 360 degrees from the full revolution of the disk by the number of phototransistors pulses, it is possible to calculate the angle of rotation. Therefore, it can be concluded that the resolution of reading the rotation angle of the disc is directly dependent on how many divisions the disc is made of and also on the number of phototransistors. Figure 4 represents the schematic of the encoder and digital pulses of the phototransistors.

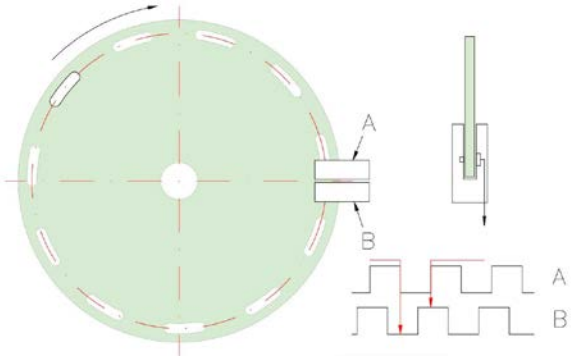


Fig. 4. The schematic of the encoder and digital pulses of the phototransistors

An optical sensor works on the principle of having an LED on one side and a phototransistor

on the other. As soon as it encounters a hole in the disk, the light from the LED will reach the phototransistor and it will read one pulse. After crossing the hole, when such a light pulse is interrupted, one pulse will also be read.

Figure 4 also shows the diagram of pulses from phototransistors A and B. The construction of the encoder is made in such a way that when one phototransistor is on the hole, the other is between the holes. In this way, pulses are obtained and shifted by an angle depending on their mutual position.

The advantages of this incremental encoder are high accuracy and reliability. Due to the minimalistic design of the disc, which can be very thin and made of light material, the moment of inertia is quite low. That means the resistance from the movement is also quite low and it does not diminish the characteristics of a machine, in this case, the motor. Also, an advantage is that the signal can be transmitted over longer distances.

The disadvantage of such a device is that it is sensitive to moisture and vibrations. By comparing with an absolute encoder, it measures the relative angle of rotation.

3. CREATION OF INCREMENTAL DIGITAL ENCODER

The components used to make the previously described encoder are the microcontroller Arduino UNO, 16x2 LCD screen, two optical sensors, a DC motor, a potentiometer for a DC motor and a disc.

In order to easier connect all the electronic parts, it is necessary to make a diagram of the interface of the encoder. Figure 5 shows a diagram of the interface of the encoder.

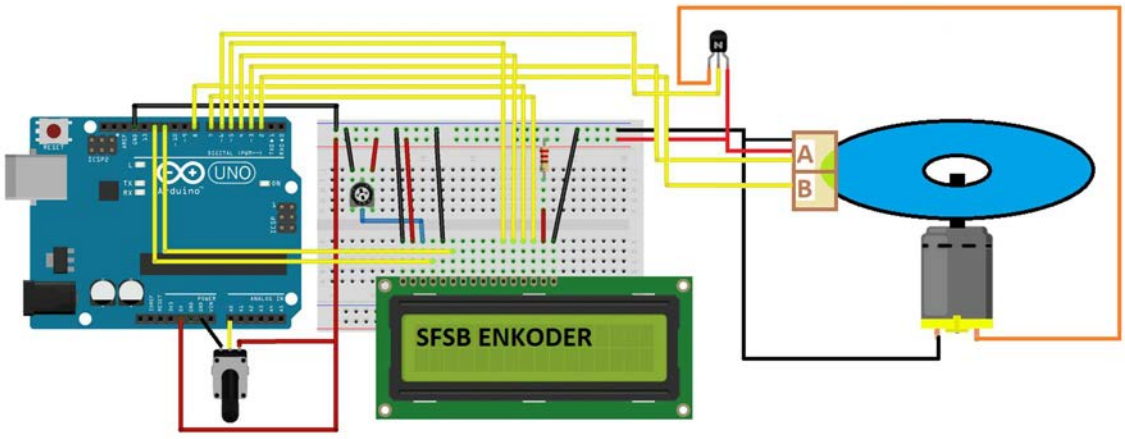


Fig. 5. A diagram of the interface of the encoder

The disc is made of a transparent material that serves as protection against scratching the CD. Paper with holes cut at equal intervals is glued to it. An essential property of the disk is that the holes are light-permeable, and the paper does not transmit enough light for the phototransistor to read.

The distance between the phototransistors is determined based on the spacing of the holes in such a way that there is a possibility that both read the same pulse. This kind of construction enabled a more accurate determination of the relative position, as well as the determination of the direction of rotation of the disc.

Also, four possible changes were made when passing over one hole. The disc is made with a total of 11 holes, which would mean that for a full rotation of the disk, the phototransistors will

read 44 pulses. Therefore, converting digital pulses to degrees would mean that every angular displacement of 8.18˚ would be read. Figure 6 shows made incremental encoder.

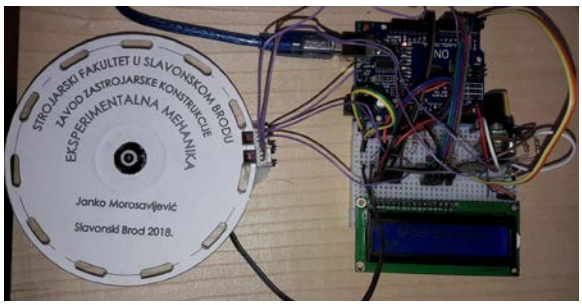


Fig. 6. Made incremental encoder

In order to make a more accurate encoder of this type, it is necessary to make a disk with a larger diameter with more holes at the same intervals, because due to the dimensions of the optical sensors, it is not possible to make a larger division on the disk.

The algorithm in the form of a block diagram is shown in Figure 7.

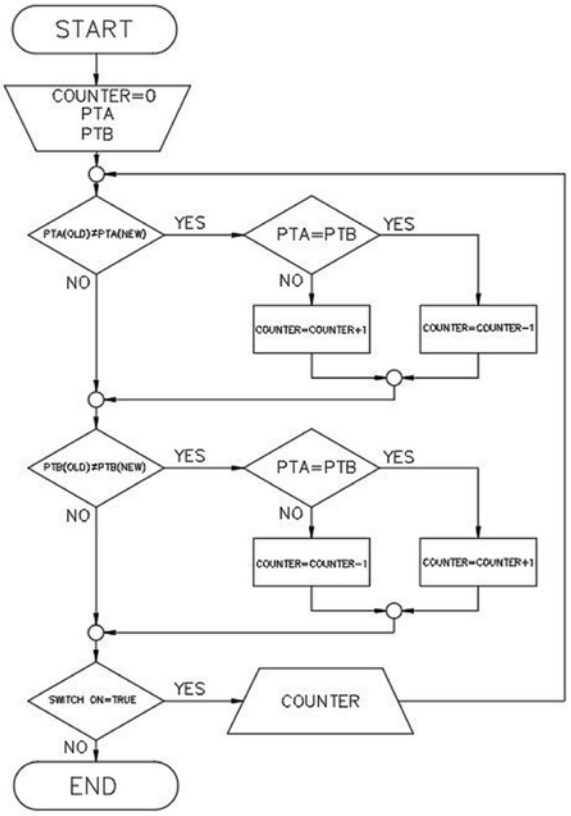


Fig. 7. Block diagram of the program for the encoder

After entering the variables, a decision is made for phototransistor A whether the old values are equal to the new ones or the reading has changed. If it did change, then it is checked whether phototransistor A shows the same values as phototransistor B. If they do, it means that the disc rotates in the negative direction (clockwise), and the counter variable is subtracted by one. If it is not, one is added in the counter variable because then the disk rotates counter-clockwise, the positive direction.

Analogously, the state of phototransistor B is tested. To create an infinite loop, it is tested whether a switch is still on. If it is, the state of the counter is printed and returns to the beginning of the program. In case the switch is turned off, the program ends.

The program code is written in the software used by Arduino. The program code from [5] is adopted and modified in order to work with the encoder.

```
/*
  LiquidCrystal Library - Hello World

 Demonstrates the use a 16x2 LCD display.
The LiquidCrystal library works with all LCD
displays that are compatible with the Hitachi
HD44780 driver. There are many of them out
there, and you can usually tell them by the 16-
pin interface.

 The circuit:
 * LCD RS pin to digital pin 12
 * LCD Enable pin to digital pin 11
 * LCD D4 pin to digital pin 5
 * LCD D5 pin to digital pin 4
 * LCD D6 pin to digital pin 8
 * LCD D7 pin to digital pin 7
 * LCD R/W pin to ground
 * LCD VSS pin to ground
 * LCD VCC pin to 5V
 * 10K resistor:
 * Ends to +5V and ground
```

```
 * Wiper to LCD VO pin (pin 3)
*/
LiquidCrystal lcd(12, 11, 5, 4, 8, 7);
int m = 6;
int p = 0;
int abc= 25;
int izlaz = 0;
int brojac = 0;
const byte led = 13;
bool provj = true;
bool stat1 = false;
bool stat2 = false;
const byte inter1 = 2;
const byte inter2 = 3;
void setup() {
  pinMode( led, OUTPUT);
  // set up the LCD's number of columns and rows:
  lcd.begin(16, 2);
  // Print a message to the LCD.
  lcd.print("  SFSB Enkoder");
  pinMode(inter1, INPUT_PULLUP);
 attachInterrupt(digitalPinToInterrupt(inter1), broji, CHANGE);
  pinMode(inter2, INPUT_PULLUP);
attachInterrupt(digitalPinToInterrupt(inter2), broji, CHANGE);
}
void loop() {
  // set the cursor to column 0, line 1
  // (note: line 1 is the second row, since counting begins with 0):
  //lcd.setCursor(0, 1);
  // print the number of seconds since reset:
  //lcd.print(millis() / 1000);
  abc = analogRead(p);
  izlaz = map(abc, 0, 1024, 25, 100);
  analogWrite(m, izlaz);
  delay(40);
}
void broji() {
  stat1 = digitalRead(inter2);
  stat2 = digitalRead(inter1);
  if ( stat1 == false and stat2 == true and provj == true) {
    brojac = brojac + 1;
    provj = false;
  }
  if ( stat1 == true and stat2 == false and provj != true  ) {
    brojac = brojac - 1;
    provj = false;
    }
  lcd.setCursor(0, 1);
  lcd.print(brojac);
}
```

4. CONCLUSIONS

Encoders are electromechanical devices that determine, depending on the type, linear or rotary position. The operation of CNC machines and robots with high accuracy and precision without encoders would be almost impossible, and therefore they have found applications on numerous machines.

A digital rotary incremental encoder is designed and made as a learning tool on which the theoretical background described in this paper can be easily observed and understood. The encoder is made from affordable parts.

Also, the logic in the form of a block diagram which is programmed into the microcontroller and tested is shown. Although

the logic of the encoder's operation is quite simple, its construction requires very precise and reliable mechanical and electronic components in order not to "skip" steps. A skipped step on a CNC machine or robot means a deviation of dimensions and an error that can be multiplied through more operations.

5. REFERENCES

[1] M. Bošnjaković; A. Stoić, Programiranje CNC strojeva. Fourth Edition, Veleučilište u Slavonskom Brodu, Slavonski Brod, (2019).

[2] Ifm electronic ag, 1120 Wien, Austria, https://www.ifm.com/, last access 11/06/2022

[3] I. Flegar, Osnove projektiranja električkih uređaja. Third Edition, Element, Zagreb, (2020).

[4] S. Paunović, Elektronički sklopovi. Fourth Edition, Element, Zagreb, (2005).

[5] ARDUINO CC, Liquid Crystal Displays (LCD) with Arduino, https://docs.arduino.cc/learn/electronics/lcd-displays, last access 15/06/2022

Numerical and experimental analysis of the application of traditional woodworking joinery on 3D printed parts

I. Morosavljević [a], D. Kozak [b], J. Morosavljević [c], I. Opačak [d]

[a] Mechanical Engineering Faculty in Slavonski Brod, University of Slavonski Brod, Trg Ivane Brlić Mažuranić 2, 35000 Slavonski Brod, Croatia, imorosavljevic@unisb.hr

[b] Mechanical Engineering Faculty in Slavonski Brod, University of Slavonski Brod, Trg Ivane Brlić Mažuranić 2, 35000 Slavonski Brod, Croatia, dkozak@unisb.hr

[c] Mechanical Engineering Faculty in Slavonski Brod, University of Slavonski Brod, Trg Ivane Brlić Mažuranić 2, 35000 Slavonski Brod, Croatia, jmorosavljevic@unisb.hr

[d] High school Matija Antun Reljković, Ivana Cankara 76, 35000 Slavonski Brod, Croatia, ivopac2019@gmail.com

Abstract

Additive manufacturing and 3D printing is becoming increasingly popular in various industries such as medical sciences, aerospace, automotive, and other industries where rapid prototyping and small quantity custom production are required. Compared to traditional manufacturing technologies, 3D printing has no additional cost for complexity and is easily adaptable to changes in the product. Still, product size limitation is usually its biggest disadvantage compared to traditional machining methods. This study presents the experimental and numerical analysis of assembly specimens connected without adhesives using Japanese traditional woodworking joinery methods. Specimens are made of polylactic acid (PLA) on a fused-deposition-modeled (FDM) technology 3D printer. Three-point flexural test was performed, and numerical analysis results are obtained to compare the performance of various joint types.

Keywords: Additive manufacturing; traditional joinery; bending; 3D printing

1. INTRODUCTION

3D printing, also known as additive manufacturing, is a technology that has been growing at an exponential rate in past few years. It represents a group of technologies that build parts out of various materials by layering relatively thin layers of material layer-by-layer, therefore creating three-dimensional objects via material delivery along two-dimensional paths. By utilizing the previously described technique 3D printers can produce very complex structures which cannot be made with traditional production technologies, for example, porous structures to save on mass and production costs. Additive manufacturing technology in comparison to traditional production technologies can be used to produce very complex structures with an almost negligible amount of waste whilst using a single machine and in a single operation.

Various techniques were developed depending on the application and used materials. Each technique varies in the way it forms parts made of metal or plastics and can differ in mechanical

properties, manufacturing speed, costs, material limitations, and product quality.

Currently, the most common methods of additive production of polymer parts are Fused Deposition Modelling (FDM) and Stereolithography (SLA). The expiry of important patents in 2009 and a huge global supply of parts for CNC machines have made it possible for many start-ups and small companies to produce FDM and SLA 3D printers available to hobbyists, students, research laboratories, and commercial practices. FDM technology 3D printers work by delivering thermoplastic polymer thread to an extruder that liquefies it. Liquid thermoplastic is extruded onto a forming bed and as the layer is finished, the printer sets out another layer until the structure is completed. [1]

Various types of polymers are being developed, but currently, mostly used ones in FDM 3D printers are acrylonitrile butadiene styrene (ABS) and polylactic acid (PLA). PLA is a common thermoplastic polymer derived from natural sources and is fully biodegradable and recyclable in contrast to most other thermoplastics which are produced from non-renewable sources. By category, PLA can be considered as biopolymer from natural origins because its monomer is largely produced by starch fermentation. [2]

Most of the FDM 3D printers available on the market are made to print relatively small parts up to 900x600x900 mm for industrial purposes and up to 200x200x200 mm for personal purposes. Considering relatively small printing sizes, to make big products, e.g., bicycle frames, it's required to connect multiple small parts into an assembly. Since it's not aesthetically appealing to have multiple bolts or pins every dozen centimetres on consumer products and applying adhesives is labour-intensive, and therefore expensive, this research will provide insights into the application of traditional Japanese woodworking joinery in connecting 3D printed parts into an assembly. Japanese traditional woodworking joinery techniques have been developed centuries ago in Japan. Japan was heavily forested, and clay and stone were absent in comparison to China and Europe. That forced Japanese carpenters and builders to develop wooden architecture methods of joinery by connecting wood purely by utilizing different geometrical shapes without the use of adhesives. [3][4]

2. METHODS AND MATERIALS USED FOR RESEARCH

The material used to make 3D specimens is PLA black filament acquired from AzureFilm d.o.o., Slovenia, rod diameter of 1.75 mm. Specimens are printed using ENDER 3 PRO FDM 3D printer at room temperature and toolpaths were generated using Ultimaker CURA 4.13.1. Printing parameters are available in Table 1. [5]

Table 1. 3D printing parameters

Parameter	Unit	Value
Bed temperature	°C	60
Print speed	mm/min	50
Nozzle diameter	mm	0.2
Nozzle temperature	°C	200
Layer thickness	mm	0.12
Fill pattern	-	Zigzag
Print direction	-	Horizontal
Infill	%	100
No. wall lines	-	3

Specimens are made in a rectangular shape with dimensions of 10x10x150mm and joints are made in dimensions shown in Figure 1. During printing, the filling density of the 3D print was set to 100% to minimize the number of internal voids and errors.

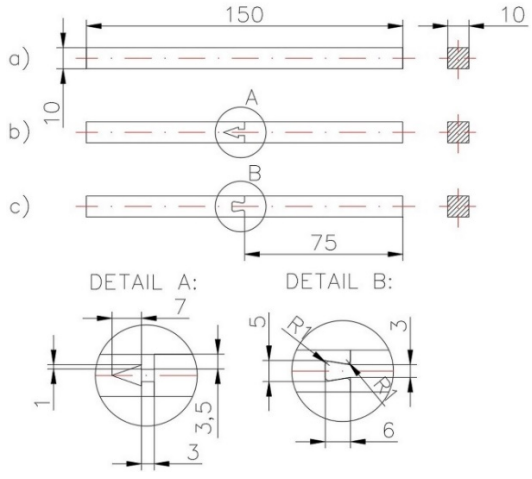


Figure 1. Specimens dimensions

2.1. Numerical analysis

After creating a 3D model according to the dimensions shown in Figure 1, flexural strength was checked by using the Static structural module within Ansys Workbench software. In total 3 analyses were made, 1 for solid specimen, and 2 for different types of traditional horizontal woodworking joints in the middle of the specimen.

PLA material properties were determined according to Table 2.

Table 2. PLA material properties [6 – 7]

Parameter	Unit	Value
Density	kg/m^3	1252
Young's Modulus	MPa	1757
Poisson's ratio	-	0.33
Tensile Yield Strength	MPa	54.1
Tensile Ultimate Strength	MPa	59.2

The first analysis was made for a solid single-piece specimen as a reference to jointed ones. For solving a problem, a mesh of tetrahedron SOLID187 elements with quadratic hexagonal finite elements were used. The mesh consists of 372844 elements and 532956 nodes. In places where stress peaks are expected mesh was refined using the sphere of influence feature. A preview of the fully meshed body is shown in Figure 2.

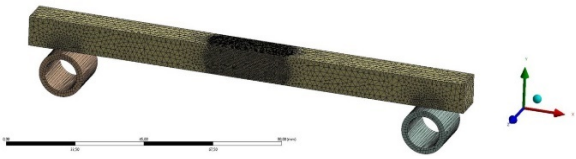


Figure 2. Solid specimen meshed body

Since the computer model of assembled parts was made with 1 joint between parts and 2 contacts with testing machine supports, it's necessary to define the contacts within Static structural module. Connections between the specimen and flexural bending test supports were defined as frictionless, where the specimen was defined as the contact body and support as the target body. Contact behaviour was defined as asymmetric and augmented Lagrange formulation was used. The specimen is loaded with a force of 5 N which corresponds to the 0.51 kg of weight used in the experimental analysis. Label C in Figure 3. represents the displacement condition which was defined with free displacement on Y axis and fixed displacement on X and Z axes to meet degrees of freedom requirement. Label B on Figure 3. represents fixed support boundary.

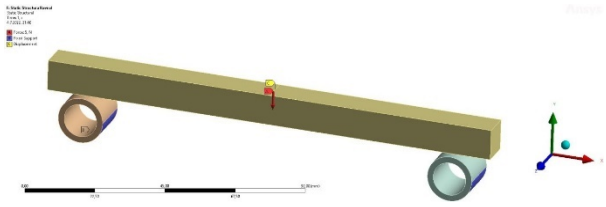


Figure 3. Defined boundary conditions and loads

Figure 4. shows the results of equivalent stress according to the Von Mises criterion, Figure 5. shows results of total deformation of the specimen and Figure 6. shows results of equivalent strain according to the Von Mises criterion.

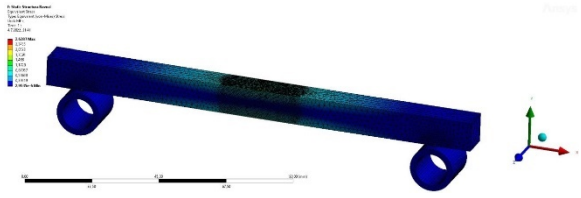


Figure 4. Equivalent stress results

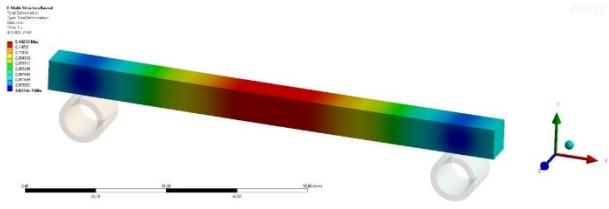


Figure 5. Specimen deformation results

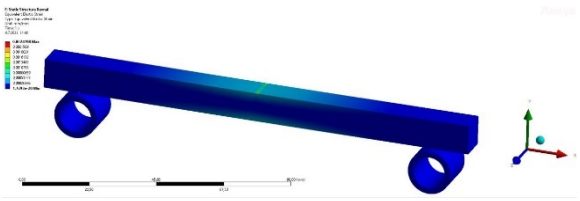


Figure 6. Equivalent strain results

The second analysis was performed by using the specimen with round "mouse" joint in the middle of the specimen. Boundary conditions and specimen-support contacts were assigned as in previously described first analysis. A mesh of tetrahedron SOLID187 quadratic elements was used, and mesh consists of 196972 elements with 290136 nodes. Preview of meshed body is available in the Figure 7.

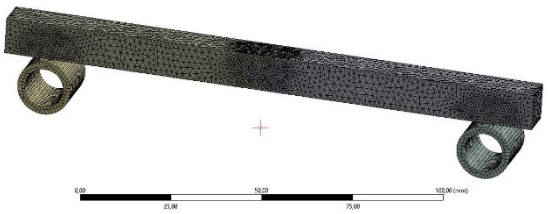


Figure 7. Meshed "Mouse" joint specimen

Joint contact is defined as frictionless symmetric contact between contact and target bodies and augmented Lagrange formulation was used. Frictionless contacts were used because specimen parts were polished after 3D printing and considering friction in calculation wouldn't provide huge difference in the results compared to the processing power and time which would be required to solve the problem.

Results of total specimen deformation are shown in Figure 8., equivalent stress results according to the Von Mises criterion are shown in the Figure 9. and equivalent strain results according to the Von Mises criterion are shown in the Figure 10.

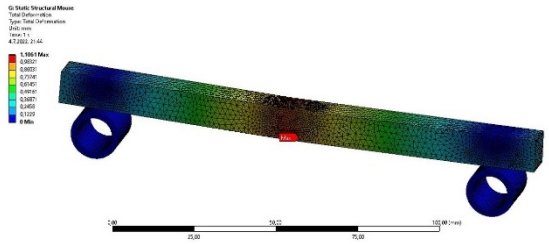


Figure 8. "Mouse" specimen deformation results

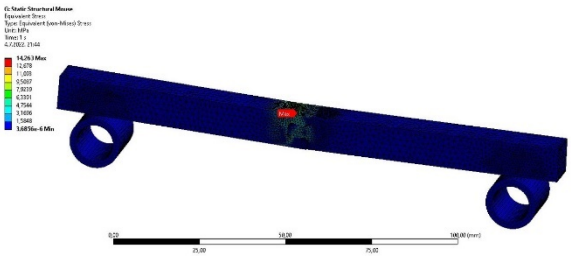


Figure 9. "Mouse" equivalent stress results

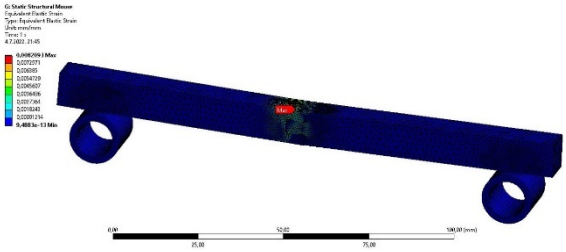


Figure 10. "Mouse" equivalent strain results

Third and the last analysis was performed using the specimen with the triangle shaped joint in the middle of the specimen. Boundary conditions and contacts definition between specimen and support were assigned as in previously described analyses. A mesh of tetrahedron SOLID187 quadratic elements was used, and mesh consists of 196972 elements with 290136 nodes. Preview of meshed body is available in the Figure 11.

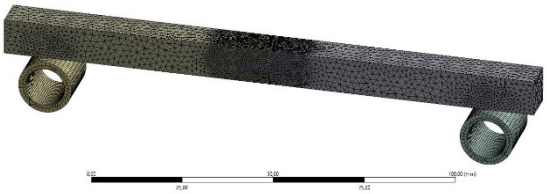


Figure 11. Meshed "Triangle" specimen

Joint contact between specimen parts is defined as in previous "Mouse" analysis. Results of total specimen deformation are shown in Figure 12, equivalent stress results according to the Von Mises criterion are shown in the Figure 13 and equivalent strain results according to the Von Mises criterion are shown in the Figure 14.

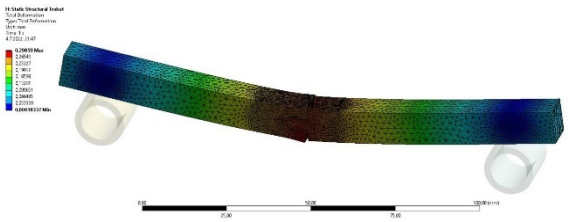


Figure 12. "Triangle" specimen deformation results

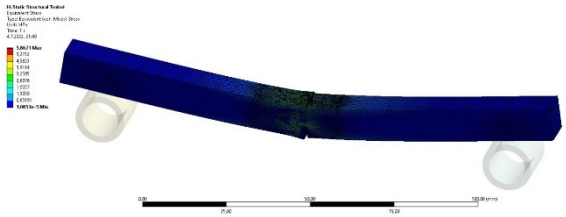


Figure 13. "Triangle" equivalent stress results

Figure 14. "Triangle" equivalent strain results

2.2. Experimental methodology

Flexural test was made on the room temperature using self-made apparatus and Arduino-based device in combination with mechano-electrical strain gauges shown in Figure 15 and 17. The strain gauges convert mechanical strain into an electrical resistance change which is read as signal in converting device. The resistance change is proportional to the generated strain because of applied load and is described as k factor.

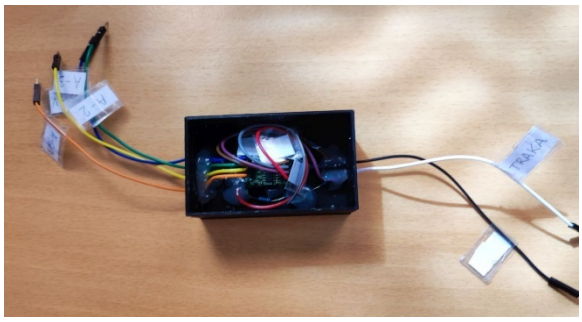


Figure 15 Measuring device

Used strain gauges are high precision BF350-3AA gauges with resistance of 349.8Ω and gauge factor of 2.1±0.1. Gauges were fixated with cyanoacrylate adhesive 1 mm away from the joint on the tensile side of the female part in assembled specimen and in the middle of the tensile side of solid specimen. Surface was previously hand-polished with 220 and 300 grit sandpaper and thoroughly cleaned with compressed air according to the manufacturer's instructions. Prepared specimens with attached strain gauges are shown in Figure 16. [8][9]

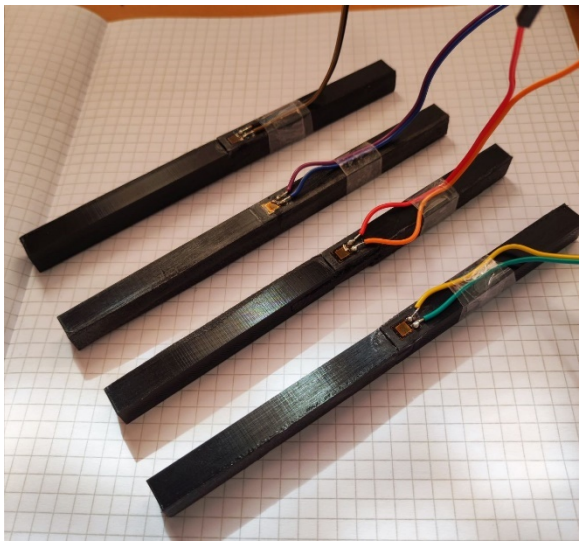


Figure 16. Prepared specimen

Test was performed by putting the controlled weight of 0.390kg onto the manual test piston

which weights 0.120kg as shown in Figure 17. Distance between supports is fixed to 125mm and load was applied in the middle of the specimen.

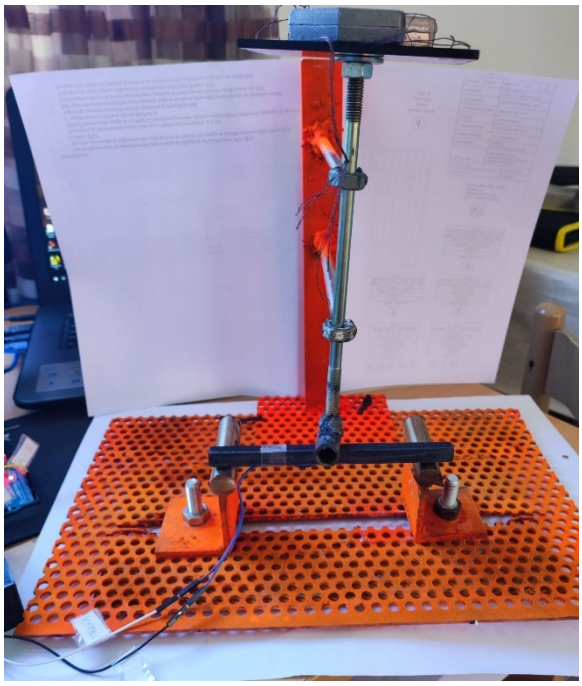


Figure 17. Performing flexural test on apparatus

3. RESULTS

Test results were produced with both numerical and experimental analyses. To acquire accurate numerical results comparable with experimental results, probe feature in Static structural module was used to obtain results on the positions where strain gauges were fixated on the specimens during experimental tests.

Equivalent stress and strain results according to Von Mises criterion taken with probe feature and maximum deformation results of all numerical analyses are shown in Table 3.

Table 3. Numerical analysis results

Specimen	Stress, *MPa*	Strain, *mm/mm*	Deflection, *mm*
Solid	0.918	5.223×10^{-4}	0.1424
Mouse	2.249	1.282×10^{-3}	1.1061
Triangle	1.525	8.683×10^{-4}	0.2986

Experimental test results of strain for solid specimen are shown in Figure 18.

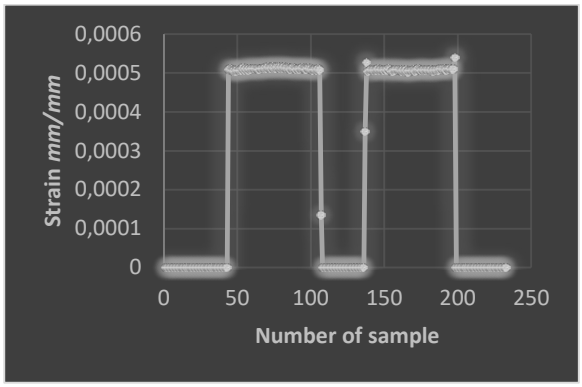


Figure 18. Strain results for solid specimen

Dataset contains 234 measurements in total, whereas specimen was twice loaded with test weight of 51 grams. First measurement dataset average is 5.1030×10^{-4} mm/mm, and second performed measurement average is 5.0864×10^{-4} mm/mm, therefore overall average of entire captured measurements is 5.0974×10^{-4} mm/mm.

Since deformation is entirely within the elastic region because of the magnitude of the applied load, stress curve can be derived by applying Hooke's law on obtained strain dataset. First stress dataset average is 0.8966 MPa, and second measurement dataset average is 0.89368 MPa, therefore overall average of entire captured data of stress for solid specimen is 0.89514 MPa.

Experimental test results of stress for solid specimen are shown in Figure 19.

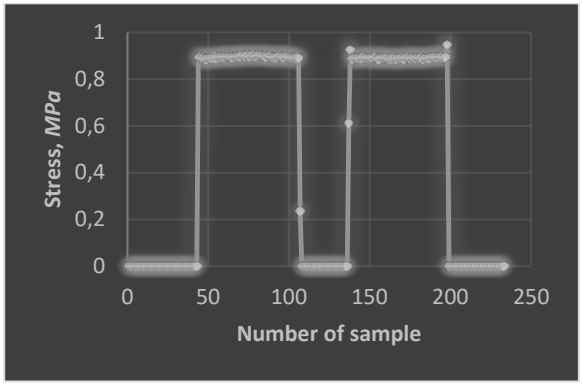


Figure 19. Stress results for solid specimen

Second experiment was performed on the Mouse specimen, and dataset contains 164 measurements in total. Same load was applied as on solid body specimen, and test was performed two times with exact same weight just as previously described for solid specimen test. First measurement dataset average is $1.233x10^{-3}$ mm/mm, and second performed measurement average is $1.231x10^{-3}$ mm/mm, therefore overall average of both measurements for Mouse specimen is $1.23219x10^{-3}$ mm/mm. Strain curve of performed test is shown in Figure 20.

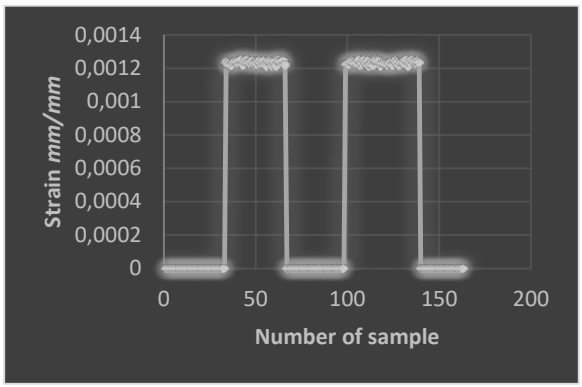
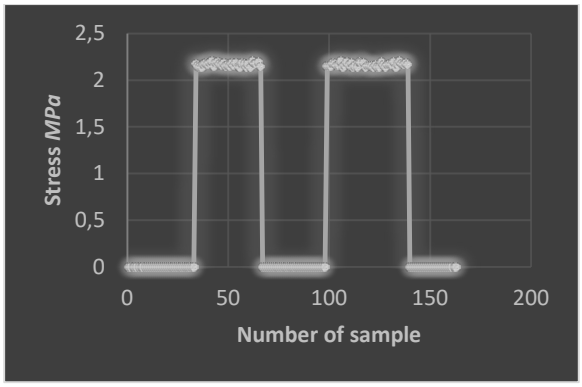


Figure 20. Strain results of Mouse specimen

Stress curve is derived from obtained strain dataset. First stress dataset average is 2.166 MPa, and second measurement dataset average is 2.1633 MPa, therefore overall average of entire captured data of stress for Mouse specimen is 2.165 MPa. Stress results are shown in Figure 21.



F*igure 21. Stress results of Mouse specimen*

Third experiment was performed on Triangle specimen and obtained dataset contains 333 taken samples. Specimen was loaded 2 times with exact same weight as previously described for Mouse and solid specimens. First measurement results average for strain is $8.4714x10^{-4}$ and for stress 1.488 MPa. Second measurement results are $8.4724x10^{-4}$ for strain and for stress 1.489 MPa. Overall average of the obtained strain measurements is $8.4719x10^{-4}$ and for stress 1.4885 MPa. Obtained strain measurements are shown in Figure 22, and stress measurements in Figure 23.

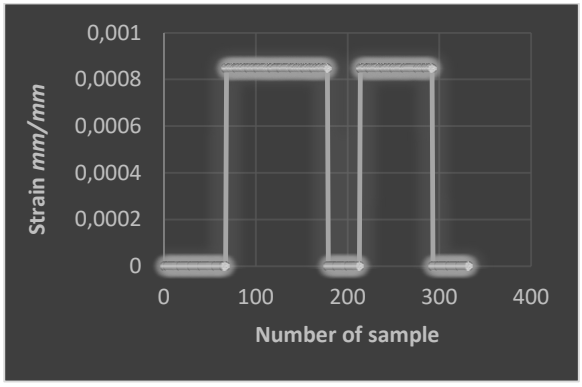
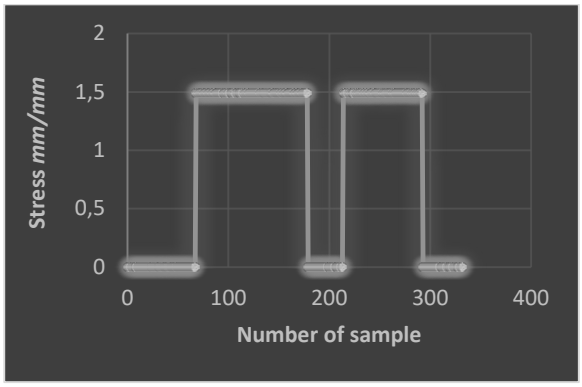


Figure 22. Strain results of Triangle specimen



F*igure 23 Stress results of Triangle specimen*

3.1. Comparison of experimental and numerical results

Table 4. Comparison of stress results in MPa

Specimen	Experimental	Numerical	Dif., %
Solid	0.89514	0.918	2.49

Specimen	Experimental	Numerical	Dif., %
Mouse	2.165	2.249	3.73
Triangle	1.4885	1.525	2.39

Table 5. Comparison of strain results in mm/mm

Specimen	Experimental	Numerical	Dif., %
Solid	0.00050974	0.0005223	2.40
Mouse	0.00123219	0.001282	3.89
Triangle	0.00084719	0.0008683	2.43

4. CONCLUSIONS

Since traditional horizontal joinery methods are expected to perform weakest on bending loads, three-point flexural test was used to compare different joining methods. Out of 2 tested joinery methods, mouse joint was the weakest by far and should be avoided in connecting parts without use of an adhesive. The stress and strain data produced for triangle shaped joint are 39.85% weaker compared to solid specimen and 67.73% stronger compared to the mouse specimen. By further research and geometry optimisation it's assumed that improvements in results can be achieved. Considering results of this research, it can be concluded that it's possible to use traditional knowledge in joinery methods for 3D printed assemblies under the bending load depending on the application.

5. REFERENCES

[1] J. Torres; J. Kart; J.Cotelo; A.P.Gordon, Mechanical Property Optimization of FDM PLA in Shear with Multiple Objectives, JOM: the Journal of the Minerals, Metals & Materials – May 2015, ISSN 1047-4838, DOI 10.1007/s11837-015-1367-y

[2] A.M. Clarinval; J. Halleux, Biodegradable Polymers for Industrial Applications, ed. R. Smith (Boca Raton: Taylor & Francis, 2005), ISBN: 9781845690762

[3] 3D printing geometry restrictions, Hubs, https://www.hubs.com, last accessed: 14. 06. 2022.

[4] K. Seike, The Art of Japanese Joinery, translated and adapted by Y. Yobuko and R.M. Davis, New York – Tokyo - Kyoto, first edition 1977, ISBN: 0834815168

[5] Ultimaker Cura, https://ultimaker.com/software/ultimaker-cura, last accessed: 15.6.2022.

[6] J.M. Chacón; M.A. Caminero; E. Garcia-Plaza; P.J. Núnez, Additive manufacturing of PLA structures using fused deposition modelling: effect of process parameters on mechanical properties and their optimal selection, (2017),doi:10.1016/j.matdes.2017.03.065

[7] V. C. Pinto; T. Ramos; S. Alves; J. Xavier; P. Tavares; P. M. G. P. Moreira; R. M. Guedes, Comparative failure analysis of PLA, PLA/GNP and PLA/CNTCOOH biodegradable nanocomposites thin films, 1st International Conference on Structural

[8] Coding System of Strain Gauges, Elecrow, https://www.elecrow.com/, last accessed: 16.06.2022.

[9] How to Prepare Material for a Strain Gauge Installation, HBK Gmbh., Germany, https://www.hbm.com/en/, last accessed: 16.06.2022.

Software for family farm - business processes of invoicing

P. Nakić [a], M. Kokanović [b], I. Matasović [c]

[a] University of Slavonski Brod, Ivane Brlić Mažuranić 2, HR-35000, Croatia, pnakic@unisb.hr

[b] Technical School Slavonski Brod, Eugena Kumičića 55, HR-35000, Croatia, kokanovic.mato@gmail.com

[c] Technical School Slavonski Brod, Eugena Kumičića 55, HR-35000, Croatia, ivan.matasovic1@gmail.com

Abstract

The paper analyzes accounting and bookkeeping of family farms. Based on the information provided by the members of family farms a mobile application was created. Furthermore, a description is given for the basics of the application program, and the way it can be used. Database overviews, registration forms, and offset reports are also presented in the text..

Keywords: software, family farm, invoicing

1. INTRODUCTION

Due to numerous rapid technological advances, all parts of economy have been affected by it and compelled to improve their ICT knowledge. The focus of this paper is on agriculture and software technologies .

A number of family farm owners have reported an increase in quantity of digital documentation they have to deal with, many of whom leave their businesses to authorised bookkeeping services, while others try to do the work themselves. The paper [1] analyzes the intensity of the presence of ICT in agriculture in rural areas in the east of the Republic of Croatia. The results show a low level of ICT use in family farms due to low interest of respondents, but also limited availability of software solutions. The paper [7] analyzes the impact of data management with a computer program on farm management. The paper [8] analyzes the possibilities of cooperative farmers using local systems.

Accounting Act [2] defines the obligation to issue invoices, as well as their required content, and account management and reporting.

This paper will describe in detail the application that could help small family farms manage bookkeeping themselves.

2. ANALYSIS OF THE CURRENT STATE OF ACCOUNTING ON SMALL FAMILY FARMS

In order to develop proper software solution and application, it is necessary to take a closer look at the present state of small family farms. By talking to the farm owners, the biggest problem cited seems to be digital illiteracy of the older generations. They do not know how to work on a computer, and state that they lack free time or personal motivation to equip themselves with the skills and knowledge required to use new technologies. This group prefers to work with a mobile application. Mobile phones are easily

accessible to them, and they generally handle them very well. The application they would use should only contain options for creating an outbound invoice. When creating a new invoice, the invoice would be automatically sent to the bookkeeping office via e-mail account. The app would save up on the time needed to physically visit bookkeeper, or print the invoice manually.

As far as the family farm owners who are digitally savvy and know how to do their own accounting are concerned, the application aims to speed up the process and save time on final accounts. It is important that the application is user-friendly and simple in design, unlike other similar apps on the market at the moment. The paper will primarily showcase the application possibilities for this group of users.

3. DATABASE DEVELOPMENT

The database uses Microsoft's SQL server because it provides excellent performance, availability and security. LINQ is used to connect to SQL Server databases and retrieve data.

LINQ provides easier access to retrieve and work with data from the database. It is linked to the C# programming language, which is used as the main language in the *Small Family Farm Software Application.*

Figure 1 shows a physical data model that contains all the necessary tables, and relationships among the tables.

Understanding of accounting laws and regulations is prerequisite for developing the model. It is necessary to know how the input data is stored and how to use it later in keeping accounting ledgers.

The model displays the *User* table as the database center. By registering, a user can have multiple *Products, Services, Outbound Accounts, Inbound Accounts* and the ability to enter multiple *Customers*

The *User* table contains the data required for creating an account, which are prescribed by the Rulebook of the Family Farm Register, accompanied by a password, *PasswordUser*. The password is required to log in to the application system, and its data is protected by the SHA2_512 algorithm.

Creating a physical data model of the database provides access to creating application design.

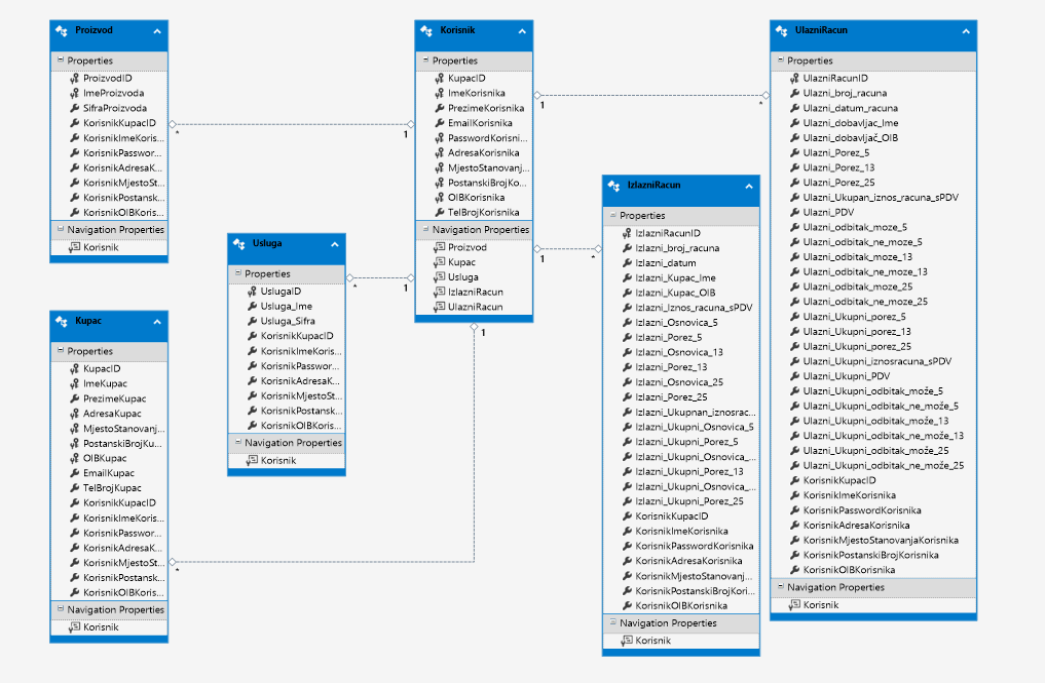


Fig. 1. Physical data model of the database

4. DESIGNING THE APPLICATION FOR WINDOWS

C # was chosen as the main programming language. It is a modern, object-oriented programming language, and users who work with C, C ++, Java and JavaScript can easily read it due to its performance. Visual Studio 2019 was selected for the development environment.

The graphical user interface for the application was created using the Windows Forms controls that are part of the System.Windows.Forms namespace. Windows Forms are a set of classes for creating a graphical interface in Windows. There were two phases of work during the development of the program. The first phase refers to the visual design of forms. The second phase involves writing code that will be executed while working with the application

The application consists of Windows forms. The first form refers to the LogIN / SignUP form, Figure 2. User registration is done in a new form, Figure 3. By filling in user data and logging into the system, a user can access the menu, Figure 5.

Figure 4 show the login form.

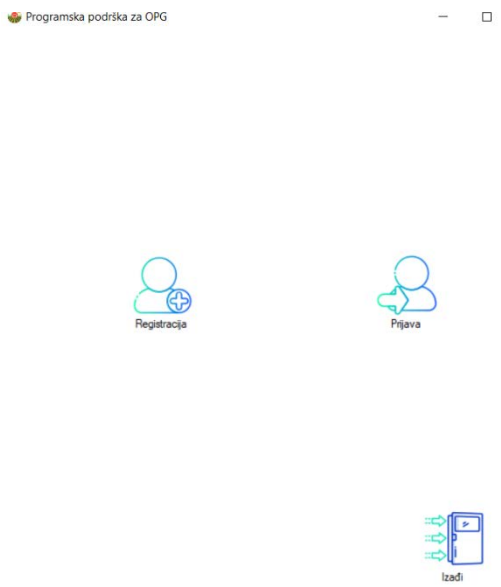


Fig. 2. LogIN / SignUP interface

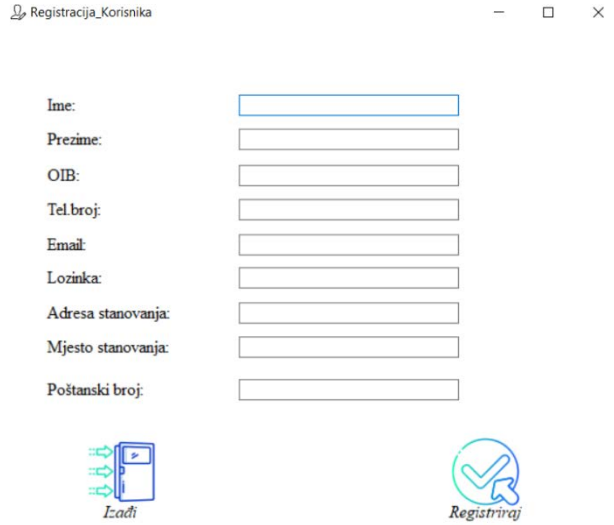


Fig. 3. User registration

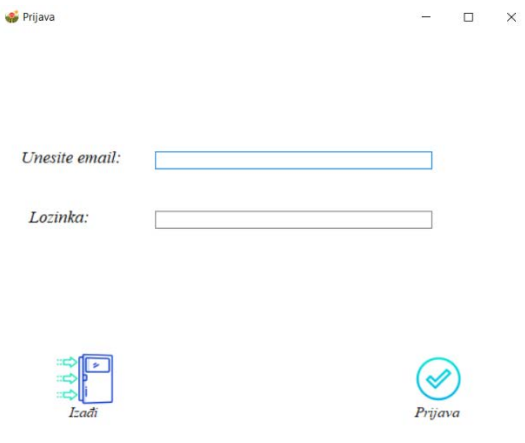


Fig. 4. Interface "LogIN“

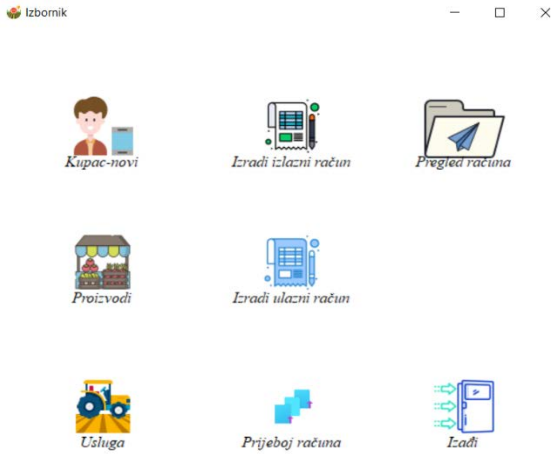


Fig. 5. Interface "Menu“

By opening the Menu, the registered user has the option of entering the data for a new customer. After the user fills in the required data, the customer information is saved in the database and their data is permanently stored. The data can be updated in the same manner. The user can also add all the products and services provided by their family farm.

The application offers the possibility of creating inbound and outbound invoices. The customer analysis made for the needs of this application found that a small number of family farms keep records of inbound invoices. Most create an outbound invoice on their own, in writing or using a computer.

By opening the menu for entering inbound invoices a simple form appears. It contains all the information needed to fill out the U-RA form. The data is stored in the database, and the user can access the account overview at the end of the month. Opening the *Account Overview* menu and selecting the *U-RA Overview* menu opens the form for selecting the month for which data is required. The data is taken from the database, and the user has all the necessary information to complete the bookkeeping for a given month.

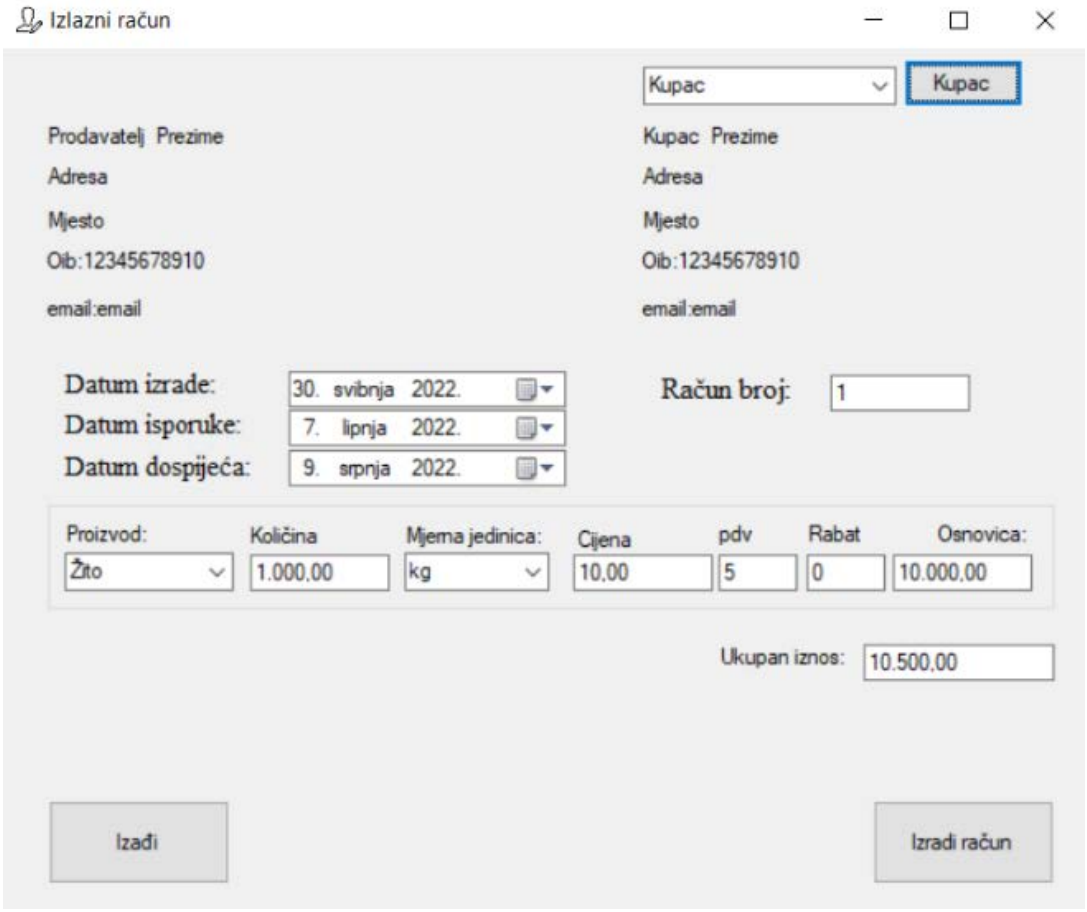


Fig. 6. Creating an outbound invoice

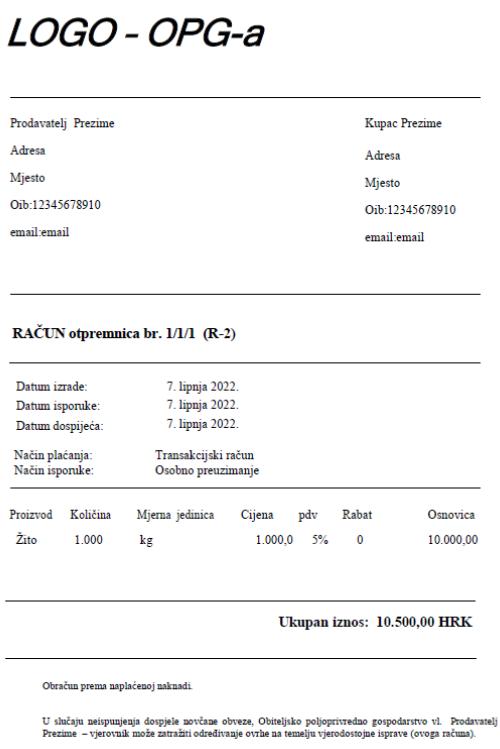
From the menu, *Create Outbound Invoice*, user can open and create the invoice form, Figure 6. by simply entering all the necessary data.

The data is stored in the database, and the user downloads a print invoice to the computer, Figure 7.

The application also offers the possibility of creating an account offset. By filling in the form,

the user prints the offset. The application enables simple data entry as well as reports on completed transactions. This enables the farmer to easily manage goods and finances.

Since it is a non-cash payment, the account does not need to be fiscalized.



LOGO - OPG-a

Prodavatelj Prezime
Adresa
Mjesto
Oib:12345678910
email:email

Kupac Prezime
Adresa
Mjesto
Oib:12345678910
email:email

RAČUN otpremnica br. 1/1/1 (R-2)

Datum izrade: 7. lipnja 2022.
Datum isporuke: 7. lipnja 2022.
Datum dospijeća: 7. lipnja 2022.

Način plaćanja: Transakcijski račun
Način isporuke: Osobno preuzimanje

Proizvod	Količina	Mjerna jedinica	Cijena	pdv	Rabat	Osnovica
Žito	1.000	kg	1.000,0	5%	0	10.000,00

Ukupan iznos: 10.500,00 HRK

Obračun prema naplaćenoj naknadi.

U slučaju neispunjenja dospjele novčane obveze, Obiteljsko poljoprivredno gospodarstvo vl. Prodavatelj Prezime – vjerovnik može zatražiti određivanje ovrhe na temelju vjerodostojne isprave (ovoga računa).

Fig. 7. Outbound invoice sample

5. CONCLUSION

A number of young people have started their own farming ventures, and in this digital day and age a lot of them have shown interest to personally control all the aspects of their enterprise, including bookkeeping. This was the primary problem that authors wanted to help with by creating this application.

With its capabilities, the application enables the user to create and keep the records of inbound and outbound invoices and prepare records for final monthly or annual accounts. Due to its simplicity, application might help many family farms to successfully manage bookkeeping. It will also be an incentive for other owners, alone or in partnership with authorized bookkeeping services, to keep their own bookkeeping records.

As far as the future of the application is concerned, authors would like to keep track of family farms and hear their experiences and feedback, and update the application with improved algorithms.

6. REFERENCES

[1] J. Šundalić, J. Mesarić, Ž. Pavić, The modern peasant and information technology, Econviews : Review of Contemporary Entrepreneurship, Business, and Economic Issues, Vol. XXIII No. 1, 2010., pp50-60

[2] Law on Accounting https://www.zakon.hr/z/118/Zakon-o-ra%C4%8Dunovodstvu last access 18/5/2022

[3] V. Anić, Lj. Đukanović, Z. Koprivčić, M.Paić Ćirić, N. Petrović, A. Šašić Šojat, K. Vranar, Artisans, freelancers and farmers, TEB-poslovno savjetovanje d.o.o., Zagreb, (2005.)

[4] Stack Overflow, C# Notes for Professionals, Creative Commons BY-SA, (2018.)

[5] Windows Forms documentation https://docs.microsoft.com/en-us/dotnet/desktop/winforms/?view=netdesktop-6.0 last acess 2/5/2022

[6] ADO.NET https://docs.microsoft.com/en-us/dotnet/framework/data/adonet/ 2.5.2022.

[7] K. Poppe, S. Wolfert, C. Verdouw, (2014). How ICT is changing the nature of the farm: A research agenda on the economics of Big Data. In 11th European IFSA Symposium, Farming Systems Facing Global Challenges: Capacities and Strategies, Proceedings, Berlin, Germany (2014). pp. 1-4.

[8] J. Lutz, B. Smetschka, N. Grima, Farmer cooperation as a means for creating local food systems—potentials and challenges. Sustainability, (2017). 9(6), 925.

Perception of security risks in electronic data interchange of student population

P. Nakić[a], T. Katinić[b], R. Simić[c] I. Marušić[d]

[a] University of Slavonski Brod, Ivane Brlić Mažuranić 2, HR-35000 Slavonski Brod, Croatia, pnakic@unisb.hr

[b] University of Slavonski Brod, Ivane Brlić Mažuranić 2, HR-35000 Slavonski Brod, Croatia, tomislav_01@yahoo.com

[c] University of Slavonski Brod, Ivane Brlić Mažuranić 2, HR-35000 Slavonski Brod, Croatia, ranko.simic@gmail.com

[d] University of Slavonski Brod, Ivane Brlić Mažuranić 2, HR-35000 Slavonski Brod, Croatia, marusic.ivan@gmail.com

Abstract

The issue of privacy and security in electronic communication has been gaining momentum since the beginning of the internet era, but it became much more significant with development of mobile technologies that made possible for a much wider group of users not only to interact with social networks and email accounts, but also to make financial transactions, particularly on mobile devices. While on one hand malicious individuals and groups are getting more inventive and sophisticated, on the other hand users of web and mobile services do not have sufficiently developed awareness and perception about potential risks, nor are they educated enough on how to protect themselves properly [1]. The most endangered are those users who do not use any form of protection against security and privacy threats that ultimately lead towards identity theft or financial damage.

Keywords: security risk, electronic data interchange, students

1. INTRODUCTION

Taking into consideration this present and emerging problem, this article will interpret the research data and make their evaluation in order to prepare conclusions for further research if necessary.

It is important to distinguish the terms security and privacy. While privacy is a measure of revealing as few as possible of your personal data, security, as a general term, is a set of tools and procedures to ensure privacy. [2]

Also, other researches that are similar to an extent use similar terminology, as awareness [3] or behaviour. In this article we use the term perception as it is a higher order concept and awareness or behaviour are derived terms.

2. RESEARCH METHODOLOGY

Hypothesis: security perception in electronic data exchange in student population is not fully developed, but in spite of that, most of them are not directly endangered in terms of security breaches.

For the research purpose, following methods were used: description method, statistical analysis method and polling. Data has been

collected by questionnaire and poll method and has been statistically analyzed.

3. GENERAL DATA INTERPRETATION

The research is done on the sample of 125 respondents from three Croatian universities.

Here are some basic figures:

60% of respondents are women.

64% of all respondents belong to age group of 19 to 24 years which is the biggest group by age.

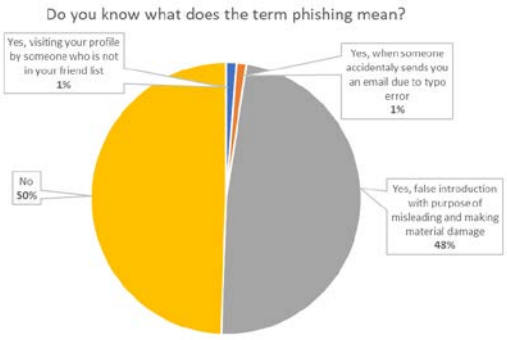
Percentage of respondents by the type of their study:

Technical sciences	30%
Social sciences	56.7%
Humanistic sciences	13.3%

3.1. Security threat management

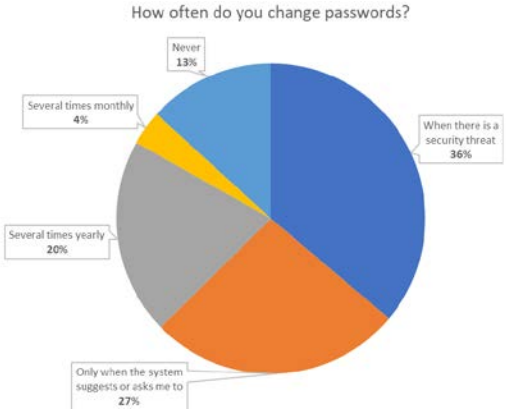
Only 3.6% of all respondents are not present on social networks, and they are all in the range of 32 to 35 years. In that same group, 66% of respondents have received some form of misleading message while half of them actually responded on such message.

In full research context, 38.9% respondents received such message, but 98.8% of them did not disclose their information to malicious correspondents. At the same time, 52% of all respondents do not know what the term *phishing* actually means.



Graph 1. Poll question about phishing

Furthermore, 51.1% of respondents use the same password for logging in multiple accounts, including the accounts of high security risk (for example, mobile payment systems such as Google pay or Apple pay). When it comes to the password changing frequency, 76% of all respondents would have never change the password on their own initiative.



Graph 2. Poll question about password changing frequency

Other habits from security domain are shown in a table 1.

Table 1. Habits from security domain.

	When changing password, I use recommendations about complexity	I use two stage authentication	I use biometric authentication
Always	46.7%	11.1%	22.2%
Only for accounts of high security risk	12.2%	28.9%	26.7%
Only if the system asks me to	37.8%	52.2%	24.5%

Never	3.3%	7.8%	26.6%

It must be taken into consideration that not all respondents currently have such devices that can provide some or any form of advanced security, so the answers are partially conditioned by that fact. In spite of that limitation, only 7.8% respondents never use two stage authentication, compared to a research with similar category where only 52% ever use that functionality. [4]

The most concerning fact in terms of security is that 43.3% of all respondents use at least one mobile payment system without any form of additional protection against malware or spyware on their mobile device.

3.2. Privacy issues

Generally, 36.6% of respondents share their locations and / or personal data on social networks, at least occasionally. At the same time, 76.7% of them discloses that data only to people in their friend list. Although 91.1% of them know what cookies are, 63.3% usually click on accept all. Only 35.6% are reviewing to which purpose their data has been collected. Additional 30% would like to know where their data (and which data) is used, but they are not educated enough to make such review.

4. ABSTRACTED USER PROFILES

Data analysis has shown that we can differentiate three distinctive types of users from security and privacy improvement point of view. Although almost none of respondents fit the profile perfectly, most of them can be easily categorized to one of the profiles:

Profile of the student that is mostly exposed to phishing threats and similar frauds:

- has more than one social network
- is frequently active
- uses several e-mail addresses
- has received misleading e-mails or messages via messenger applications
- potentially, it contacted malicious correspondents

In this data sample, only one student has responded to such email, although it did not have any social networks.

Profile of the student that is mostly exposed to identity theft or privacy violation

- has more than one social network
- is frequently active
- discloses locations or personal data
- wider circles of users can see their posts / statuses
- uses more than one e-mail address
- uses the same password on multiple accounts
- rarely changes password and does not comply to password strength recommendations
- does not use advanced authentication
- accepts all cookies and does not care to which purpose which data is collected

Those who are active on social media, disclose information and locations to wider circles of users and use same password that is rarely changed, still use strong passwords or two-stage authentication or biometric authentication when needed. However, their privacy is partially compromised.

Profile of the student that is mostly exposed to financial damage

- uses mostly mobile payment services like Google pay or Apple pay

- does not have antimalware or antispyware protection on their mobile device
- uses the same password on multiple accounts
- rarely changes password and does not comply to password strength recommendations
- does not use advanced authentication

This profile fits entirely for 7.2% of respondents that do not use biometrics, have mobile payment services, do not have any antivirus software and use the same outdated password that is probably mediocre in terms of strength.

5. CONCLUSIONS

Hypothesis: security perception in electronic data exchange in student population is not fully developed, but in spite of that, most of them are not directly endangered in terms of security breaches according to the presented results, it is confirmed. Students do not have fully developed perception about security risks, so it is required to introduce better education on universities, regardless of their type, about how and why better protection of privacy and utilization of security measures is needed and about potential consequences of security threats such as identity theft or financial damage. Another effective method of raising security risk awareness could be development of security habits, similar as healthy way of life or safety precautions. [5]

Generally speaking, student population consists mostly of younger people that are considered to be technologically advanced by default, in terms of using the available technologies, but there is still much room for improvement in privacy and security perception. It is only assumable that older groups of users who did not grow up surrounded by modern technology but had a much steeper learning curve probably have additional disadvantage – it might be more challenging for them to even use those technologies, not mentioning potential concerns brought in this article about privacy and security.

Although students do not change their passwords regularly, they still choose stronger passwords by requirement or recommendation from various systems, which in combination with biometrics or two-stage authentication still provides minimally satisfactory level of security. If those systems did not have such mandatory terms and standards and if students were given freedom to choose for themselves, results would be undoubtedly much worse.

To conclude, only 19.28% of respondents change their passwords regularly, using strong passwords, two-stage authentication and biometrics, at least for the accounts of high security risk.

5. REFERENCES

[1] V. Stanciu, A. Tinca: Students awareness on information security between own perception and reality – an empirical study, (2016)

[2] B. Drolet, J. Marwaha, B. Hyatt, P. Blazar, S. Lifchez: Electronic Communication of Protected Health Information: Privacy, Security, and HIPAA Compliance, (2017)

[3] K. Eyong, "Recommendations for information security awareness training for college students." Information Management & Computer Security (2014).

[4] M. Abbas, Cybersecurity Awareness Among Students and Faculty. CRC Press, (2019).

[5] Y. Cheolho, J. Hwang, R. Kim., Exploring factors that influence students' behaviors in information security. (2012).

Surface roughness testing on 3D printed test bodies

G. Pačarek [a], J. Stojšić [b], I. Vidaković [c]

G. Rozing [d]

[a] Faculty of Agrobiotechnical Sciences Osijek, Vladimira Preloga 1, 31000, Croatia, gpacarek@fazos.hr

[b] Mechanical Engineering Faculty in Slavonski Brod, Trg Ivane Brlić Mažuranić 2, 35000, Croatia, jstojsic@unisb.hr

[c] Faculty of Agrobiotechnical Sciences Osijek, Vladimira Preloga 1, 31000, Croatia, ivan.vidakovic@fazos.hr

[d] Faculty of Electrical Engineering, Computer Science and Information Technology Osijek, Kneza Trpimira 2B, 31000, Croatia, goran.rozing@ferit.hr

Abstract

The application of 3D printing is very wide and significant especially in designing and prototyping a new product, as well as in abstract art and visualization concepts. Selecting the appropriate parameters for 3D printers can directly affect the surface roughness of printed object. Surface roughness affects the dynamic durability, friction and wear of loaded surfaces and the bearing capacity of the clamping joint. In this paper, the dependence of the roughness of the printed test specimens on the selected thickness of the print layer was examined. By choosing the thinnest layer of filament od 0,05mm, the best possible surface roughness of Ra 5,39 μm and Rz 6,659 μm was obtained with longest production time, while selecting the thickest filament layer of 0,3 mm, the worst surface roughness Ra 22,381 μm and Rz 27,080 μm was obtained with the shortest production time.

Keywords: 3D printing; Surface roughness; PLA; Thickness of the print layer; Ra; Rz

1 INTRODUCTION

Additive technology, known as 3D printing, is the addition of layers of material to a previously constructed object using a CAD program. The path of the nozzle is predetermined by the extracted G code from the CAD model. 3D printing enables the creation of three-dimensional structures with minimal material waste. The application of 3D printing is very wide and significant, especially in designing and prototyping a new product, art and visualizing an abstract concept.

Additive manufacturing and 3D printing can be counted as disruptive technologies, that is, technologies that will change the way things are normally made and are predicted to be at the forefront of the fourth industrial revolution. The global market for 3D printing products and services are estimated at around 12.6 billion U.S. dollars in 2020. The industry is projected to grow at a compound annual growth rate of approximately 17% between 2020 and 2023. According to Figure 1.1, it can be concluded that the 3D printing services market is projected to grow to 37.2 billion U.S. dollars and compared to 2020, this is a growth of the total market of 295.23%. Among the fastest growing 3D printing services for a specific type of material are metals and metal alloys. 3D metal printing is a relatively new field, but every year great discoveries are made and metal printing is usually more expensive. It is estimated that as more companies have their own 3D printers, printer software will grow faster than 3D printing services [1].

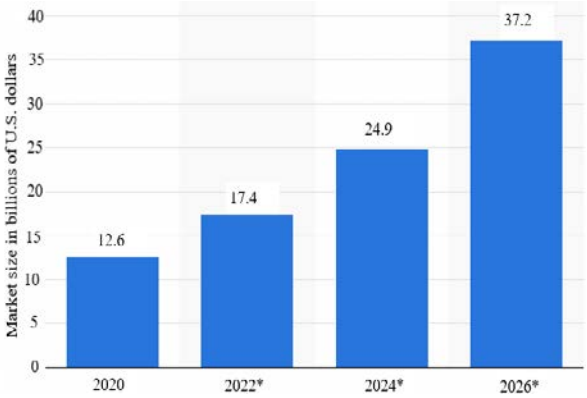


Fig. 1. Global market size for 3D printer products and services from 2020 to 2026 [1].

1.1 Surface roughness

The quality of the final processing is necessary not only for improving the functionality and appearance, but also for reducing costs and overall saving time in the creation of the object. The working principle of additive technology is the layer-by-layer stacking process, and one of the main disadvantages of the FDM process, that is, the technique of making joined filaments, is the roughness of the surface, which is rougher compared to other material processing technologies. The reasons for the poor surface roughness observed at the end of the FDM process are due to the layer-by-layer joining process and the influence of the tessellation of the original CAD model. In order to achieve better surface quality, attention must be paid to the parameters of the production process [2].

The layer's thickness is directly related to the surface roughness, as the thickness of layers increases, the roughness of the surface increases too. By increasing the layer's thickness, the surface of the printed part is sharper and layers appear more. In addition, with increasing the speed, the roughness firstly decreases and then increases. Hybrid algorithm and the response surface method have high ability to optimize and predict the roughness of parts printed with 3D FDM printers. The optimization results show that both response surface and hybrid algorithm can estimate the optimal parameters with an error of less than 10%. The use of meta heuristic algorithms improves the performance of printed parts during 3D printing process [3].

Li et al. [4], they report that the predictive models are capable of predicting the surface roughness of the 3D printed specimens using machine learning algorithms. The ensemble learning algorithm combined six different machine learning algorithms, including RF, AdaBoost, CART, SVR, RR, and RVFL network.

3D printer system vibrations have a significant influence on the surface roughness of fabricated products. Vibration in 3D printer system exist throughout the fabricating process while influenced by many sources such as 3D printer structure, nozzle type, filling structure type etc. [5].

In this paper, the surface roughness of the profile's Ra and Rz of manufactured test bodies obtained by the FDM process at an angle of 90° is observed. Ra is the mean arithmetic deviation of the profile, that is, the mean arithmetic value of the absolute profiles y within the limits of the referent of length l, which is shown in Figure 1.2 [6].

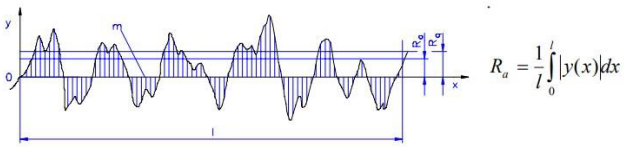


Fig. 1.2. Mean arithmetic deviation Ra [6]

The height of profile (Figure 1.3) irregularities measured at ten points Rz is the mean value of the absolute values of the height of the five highest protrusions y_{pi} and the depth of the five deepest depressions y_{vi} within the limits of the reference length l [3].

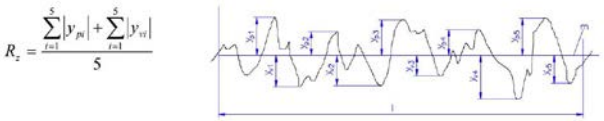


Fig. 1.3. Height of profile unevenness measured in ten points Rz [6]

Alsoufi and Abdulrhman [2], state that measuring at the angle of 90° is more suited for measuring the behaviour of the surface roughness compared to the other angles. Also, by conducting a surface roughness test, they determined that the highest average surface roughness behaviour at 32.16±0.61 µm when the nozzle diameter and layer height were 0.5 mm and 0.3 mm, respectively. They also obtained the lowest average surface roughness at 9.13±0.90

μm when the nozzle diameter and layer height were 0.3 mm and 0.1 mm, respectively.

Radhwan et al. [7], they studied the influence of the layer thickness, print speed, and fill density on the surface roughness and concluded that:

1. Low layer thickness, low print speed, and low fill density useful to reduce the surface roughness.
2. The lower value of layer thickness can be used to increase the surface finish quality, and it is the most significant factor on the surface roughness.
3. Fill density significantly improve the quality of surface roughness.

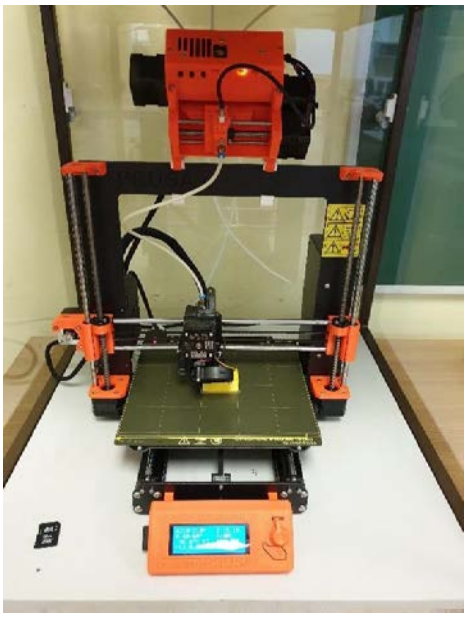


Figure 2.1. Original Prusa i3 MK3S+ print test body

2 EXPERIMENTAL METHODOLOGY

In this chapter, a device for printing test bodies, a filament printer and a device for testing roughness are presented.

2.1 3D printer and filament

The Original Prusa i3 MK3S+ (Figure 2.1) and the PrusaSlicer software (Figure 2.2 and Figure 2.3) were used to create test specimens. When making the test samples, all machine parameters were set by the manufacturer. The technical characteristics of the 3D printer are shown in table 2.1. The dimensions of the test bodies are: 50 × 30 × 20 mm.

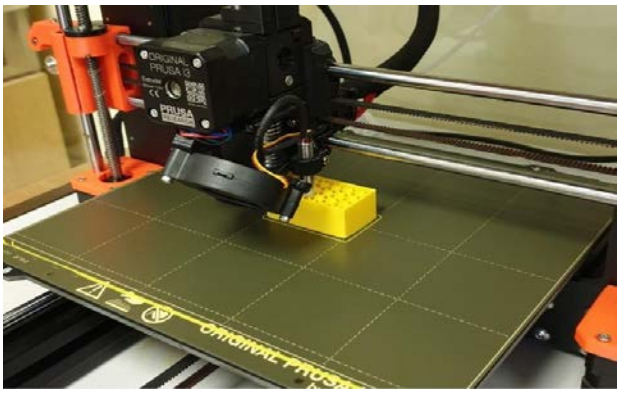


Figure 2.2. The process of printing the test body

Figure 2.3. Prepared test bodies

Table 2.1. Technical characteristics of Original Prusa i3 MK3S+

Product dimensions	25×21×21 cm
Layer height	0,05 – 0,35 mm
Nozzle	0,4 mm standard, a wide range of other diameters are supported
Filament diameter	1,75 mm
Supported materials	A wide range of plastomers, including PLA, PETG, ASA, ABS, PC, CPE, PVA/BVOH, PVB, HIPS, PP, Flex, nGen, Nylon, plastomer reinforced with carbon fibers, filled with wood and other material
Max. speed of movement	200 + mm/s
Max. nozzle temperature	300 °C
Max. base temperature	120 °C
Extruder	Direct drive, Bondtech gears, E3D V6 hotend
Print surface	Interchangeable magnetic steel plate with different surface roughness, compensation of heating plate and cold corners
Printer dimensions	7 kg, 50 × 55 × 40 cm (X×Y×Z)
Electricity consumption	PLA settings: 80 W / ABS settings: 120W

Commonly, PLA (Polylactic acid) is used as medical applications, containers, packages, automobile components, etc. [2]. Contrary to other thermoplastics which are petroleum-based, some of the raw materials used for PLA's production include corn starch, tapioca roots, or sugarcane. Its properties, however, are comparable to other plastics in the industry. These properties make PLA the most used in 3D printing [8]. PLA and PLA+ show excellent surface profile ratio with approximate constant deviations in surface roughness, waviness and primary profile [9].

PLA filament was used to make the test samples. PLA melts at a relatively low temperature of 175 °C. A property of PLA is the ability to be repeatedly heated above its melting point with very little degradation. PLA has good hardness, but it is also a fragile material that scatters after cracking. Only PLA material has proven properties for a layer height of 50 μm. The disadvantage of PLA is its low temperature resistance. Parts begin to lose their mechanical properties at temperatures above 60 °C. Combination of low UV and temperature resistance prove that it is not ideal for outdoor use. PLA is exclusively soluble in chemicals such as chloroform or hot benzene. When joining several parts, it is best to use only glue. When finishing the piece after printing, it is best to use wet sanding because during sanding there would be heating due to friction which would cause the material to soften and make it harder to sand [10].

2.2 Parameters of making test samples

The process of printing an object using the FDM technique is influenced by many parameters that can be controlled and that can affect the properties of the printed piece. Parameters that affect the printing process are: nozzle temperature, plate temperature, printing speed, workpiece orientation, layer stacking orientation, layer height, filament diameter, nozzle diameter, air gap and filament type [2].

When printing the test body, the body fill parameter is set to 15%. The duration of the printing process is significantly affected by the fill percentage. For example, for 0.1 mm layer settings at 15% filling, the printing time is 1:44 hours, while for 50% filling, the printing time is 4:07 hours, and for 90% filling, it is 7:34 hours.

Table 2.2. Used parameters of the 3D printer

Parameters	Values
Filament material	PLA
Color	Yellow
Layer height (mm)	0,05, 0,07, 0,1, 0,2, 0,3
Filling (%)	15
Nozzle diameter (mm)	0,4
Wire diameter (mm)	1,75
Nozzle temperature °C	215
Base temperature °C	60
Room temperature °C	25±1
Air humidity %	40±5
Print speed mm/s	45

2.3 Roughness measurement procedure

The direction of the roughness test takes place at an angle of 90°. For testing purposes, the side of the test body was measured due to the smallest deformations of the layer during printing. When heating the table of the 3D printer and applying the first layer, the PLA material begins to deform at 60°C and the deformation of the first layer occurs. The deformations and roughness of the layer are therefore not homogeneous on the surface of the test body and therefore do not provide relevant data. In this seminar paper, the mean arithmetic deviation of the profile Ra and the height of the unevenness of the profile measured in ten points Rz were examined. The device with which the roughness was tested was the Mitutoyo SJ-210. The standard settings of the Mitutoyo SJ-210 device were used for the roughness test, and the values are shown in table 2.3.

Table 2.3. Roughness measurement parameters

Parameters	Values
Industry standard	ISO - 1997
Measurement force	0,75 mN
Angle of the tip	60°
Measurement profile	R
Measurement length $\boldsymbol{\lambda c}$ mm/s	2,5
Number of measurement repetitions	4
Digital filter	Gauss
Measuring speed mm/s	0,75

The roughness test is carried out in such a way that the diamond tip of the needle passes over a previously defined path and then reads the geometric irregularities of the measured surface. The diamond tip is 60° and acts with a force of 0.75 mN. The diamond tip of the needle is located in a housing that has its own drive and the test procedure, that is, the movement of the mechanism takes place axially. The movement speed of the needle mechanism itself can be adjusted to the needs of the measurement.

Figure 2.4. shows the diamond needle tip in its housing, and Figure 2.5 shows the Mitutoyo SJ - S210 device and the diamond needle tip attached to the housing of the mechanism that provides axial displacement during roughness measurement.

Figure 2.4. Diamond tip

Figure 2.5. Mitutoyo SJ – 210

The procedure for testing the roughness of the test body is shown in Figures 2.6. and 2.7. The pictures show how the process of testing the roughness of the test sample on the sides was carried out. The diamond tip of the test needle is returned to its original position and the measured values are displayed. Figure 2.7. shows the roughness test of the test sample with a layer thickness of 0,2 mm.

Figure 2.6. Roughness test procedure

Figure 2.7. Roughness test procedure

3 EXPERIMENTAL RESULTS

The roughness test procedure includes six test bodies. When printing the test body, the following thicknesses of the print layer were observed: 0,05, 0,07, 0,1, 0,15, 0,2 and 0,3 mm. Each of the test bodies was measured five times and the smallest measurement value obtained was considered. The aim of the measurement was to obtain the lowest possible value of the surface roughness of the test body so that the results could be more precisely put into context with conventional metal processing methods by particle separation.

The test body was tested at a room temperature of 24 °C and a relative humidity of 40%. All thickness variations of the layers offered by the PrusaSlicer program are covered. In addition to the roughness, the time required to print the test body was observed. SPSS statistical software package was used for statistical data processing. Variations of printing layers:

1. 0,05 mm – ultradetail
2. 0,07 mm – ultradetail
3. 0,1 mm – quality
4. 0,15 mm – quality
5. 0,2 mm – quality
6. 0,3 mm – draft

Table 3.1. Measurement results for a layer thickness of 0.05 mm

0,05 mm - ultradetail		
Roughness profile	Measurement results	Build time (h)
Ra	5,39 µm	4:43
Rz	6,659 µm	

Table 3.2. Measurement results for a layer thickness of 0.07 mm

0,07 mm - ultradetail		
Roughness profile	Measurement results	Build time (h)
Ra	6,826 µm	3:06
Rz	8,250 µm	

Table 3.3. Measurement results for a layer thickness of 0.1 mm

0,1 mm - quality		
Roughness profile	Measurement results	Build time (h)
Ra	8,963 µm	1:44
Rz	11,087 µm	

Table 3.4. Measurement results for a layer thickness of 0.15 mm

0,15 mm - quality		
Roughness profile	Measurement results	Build time (h)
Ra	10,579 µm	1:06
Rz	12,839 µm	

Table 3.5. Measurement results for a layer thickness of 0.2 mm

0,2 mm - quality		
Roughness profile	Measurement results	Build time (h)
Ra	13,710 µm	0:53
Rz	16,379 µm	

Table 3.6. Measurement results for a layer thickness of 0.3 mm

0,3 mm - draft		
Roughness profile	Measurement results	Build time (h)
Ra	22,381 µm	0:30
Rz	27,080 µm	

The roughness tables (3.1, 3.2, 3.3, 3.4, 3.5, 3.6) show the results obtained by measuring the roughness of the test body and the time required to print one test body. From the tables, it can be concluded that the smallest roughness of the Ra and Rz profiles for the thinnest filament layer is 0,05 mm thick, while the highest expected roughness for the thickest filament layer is 0,3 mm. Also, the production time of the test body is the longest for the thinnest layer of filament with a thickness of 0,05 mm, while the shortest expected production time is for the thickest layer of filament of 0,3 mm.

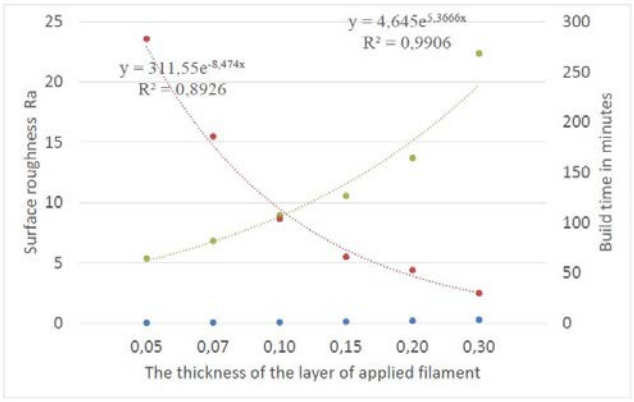


Diagram 3.1. Scatter diagram with exponential trendlines

The total measured length of the evolution profile is 10 mm at a speed of 0,75 mm/s. The total times of printing the test body are shown in scatter diagram 3.1. in which it can be seen that the value of the production time increases depending on the thickness of the applied filament, that is, the smaller the thickness of the filament layer, the longer the production time. In addition to the exponential trendline of the total production time, the diagram shows the surface roughness line Ra. It can be seen from the diagram that the lines intersect at 0,1 mm thickness of the applied filament layer. Furthermore, the diagram shows that the variability of the obtained model for the manufacturing time in relation to the thickness

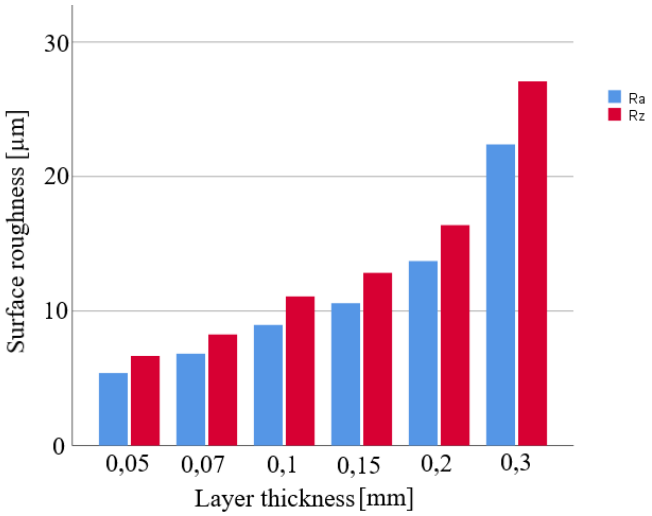


Diagram 3.2. Comparison of roughness

Table 3.7. Descriptive statistics

	N	Range	Minimum	Maximum	Mean	Std. Deviation
Build time in minutes	6	253	30	283	120,33	96,628
Ra	6	16,991	5,390	22,381	11,308	6,156
Rz	6	20,421	6,659	27,080	13,715	7,389

	N	Range	Minimum	Maximum	Mean	Std. Deviation
Build time in minutes	6	253	30	283	120,33	96,628
Ra	6	16,991	5,390	22,381	11,308	6,156
Rz	6	20,421	6,659	27,080	13,715	7,389

of the filament is R^2=0,89, while the variability of the obtained model for the surface roughness Ra in relation to the thickness of the filament is R^2=0,99. A detailed presentation of the obtained values by descriptive statistics is shown in table 3.7.

From the bar chart 3.2, it can be seen that the roughness of the profile surface Ra and Rz has increasing functions depending on the thickness of the applied filament layer, and it can be concluded that the surface roughness value is smaller with a smaller thickness of the applied filament.

4 CONCLUSION

To estimate the roughness of the surface in engineering practice, the average arithmetical deviation of the profile Ra and the height of the unevenness of the profile measured in ten points Rz are most often used. Comparing conventional methods of metal processing by separating particles, such as turning and milling with 3D printing, it can be concluded that the best obtained roughness of the surface of the test body for a layer thickness of 0.05 mm belongs to the 9th roughness class, i.e. in the context of the mentioned conventional methods, they belong to rough turning and milling. The time required to produce the test body is directly related to the thickness of the applied filament layer. The shortest production time for the test body was 30 minutes for a layer thickness of 0.3 mm, while for a layer thickness of 0.05 mm the production time was 283 minutes.

When printing parts, it is necessary to take care of the application of the printed parts because surface roughness, i.e. micro geometrical irregularities are directly related to the selection of the thickness of the filament layer, and the thickness of the filament layer is directly related to the time required for printing the parts. Based on this, it can be concluded that if you want a better roughness of the printed parts, then you have to choose a smaller thickness of the filament layer with a significant increase in the total production time.

5 REFERENCES

[1] Placek, Martin., (2021), Satista [online]. Available at: https://www.statista.com/topics/1969/additive-manufacturing-and-3dprinting/#dossierKeyfigures, [accessed 26.1.2022.]

[2] Mohammad S. Alsoufi, Abdulrhman E. Elsayed, (2017), How Surface Roughness Performance of Printed Parts Manufactured by Desktop FDM 3D Printer with PLA+ is Influenced by Measuring Direction, *American Journal of Mechanical Engineering*, 5 (5)

[3] Shirmohammadi, M., Goushchi, S. J., & Keshtiban, P. M. (2021). Optimization of 3D printing process parameters to minimize surface roughness with hybrid artificial neural network model and particle swarm algorithm. *Progress in Additive Manufacturing*, *6*(2), 199-215.

[4] Li, Z., Zhang, Z., Shi, J., & Wu, D. (2019). Prediction of surface roughness in extrusion-based additive manufacturing with machine learning. Robotics and Computer-Integrated Manufacturing, 57, 488-495.

[5] Menderes, K. A. M., SARUHAN, H., & İPEKÇİ, A. (2019). Investigation the effect of 3D printer system vibrations on surface roughness of the printed products. *Düzce Üniversitesi Bilim ve Teknoloji Dergisi*, *7*(2), 147-157.

[6] Fakultet strojarstva i brodogradnje, 2.2. Standardizacija (normizacija) i tipizacija, (Standardization (normization) and typification). Available at: https://elemstroj.fsb.hr/pdf/design/normizacija_hrapavost.pdf, [accessed 28.1.2022.]

[7] Radhwan, H., Shayfull, Z., Farizuan, M. R., Effendi, M. S. M., & Irfan, A. R. (2019, July). Optimization parameter effects on the quality surface finish of the three-dimensional printing (3D-printing) fused deposition modeling (FDM) using RSM. In *AIP conference proceedings* (Vol. 2129, No. 1, p. 020155). AIP Publishing LLC.

[8] Mirón, V., Ferràndiz, S., Juàrez, D., & Mengual, A. (2017). Manufacturing and characterization of 3D printer filament using tailoring materials. *Procedia Manufacturing*, *13*, 888-894.

[9] Alsoufi, M. S., & Elsayed, A. E. (2018). Surface roughness quality and dimensional accuracy—a comprehensive analysis of 100% infill printed parts fabricated by a personal/desktop cost-effective FDM 3D printer. *Materials Sciences and Applications*, *9*(01), 11.

[10] Prusa Research, Prusament PLA, [accessed 28.1.2022.]

Fuzzy Logic Modelling of Dross Height in Plasma Jet Cutting of Shipbuilding Aluminium Alloy 5083

I. Peko [a], D. Marić [b], T. Šolić [b], T. Matić [a], M. Samardžić [c], I. Samardžić[b]

[a] Faculty of Science, University of Split, R. Boškovića 33, 21000 Split, Croatia, ipeko@pmfst.hr (I.P.), tmatic@pmfst.hr (T.M.)

[b] Mechanical Engineering Faculty in Slavonski Brod, University of Slavonski Brod, Trg I. B. Mažuranić 2, 35000 Slavonski Brod, Croatia, dmaric@unisb.hr (D.M.), tsolic@unisb.hr (T.Š.), isamardzic@unisb.hr (I.S.),

[c] Đuro Đaković Termoenergetska postrojenja d.o.o. (ĐĐ TEP), Ulica Dr. Mile Budaka 1, 35000 Slavonski Brod, Croatia, samardzic.mijat@gmail.com (M.S.)

Abstract

In this paper experimentations were made on shipbuilding aluminium alloy EN AW 5083 thickness of 8 mm in order to investigate influence of variable plasma jet cutting process parameters such as gas pressure, cutting speed, arc current and cutting height on formation of dross on the exit of the plasma jet from the workpiece material. Dross is significant cut quality response in plasma jet cutting process. It can be defined as blown molten metal concentrated on the bottom side of the sheet. Artificial intelligence method fuzzy logic was applied to model relations between input parameters and analysed response. Prediction accuracy of developed fuzzy logic model was checked by comparison between experimental and predicted data. Mean absolute percentage error (MAPE) and coefficient of determination (R^2) were used as prediction accuracy measures. After prediction accuracy was proved it was concluded that such defined fuzzy logic model represents good basis for further more detailed experimental research in this area. Furtherly, it allows creation of fuzzy expert system that will enable deeper understanding of process parameters effects on dross formation and quite better response prediction.

Keywords: Plasma jet cutting, shipbuilding aluminium, dross height, fuzzy logic modelling

1. INTRODUCTION

Plasma jet cutting process is nonconventional manufacturing process that is very present in shipbuilding and metal industry especially as pre-processing technique for welding of metal sheets. In order to minimize post processing actions such as cleaning and grinding before welding it is very important to reach the best possible cut quality. Aluminium alloy 5083 is a high magnesium alloy with a good strength, excellent corrosion resistance and weldability. Excellent corrosion resistance makes this alloy very acceptable for applications in shipbuilding industry as well as in automotive and aircraft industry. Regarding cut quality responses in plasma jet cutting process of aluminium some authors have already investigated influence of variable process parameters on different quality responses and applied various mathematical techniques in order to find out optimal cutting conditions that result with best possible cut quality. Peko et al. [1] analysed the influence of cutting speed, arc current and cutting height in plasma jet cutting process of aluminium 5083 thickness 3 mm. Cut quality responses that were

analysed are: kerf width, bevel angle, surface roughness *Ra* and *Rz* and material removal rate (MRR). Regression analysis and ANOVA (Analysis of variance) were applied to define mathematical models for responses and to determine the significance of influence of process parameters and their interactions on each response. Multi-objective optimization was performed using Desirability analysis and optimal cutting region where all analysed cut quality responses have optimal values was defined. Peko et al. [2] applied fuzzy logic technique for modelling dross height as cut quality response in plasma jet cutting process of aluminium alloy 5083 thickness 3 mm. Experimentations were made by varying three process parameters: cutting speed, arc current and cutting height. Fuzzy expert system created in this paper was validated and effectively used for prediction of dross height depending of various input parameters values as well as for determination of optimal cutting areas. Peko et al. [3] defined artificial neural network (ANN) model to predict influence of cutting speed, arc current and cutting height on kerf width in plasma jet cutting process of aluminium alloy 5083 thickness 3 mm. Developed mathematical model was tested and validated on two different datasets. After prediction accuracy of developed model was checked 2D and 3D plots were created to analyse the influence of process parameters on kerf width response and to define optimal cutting conditions. Peko at al. [4] conducted optimization of bevel angle in plasma jet cutting process of aluminium alloy 5083 thickness 3 mm using Taguchi method. Process parameters that were varied in experimentations were cutting speed, arc current and cutting height. Main and interactions effects plots were generated to determine optimal cutting conditions. ANOVA was performed to check significance of the influence of each parameter and their interactions on bevel angle response. Kadirgama et al. [5] defined mathematical model by using response surface method in order to predict influence of current, standoff gap and pressure on heat affected zone (HAZ) in plasma cutting of aluminium alloy 6061. Partial swarm optimization algorithm was applied to find out process parameters values that lead to minimal HAZ. Patel et al. [6] investigated influence of arc current, standoff distance, gas pressure and cutting speed on MRR, top and bottom kerf width and bevel angle in plasma jet cutting process of aluminium alloy 6082 thickness 5 mm. In order to discuss the influence of process parameters, main effects plots for each cut quality response were generated. ANOVA was performed to check process parameters contributions on analysed responses. Hamid et al. [7] conducted experimentations on aluminium alloy 5083 thickness 10 mm in order to analyse the influence of process parameters such as arc current, feed rate, gas pressure and cutting distance on surface roughness and conicity responses. Grey relational analysis combined with ANOVA was applied to define parameters values that lead to minimal surface roughness and conicity as well as to define parameters significance for analysed process responses.

In this paper influence of gas pressure, cutting speed, arc current and cutting height on dross height in plasma jet cutting process of aluminium alloy 5083 thickness 8 mm was examined. According to experimental trials constraints regarding process parameters values that do not allow cutting process were defined. Due to width of experimental space and nature of analysed process and response values fuzzy logic technique was applied to describe relations between input parameters and output. Such defined fuzzy logic model enables good base for further design of fuzzy logic expert system that would be upgraded with more detailed experimentations and that will enable even better prediction of dross formation on the plasma jet exit side.

2. EXPERIMENTAL PROCEDURE

All experimentations were conducted on shipbuilding aluminium alloy EN AW 5083 thickness 8 mm. CNC machine FlameCut 2513 (Arpel Automation) was used for cutting. As arc current source an LG 100 IGBT Inverter Air

Plasma Cutting Machine was used. For preparing compressed air as plasma gas compressor SCK5 200 PLUS (ALUP Kompresoren Gmbh) was applied. A purifier and air-drying system are integrated in the compressor. Experimental plan was created according to Taguchi L_{27} orthogonal array where gas pressure, cutting speed, arc current and cutting height were varied on three levels. Constant parameter was outlet nozzle diameter: 1.2 mm. Due to complexity of manufacturing process on the one side and aim to cover as wider experimental space as possible there are some cutting constraints regarding process parameters levels that do not allow cutting of the workpiece material. These process parameters levels are marked in Fig. 1. with bold blue lines. According to these statements there are 9 experimental points where cutting is not possible.

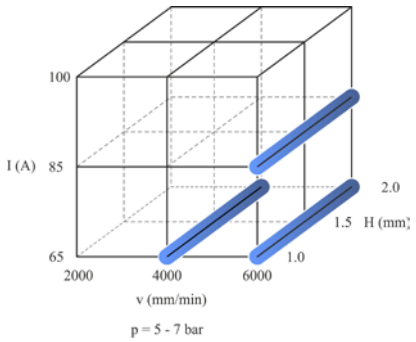


Fig. 1. Cutting process constraints

Experimental trials were made of straight cuts length 80 mm. Universal optical microscope was used to measure dross height on the bottom side of the workpiece material. Each measurement was done on three equidistant places in the middle of the cut. Mean value of all three measurements was taken as experimental result (Fig. 2.). Experimental results as well as variable process parameters values are shown in Table 1.

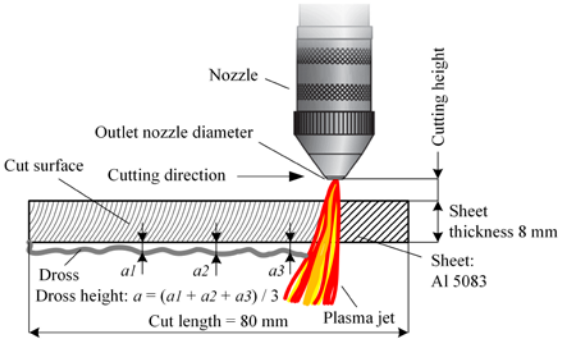


Fig. 2. Experimental setup and dross height measurements

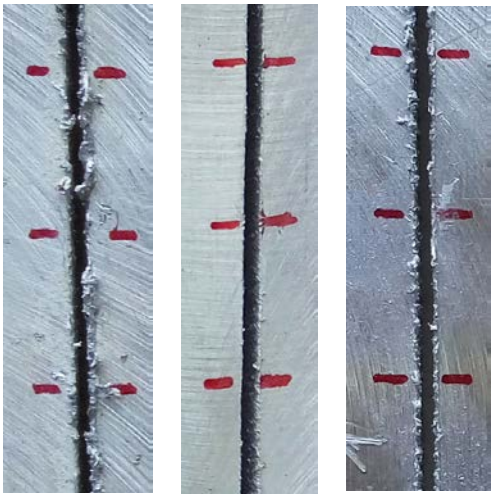
In Table 2. are given examples of dross formation on the bottom side of the workpiece depending on different process parameters values.

Table 1. Experimental results

Exp. Trial	Gas pressure p / bar	Cutting speed v / mm/min	Arc current I / A	Cutting height H / mm	Dross height a / mm
1	5	2000	65	1	1.63
2	5	2000	85	1.5	0.32
3	5	2000	100	2	0.36
4	5	4000	85	2	2.00
5	5	4000	100	1	0.66
6	5	6000	100	1.5	4.12
7	6	2000	65	1	0.50
8	6	2000	85	1.5	0.19
9	6	2000	100	2	0.18
10	6	4000	85	2	0.61
11	6	4000	100	1	0.42
12	6	6000	100	1.5	1.11
13	7	2000	65	1	3.34
14	7	2000	85	1.5	0.36
15	7	2000	100	2	0.24

16	7	4000	85	2	1.11
17	7	4000	100	1	0.63
18	7	6000	100	1.5	1.08

Table 2. Dross formation depending on different cutting conditions



p = 5 bar v = 2000 mm/min I = 65 A H = 1 mm	p = 6 bar v = 2000 mm/min I = 85 A H = 1.5 mm	p = 7 bar v = 4000 mm/min I = 85 A H = 2 mm

3. FUZZY LOGIC MODELLING

Fuzzy logic is one of the artificial intelligence (AI) methods that is quite useful in describing manufacturing processes and systems with imprecise and incomplete measurements data and where greater presence of ambiguity and noises is usual. Also, it is very convenient for modelling of complex manufacturing processes where because of their nature it is not possible to develop mathematical models by using conventional methods such as regression analysis. Aim of this paper is to create functional relations between plasma cutting process parameters and dross height response by using fuzzy logic technique. Created fuzzy logic model will be base for fuzzy expert system that will be updated furtherly with new and more detailed experimental findings.

In order to define relations between process inputs and output fuzzy logic technique uses few modules: fuzzification module, fuzzy inference module and defuzzification module [8, 9]. Fuzzification module converts analysed process inputs and outputs real data into fuzzy linguistic variables using different membership functions such as: Gaussian, trapezoidal, triangular etc. Membership function defines for each value of inputs and outputs degree of membership between 0 and 1. Fuzzy inference module applies knowledge base of fuzzy IF-THEN rules and membership functions to perform fuzzy reasoning and create relations between inputs and outputs. Two most popular fuzzy inference systems are Mamdani and Sugeno. Mamdani is more widely used because of its relatively simple structure and intuitive and interpretable fuzzy IF-THEN rules base. Finally, defuzzification module converts fuzzy outputs into a real values [9-11].

In this paper, in order to develop fuzzy logic model of dross height and to define functional relations between process input parameters and analysed cut quality response Mamdani fuzzy inference system was applied. Applied settings of the Mamdani fuzzy inference system are: and method: min, or method: max, implication: min, aggregation: max, defuzzification method: centroid. Plasma cutting process parameters: gas pressure, cutting speed, arc current and cutting height are taken as inputs and dross height as output of developed fuzzy logic system (Fig. 3.).

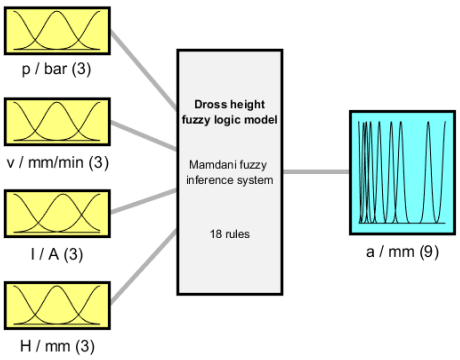
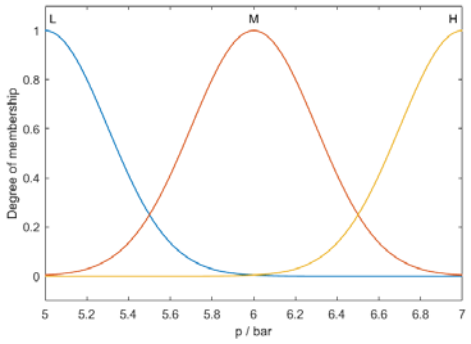


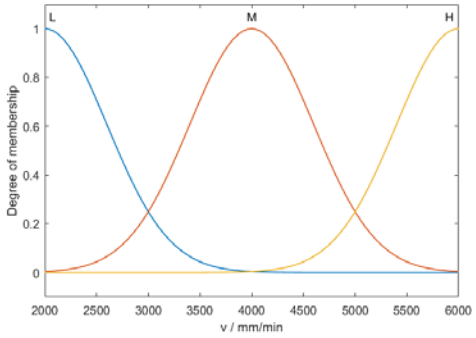
Fig. 3. Fuzzy logic system for dross height modelling

For each of input parameters three Gaussian membership functions were defined: low (L), medium (M), high (H), Fig. 4. a), b) c), d)).

Dross height as output was described with nine Gaussian membership functions: extreme low (EL), very low (VL), low (L), medium low (ML), medium (M), medium high (MH), high (H), very high (VH), extreme high (EH) (Fig. 5.).



a)



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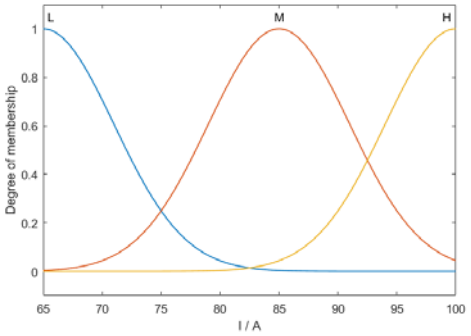

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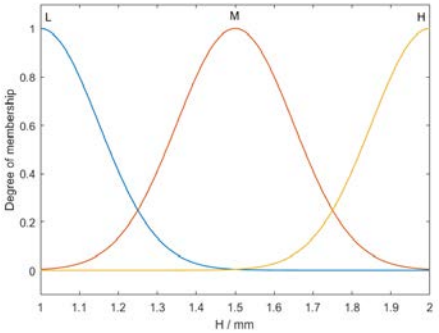


d)

Fig. 4. Membership functions for: a) gas pressure, b) cutting speed, c) arc current, d) cutting height

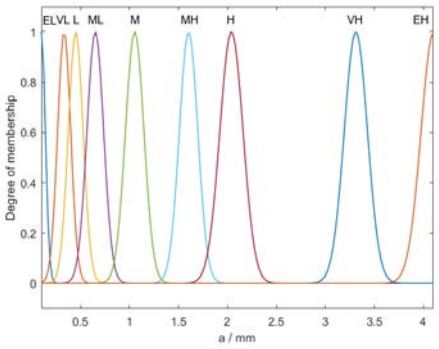


Fig. 5. Membership functions for dross height

In order to define relations between cutting process parameters and dross height set of 18 fuzzy IF-THEN rules was created. Graphical representation of defined rules is shown in Fig. 6.

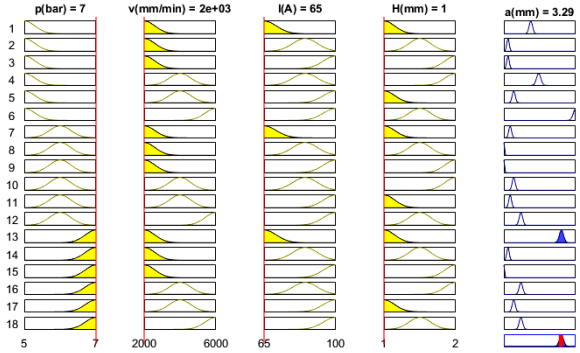


Fig. 6. Graphical representation of fuzzy IF-THEN rules

Converting dross height fuzzy values into non-fuzzy numerical values was performed by using MatlabR2015 defuzzification module toolbox. In order to check prediction accuracy of developed fuzzy logic model comparison between experimental dross heights and those predicted by created fuzzy logic model was conducted. As prediction accuracy measures mean absolute percentage error (MAPE) and coefficient of determination (R^2) were used. Comparison results are shown in Fig. 7 and Fig. 8. MAPE of 14.89% and R^2 of 0.99 present good prediction accuracy of developed fuzzy logic model.

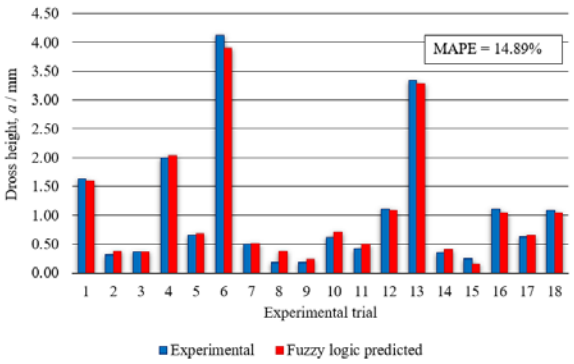


Fig. 7. Comparison of experimental and fuzzy logic predicted dross height with MAPE

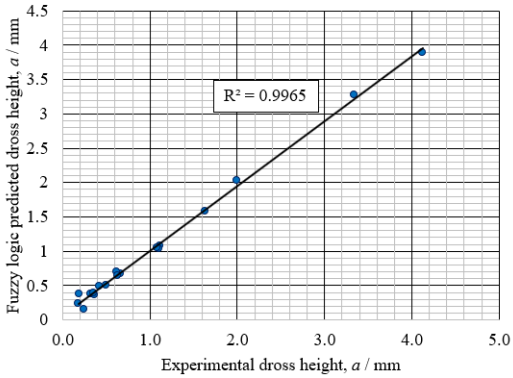


Fig. 8. Comparison of experimental and fuzzy logic predicted dross height with R^2

4. RESULTS

After the prediction accuracy of developed fuzzy logic model was proved the model was furtherly used to generate surface plots to discuss the influence of process parameters values on the dross formation. These plots are shown in Figure 9.

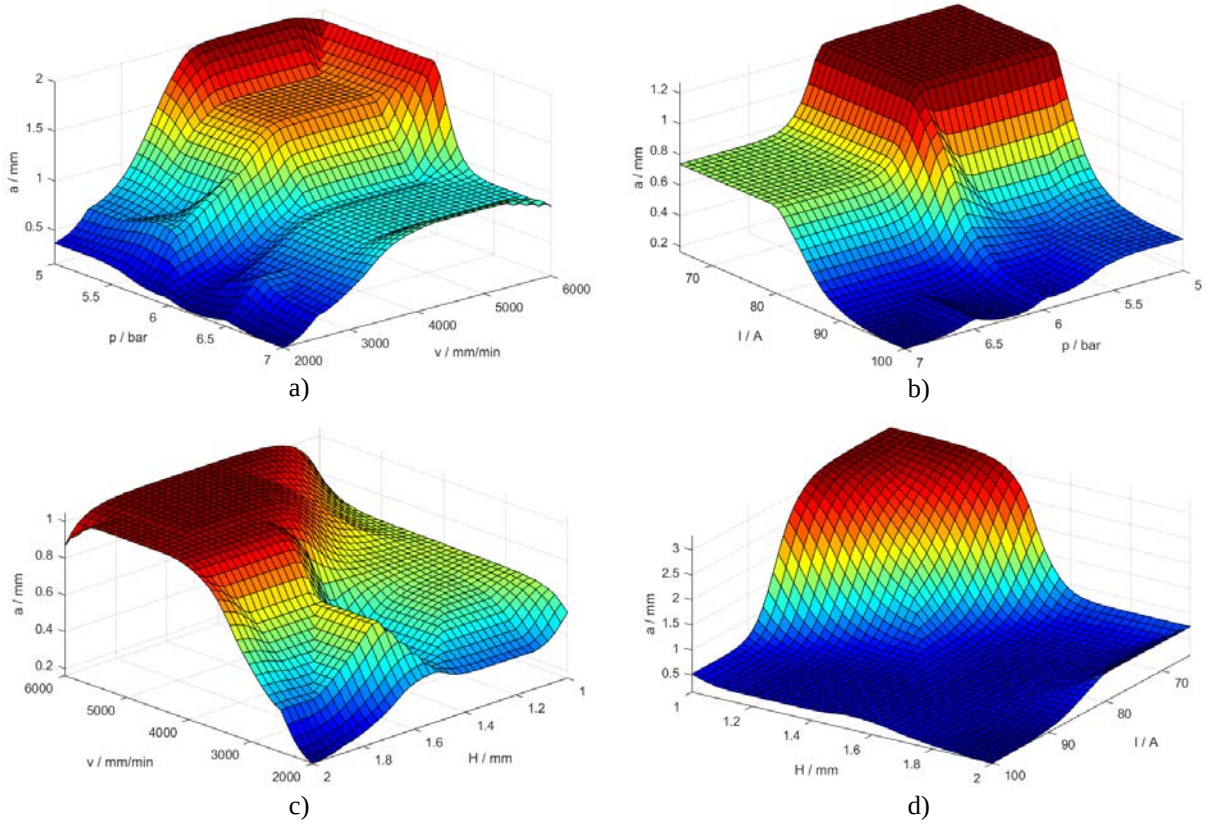


Fig. 9. Effects of process parameters values on dross height when: a) I = 100 A, H = 2 mm, b) v = 2000 mm/min, H = 2 mm, c) p = 7 bar, I = 100 A, d) p = 7 bar, v = 2000 mm/min

From Figure 9 it can be observed that process parameters differently affect dross formation in plasma jet cutting process of aluminium alloy 5083 thickness 8 mm. Figure 9a) shows that higher cutting speed and lower gas pressure when arc current is 100 A result with higher dross on the bottom side of the workpiece. High cutting speed (v: 6000 mm/min) and high arc current (I: 100 A) lead to the high energy input in the workpiece material combined with strong

disturbance of the melt flow, consequently to the higher dross. These parameters values request higher gas pressure to blow molten material from the cutting zone and to achieve lower dross. From Figure 9b) it can be concluded that plasma cutting process is less stable at lower arc currents such as 65 A and due to that dross formation is more noticeable at parameters levels p: 5 bar, v: 2000 mm/min, I: 65 A. Figure 9c) and 9d) confirm earlier mentioned statements regarding cutting speed and arc current values and their influence on dross formation. Regarding cutting height, it can be affirmed that it doesn't have a significant influence on dross formation. It is also stated in [2].

These findings were derived from conducted experimental trials and generated fuzzy logic model. In order to discuss more precisely process parameters effects on dross formation in cutting aluminium sheet 5083 thickness 8 mm it is desirable to conduct additional experimentations and to upgrade presented fuzzy logic model.

5. CONCLUSIONS

In this paper application of artificial intelligence method fuzzy logic to analyse the influence of variable process parameters such as: gas pressure, cutting speed, arc current and cutting height on dross formation in plasma jet cutting process of shipbuilding aluminium alloy 5083 thickness 8 mm was presented.

Based on conducted experimentations and generated fuzzy logic model next findings can be derived:

- Artificial intelligence method fuzzy logic can be successfully implemented for modelling manufacturing processes (such as plasma jet cutting) that have imprecise, uncomplete and obscure responses data and where application of traditional mathematical modelling approaches is not convenient.

- Combination of Mamdani fuzzy inference system, Gaussian membership functions and centroid defuzzification method present good settings to model and predict dross height response.

- Variable process parameters differently affect dross formation.

- Cutting speed and arc current have the most significant effect on the dross height response.

- Process parameters levels such as v: 2000 mm/min, I: 65 A / v: 6000 mm/min, I: 100 A lead to higher dross due to the lower stability of the plasma jet cutting process, higher energy input combined with the strong disturbance of the melt flow. These parameters levels request higher gas pressure values (7 bar) to blow molten material from the cutting area and to accomplish lower dross.

- Based on conducted experimental trials and defined fuzzy logic model optimal cutting parameters that lead to minimal dross formation are: p: 7 bar, v: 2000 mm/min, I: 100 A, H: 1…2 mm.

- This research presents good base for further experimentations in this area. In order to discuss more precisely process parameters effects on dross formation it is desirable to conduct additional experimentations to cover all experimental space and to upgrade presented fuzzy logic model with new measurement results.

6. REFERENCES

[1] I. Peko; D. Marić; B. Nedić; I. Samardžić, Modeling and Optimization of Cut Quality Responses in Plasma Jet Cutting of Aluminium Alloy EN AW-5083. Materials 14 (2021), pp.5559

[2] I. Peko; B. Nedić; M. Dunđer; I. Samardžić. Modelling of Dross Height in Plasma Jet Cutting Process of Aluminium Alloy 5083 Using Fuzzy Logic Technique. Tehnički vjesnik 27 (2020), pp.1767-1773

[3] I. Peko; B. Nedić; A. Đorđević; I. Veža. Modelling of Kerf Width in plasma jet

cutting process using ANN approach. Tehnički vjesnik 25 (2018), pp.401-406

[4] I. Peko; B. Nedić; M. Dunđer; I. Samardžić. Taguchi optimization of bevel angle in plasma jet cutting process of aluminium alloy 5083. Journal of Production Engineering 23 (2020), pp.1-6

[5] K. Kadirgama; M.M. Noor; W.S.W. Harun; K.A. Aboue-El-Hossein. Optimisation of heat affected zone by partial swarm optimisation in air plasma cutting operation. Journal of Scientific & Industrial Research 69 (2010), pp.439-443

[6] S.B. Patel; T.K. Vyas. Parametric Investigation of Plasma Arc Cutting on Aluminium Alloy 6082. Proceedings of the International Conference on Ideas, Impact and Innovation in Mechanical Engineering, Pune, India, 1-2 June 2017, pp.87-93

[7] A. Hamid; O. Novareza; T. Dwi Widodo. Optimization of process parameters and quality results using plasma arc cutting in aluminium alloy. Journal of Engineering and Management in Industrial System 7 (2019), pp.7-14

[8] M. Dragičević; E. Begović; I. Peko. Optimization of dry turning process parameters using Taguchi method combined with fuzzy logic approach. Proceedings of the 16th International Conference on Tribology, Kragujevac, Serbia, 15-17 May 2019, pp.429-435

[9] M. Madić; Ž. Ćojbašić; M. Radovanović. Comparison of fuzzy logic, regression and ANN laser kerf width models. UPB Scientific Bulletin, Series D: Mechanical Engineering 78 (2016), pp.197-212

[10] M. Madić; M. Radovanović; Ž. Ćojbašić; B. Nedić; M. Gostimirović. Fuzzy Logic Approach for the Prediction of Dross Formation in CO_2 Laser Cutting of Mild Steel. Journal of Engineering Science and Technology Review, 8 (2015), pp.143-150

[11] P. Kovač; D. Rodić; V. Pucovsky; B. Savković; M. Gostimirović. Application of fuzzy logic and regression analysis for modeling surface roughness in face milling. Journal of Intelligent Manufacturing, 24 (2013), pp. 755-762

Investigation of the Parameters Effects on the Kerf Width in Plasma Jet Cutting Process of Aluminium 5083 using Fuzzy Logic Technique

I. Peko [a], D. Marić [b], M. Dragičević [c], T. Šolić [b]

[a] Faculty of Science, University of Split, R. Boškovića 33, 21000 Split, Croatia, ipeko@pmfst.hr (I.P.)

[b] Mechanical Engineering Faculty in Slavonski Brod, University of Slavonski Brod, Trg I. B. Mažuranić 2, 35000 Slavonski Brod, Croatia, dmaric@unisb.hr (D.M.), tsolic@unisb.hr (T.Š.)

[c] Burkhard Anlagenbau AG, R. Joweid Zentrum 1, 8630 Rüti, Switzerland, mariodragicevic@hotmail.com (M.D.)

Abstract

This paper examined influences of the process parameters such as: gas pressure, cutting speed, arc current and cutting height on the kerf width cut quality response in the plasma jet cutting process of aluminium alloy 5083. Kerf width is important cut quality characteristic that represents the amount of the workpiece material that is wasted during cutting. According to that, aim of each cutting process is to reach as narrow kerf as possible. In this paper, experimentations were conducted on aluminium alloy 5083 thickness 8 mm according to Taguchi L_{27} orthogonal array. In order to check as wider experimental space as possible constraints regarding process parameters values that do not allow sheets cutting were identified. Artificial intelligence (AI) technique fuzzy logic was applied to define functional relations between input parameters and kerf width and to analyse process parameters effects. Created fuzzy logic model was checked by comparison between experimental and predicted response data by using mean absolute percentage error (MAPE) and coefficient of determination (R^2) as validation measures. Defined fuzzy logic system proved good prediction accuracy of kerf width response and represents good basis for further more detailed experimentations and analysis in this area.

Keywords: Plasma jet cutting, kerf width, fuzzy logic, aluminium 5083

1. INTRODUCTION

Plasma jet cutting process is very present in shipbuilding as well as in construction and automotive industry. It can be effectively used for cutting different types of materials, especially steels and non-ferrous metals, at various thicknesses. Result of each cutting process is cut and its quality characteristics such as: surface roughness, kerf width, bevel angle, dross formation on the exit of the plasma jet from the workpiece sheet. Usually, plasma cutting precedes the welding process and due to that the goal is to achieve the best possible cut quality so the cutting postprocessing and welding preparing actions are minimal. In order to achieve good cut quality many plasma equipment manufacturers define process parameters recommendations. These instructions mostly correspond to manufacturers business goals and concentrate on the several cut quality

characteristics but not all of them simultaneously. Also, there is lack of understanding different process parameters effects on multiple cut quality characteristics and their optimization.

Aluminium alloy 5083 has very good corrosion resistance and strength and according to that it is very convenient in many shipbuilding applications. Also, aluminium characterizes high thermal conductivity and due to that it is quite sensitive to thermal cutting processes such as plasma jet cutting. There exist many insecurities in aluminium plasma cutting in defining process parameters values that lead to optimal cutting conditions and cut quality characteristics. This requires comprehensive researches in order to explore the influence of different process parameters on various cut quality responses and to determine optimal cutting zones. A few papers were already made in this area.

Peko et al. [1] conducted experimentations on the aluminium alloy 5083 thickness 3 mm by varying three process parameters cutting speed, arc current and cutting height. Artificial intelligence method fuzzy logic was applied for prediction of dross height as cut quality response. Prediction accuracy of developed fuzzy logic model was proved by comparison between experimental and predicted data of dross heights. Developed fuzzy logic model was applied to created surface and contour plots to define optimal cutting areas where dross is minimal. Peko et al. [2] defined artificial neural network (ANN) model for prediction of kerf width in plasma jet cutting process of aluminium alloy 5083 thickness 3 mm. Process parameters that were analysed are cutting speed, arc current and cutting height. Developed mathematical model was checked by using response data sets for validation and testing. Furtherly, contour and surface plots were generated to discuss influence of process parameters values on kerf width response and to determine optimal cutting conditions that lead to kerf width as narrow as possible. Peko et al. [3] conducted comprehensive research in order to develop mathematical models for prediction of kerf width, bevel angle, surface roughness *Ra* and *Rz*, and material removal rate (MRR) in plasma jet cutting process of aluminium alloy 5083 thickness 3 mm. Experimentations were conducted by varying process parameters: cutting speed, arc current and cutting height. Mathematical modelling was performed by using regression analysis. Analysis of variance (ANOVA) was applied to define contribution of each parameter as well as their interactions on each cut quality response. Finally, in order to define optimal cutting area multi-objective optimization of defined cut quality responses functions was conducted by using desirability analysis. Solutions were presented numerically and graphically. Kadirgama et al. [4] conducted experimentations on aluminium alloy sheet 6061 to investigate the influence of arc current, standoff gap and gas pressure on the heat affected zone (HAZ). Mathematical modelling of HAZ was performed by using response surface method. Cutting conditions that lead to minimal HAZ were defined by partial swarm optimization algorithm. Peko et al. [5] applied Taguchi method to find out process parameters values that lead to minimal bevel angle in plasma jet cutting process of aluminium 5083 thickness 3 mm. Experimentations were made according to Taguchi L_{27} orthogonal array by varying parameters such as: cutting speed, arc current and cutting height. Main and interactions effects plots were generated to discuss effects of each process parameter and parameters interactions on the bevel angle response. Hamid et al. [6] investigated influence of arc current, feed rate, gas pressure and cutting distance on surface roughness and conicity in plasma jet cutting process of aluminium alloy 5083 thickness 10 mm. Multi-objective optimization as well as significance of process parameters on analysed responses was discussed by application of grey relational analysis combined with ANOVA. Patel et al. [7] conducted experimentations on the aluminium 6082 thickness 5 mm by varying arc current, standoff distance, gas pressure and cutting speed to determine their influence on MRR, top and

bottom kerf width and bevel angle responses. Main effects plots were generated to discuss process parameters influence as well as to define their levels that result with optimal cutting conditions. ANOVA was applied to define contribution of parameters and their interactions on analysed cut quality responses.

In this paper experimentations were made on aluminium alloy 5083 thickness 8 mm in order to investigate influence of gas pressure, cutting speed, arc current and cutting height on top and bottom kerf width responses. Due to complexity of the manufacturing process and the goal to investigate as wider experimental space as possible some constraints regarding parameters values that do not allow sheets cutting were identified. In this case, where application of conventional mathematical modelling approaches is not possible, artificial intelligence technique fuzzy logic was proved as a good solution to define functional relations between input process parameters and output kerf widths. Such defined kerf widths fuzzy logic model represents good base for further design of fuzzy expert system that will be upgraded with additional more detailed experimental data and that will enable better understanding of cutting process as well as more precisely determination of optimal cutting conditions.

2. EXPERIMENTAL PROCEDURE

In this paper experimental trials were made on the aluminium alloy 5083 thickness 3 mm. Plasma jet cutting machine was CNC FlameCut 2513 (Arpel Automation). LG 100 IGBT Inverter Air Plasma Cutting Machine was used as arc current source. As plasma gas compressed air prepared in compressor SCK5 200 PLUS (ALUP Kompresoren Gmbh) was applied. This compressor has an integrated system for gas purifying and drying. Experimental trials were conducted according to Taguchi L_{27} orthogonal array by varying gas pressure, cutting speed, arc current and cutting height on three levels. In all trials nozzle has constant outlet diameter 1.2 mm.

Due to complexity of cutting process and aim to investigate as wider experimental space as possible there are several constraints regarding process parameters levels where cutting process is not possible. These constraints are shown in Figure 1. bold with blue lines. Consequently, there are 9 experimental points excepted from Taguchi L_{27} experimental plan.

In all experimental trials parallel straight cuts length 80 mm were made. Top and bottom kerf width measurements were performed by using Universal Toolmaker's Microscope in the middle of the cut and 15 mm left and right on the top and bottom side of the workpiece sheet. Average value of all three measurements was treated as single experimental result. Whole experimental setup is presented in Figure 2 while experimental results as well as process parameters are shown in Table 1.

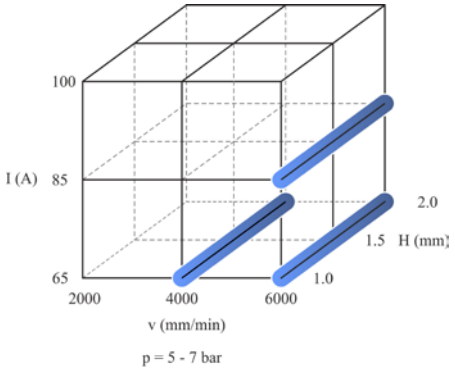


Fig. 1. Cutting process constraints

3. FUZZY LOGIC MODELLING

Fuzzy logic is artificial intelligence method quite convenient for modelling complex manufacturing processes that have imprecise, incomplete and ambiguous measurements data and where application of conventional mathematical modelling techniques is not possible. In this case, due to incomplete data in covered experimental space, aim is to apply fuzzy logic technique to model relations between plasma jet cutting process inputs and outputs. Developed fuzzy logic model will serve as base for fuzzy expert system that will be upgraded with additional experimental results to achieve greater understanding of the cutting process as well as for better prediction and optimization of analysed process responses.

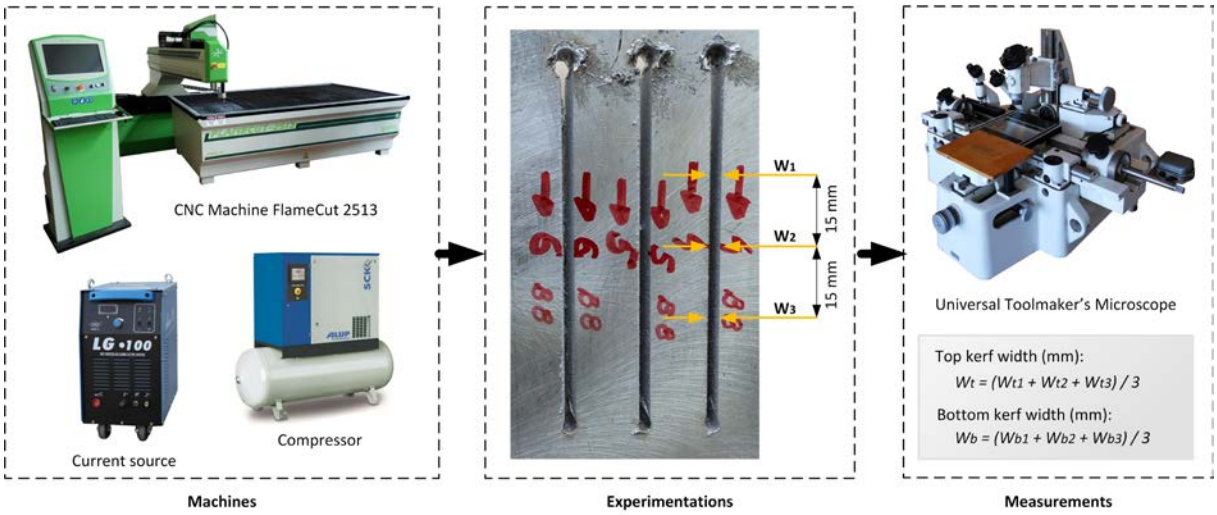


Fig. 2. Experimental setup

Table 1. Experimental results

Exp. Trial	Gas pressure *p* / bar	Cutting speed *v* / mm/min	Arc current *I* / A	Cutting height *H* / mm	Top kerf width *Wt* / mm	Bottom kerf width *Wb* / mm
1	5	2000	65	1	2.306	1.249
2	5	2000	85	1.5	2.697	1.569
3	5	2000	100	2	2.967	1.967
4	5	4000	85	2	2.478	1.267
5	5	4000	100	1	2.465	1.456
6	5	6000	100	1.5	2.679	1.480
7	6	2000	65	1	2.448	1.217
8	6	2000	85	1.5	2.691	1.499
9	6	2000	100	2	3.090	1.857
10	6	4000	85	2	2.779	1.355
11	6	4000	100	1	2.735	1.262
12	6	6000	100	1.5	2.363	0.958
13	7	2000	65	1	2.643	1.514
14	7	2000	85	1.5	2.068	1.567
15	7	2000	100	2	2.653	1.896
16	7	4000	85	2	2.388	1.320
17	7	4000	100	1	2.386	1.314
18	7	6000	100	1.5	2.689	1.254

In order to define relations between process/system inputs and outputs fuzzy logic technique uses few modules: fuzzification module, fuzzy inference module and defuzzification module [8, 9]. Fuzzification module converts numerical values of inputs and outputs, obtained usually in experimentations, into a fuzzy linguistic variables using different membership functions such as: triangular, Gaussian, trapezoidal etc. Membership functions define for each numerical value of inputs and outputs degree of membership between 0 and 1. Fuzzy inference module uses knowledge base composed of fuzzy IF-THEN rules and chosen membership functions to perform fuzzy reasoning and to create functional relations between process inputs and outputs. There are several fuzzy inference systems. Two of them the most popular are Mamdani and Sugeno. Defuzzification module converts outputs fuzzy values into a real values [9-11].

In this paper, Mamdani fuzzy inference system was used to define functional relations between process parameters: gas pressure, cutting speed, arc current and cutting height and cut quality responses: top and bottom kerf width. Process parameters were defined as inputs in fuzzy inference system while top and bottom kerf width as outputs. Settings of applied Mamdani fuzzy inference system are: and method: min, or method: max, implication: min, aggregation: max, defuzzification method: centroid. Scheme of created fuzzy logic system is presented in Figure 3.

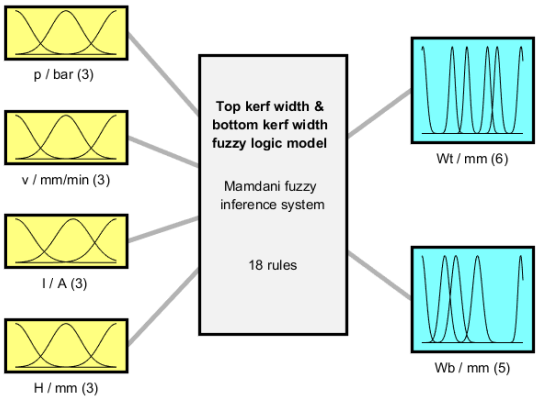
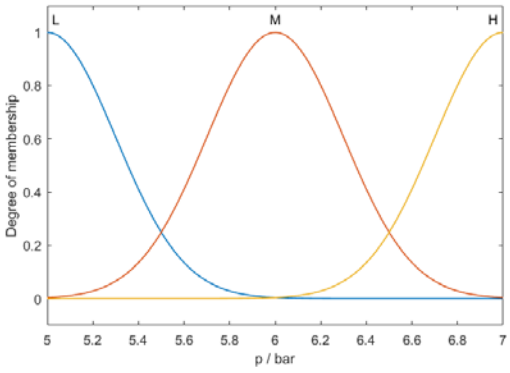
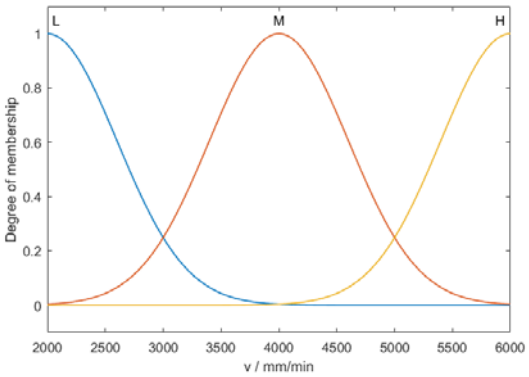


Fig. 3. Fuzzy logic system for modelling of top and bottom kerf width

For each of input parameters three Gaussian membership functions were defined: low (L), medium (M), high (H), Fig. 4. a), b) c), d)). Top kerf width was described with six Gaussian membership functions: low (L), medium low (ML), medium (M), medium high (MH), high (H), very high (VH) (Fig. 5.). Bottom kerf width was defined with five Gaussian membership functions: low (L), medium low (ML), medium (M), medium high (MH), high (H) (Fig. 6.).



a)



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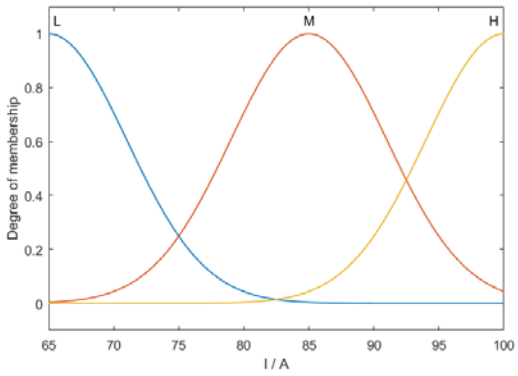

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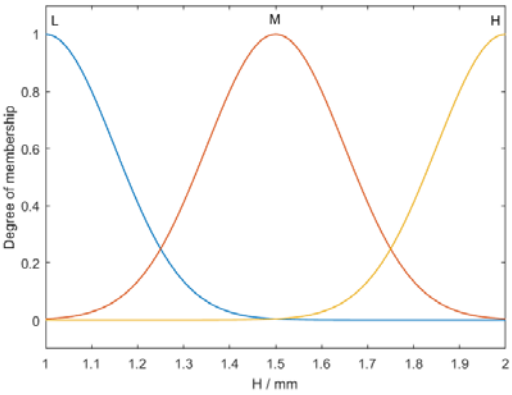

d)

Fig. 4. Membership functions for: a) gas pressure, b) cutting speed, c) arc current, d) cutting height

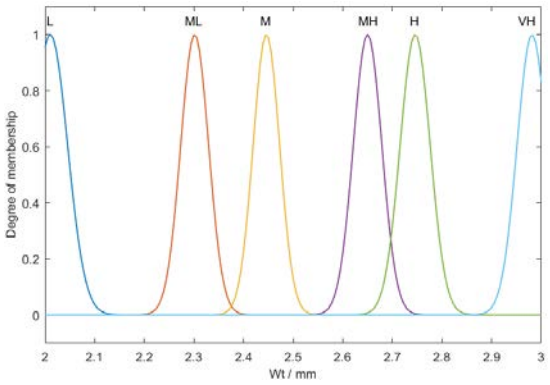

Fig. 5. Membership functions for top kerf width

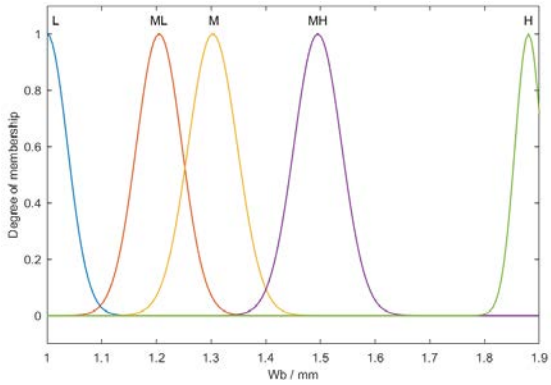

Fig. 6. Membership functions for bottom kerf width

Functional relations between process parameters and analysed responses were established by defining set of 18 fuzzy IF-THEN rules. Graphically these rules are shown in Figure 7.

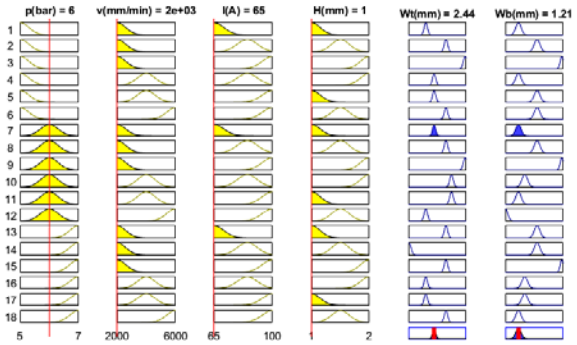

Fig. 7. Graphical representation of fuzzy IF-THEN rules

Finally, defuzzification module converted fuzzy values of top and bottom kerf width into a real numerical values. In order to check accuracy of developed fuzzy logic model for top and bottom kerf width comparison between experimental and predicted data was performed. As prediction accuracy measures mean absolute percentage error (MAPE) and coefficient of determination were applied (R^2). Comparison results as well as MAPE and R^2 are shown in Figure 8. and Figure 9. From these figures it is visible that developed fuzzy logic model for top kerf width (MAPE: 1.36%, R^2: 0.9775) as well as for bottom kerf width (MAPE: 2.98%, R^2: 0.9733) has high prediction accuracy and can be furtherly used for process parameters effects analysis as well as for additional experimentations and creation of fuzzy expert system.

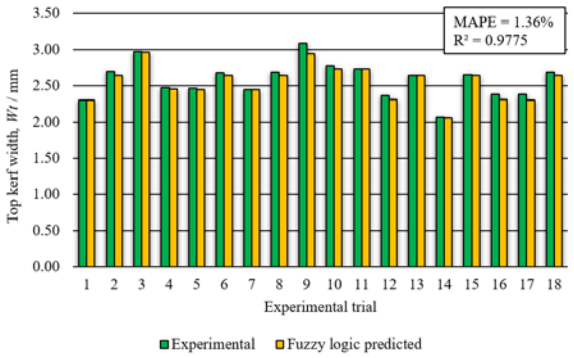

Fig. 8. Comparison of experimental and fuzzy logic predicted data for top kerf width

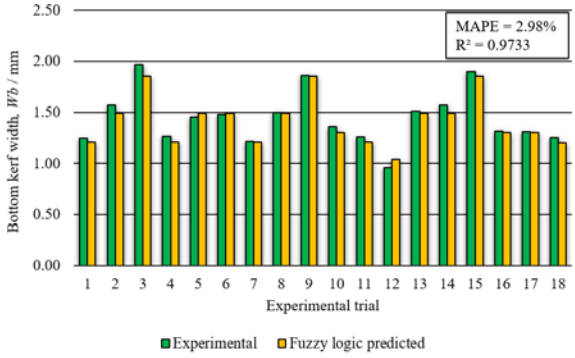

Fig. 9. Comparison of experimental and fuzzy logic predicted data for bottom kerf width

4. RESULTS

In order to discuss process parameters effects on analysed cut quality responses developed fuzzy logic model was used to generate surface plots. These plots represent interactions process parameters effects while two of parameters are kept constant (Fig. 10., Fig. 11.).

From Figure 10. and Figure 11. it is visible that lower cutting speed and higher arc current result with the larger top and bottom kerf width. Cutting heat input is proportional to the arc current and arc voltage and inversely proportional to the cutting speed. That means that higher arc current and lower cutting speed lead to the higher heat input in the workpiece sheet and consequently to the increase of the top and bottom kerf width [3, 12]. From Figure 10. a) and b) it can be derived that higher gas pressure results with the lower kerf width at cutting speed: 2000 mm/min, arc current: 100 A and cutting height: 2 mm. Higher gas pressure makes plasma jet more focused and regular that finally brings to the narrower cut.

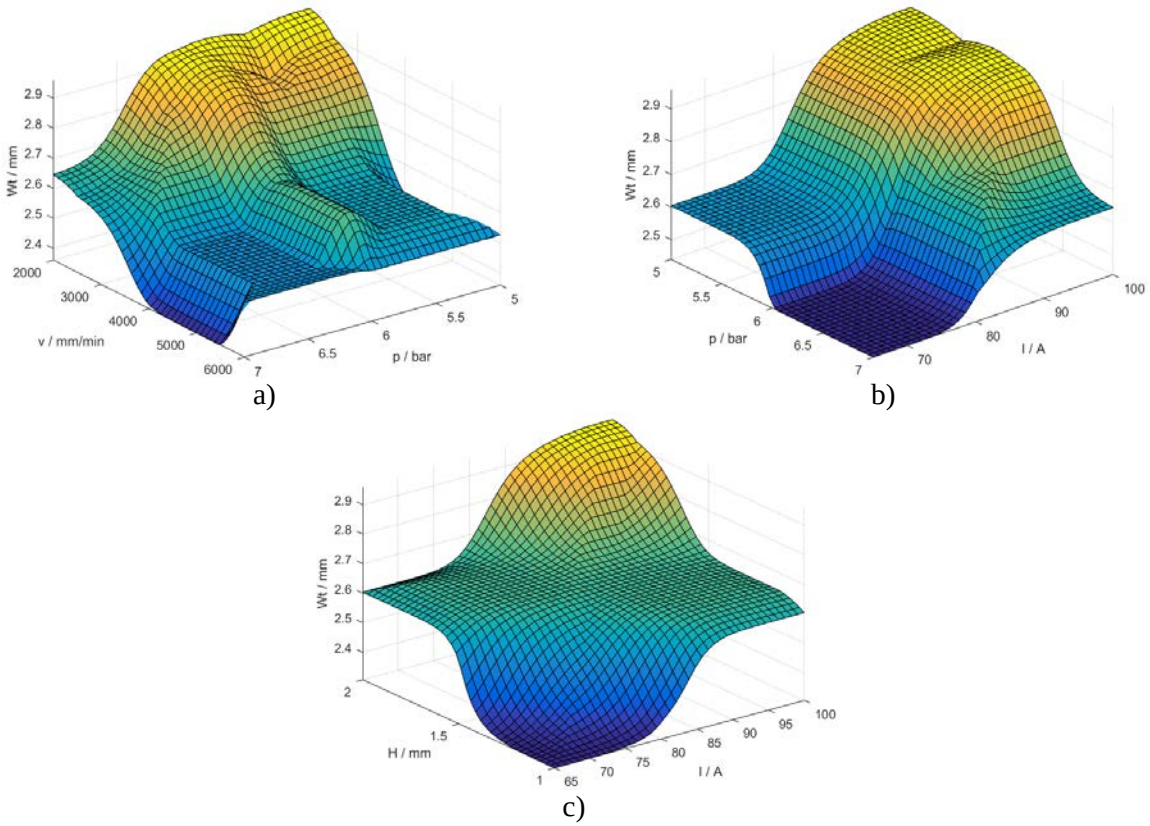

Fig. 10. Process parameters effects on top kerf width when: a) I = 100 A, H = 2 mm, b) v = 2000 mm/min, H = 2 mm, c) p = 5 bar, v = 2000 mm/min

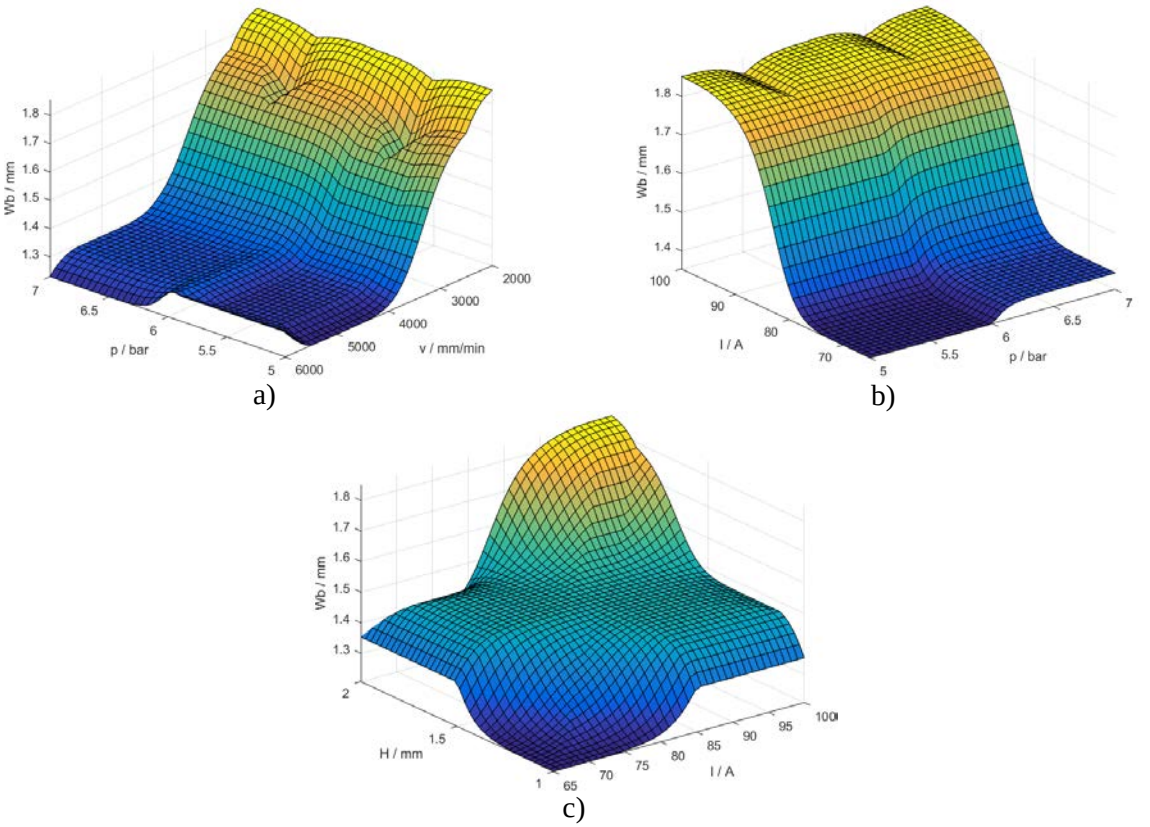

Fig. 11. Process parameters effects on bottom kerf width when: a) I = 100 A, H = 2 mm, b) v = 2000 mm/min, H = 2 mm, c) p = 5 bar, v = 2000 mm/min

From Figure 11. a) and b) it is visible that gas pressure doesn't have so significant effect on the bottom kerf width as on the top. That confirms that higher gas pressure at cutting speed: 2000 mm/min, arc current: 100 A and cutting height: 2 mm contributes more to the focus and regularity of the plasma jet on its top at the nozzle outlet than on its bottom where plasma jet is by itself wider and more erratic. Figure 10. c) and Figure 11 c) confirms that higher cutting height creates a lack of plasma arc coherence resulting with deflection of the arc and larger top and bottom kerf width [3, 13].

Above mentioned statements are derived according to conducted experimental research on aluminium sheet 5083 thickness 8 mm and defined fuzzy logic model. In order to determine more precisely conclusions about process parameters effects on the kerf width it would be desirable to conduct additional experimentations to cover all experimental space and upgrade created fuzzy logic model.

5. CONCLUSIONS

This paper investigated the influence of variable process parameters on the top and bottom kerf width values in plasma jet cutting process of aluminium alloy 5083 thickness 8 mm. Fuzzy logic artificial intelligence technique was applied to define functional relations between process parameters and analysed cut quality responses.

According to conducted experimental research and defined fuzzy logic model next conclusions can be given:

- Application of fuzzy logic technique was shown as a good approach to model manufacturing processes such as plasma jet cutting especially when there is lack of all experimental data and when due to unknown and incomplete informations application of traditional mathematical modelling methods is not possible.
- Mamdani fuzzy inference system combined with appropriately defined Gaussian membership functions, set of fuzzy IF-THEN rules and defuzzification centroid method proved as a good settings to predict top and bottom kerf width depending on variable input parameters values.
- All analysed process parameters have visible and significant effect on the top and bottom kerf width.
- Larger kerf width appears in situations when arc current is lower and cutting speed is higher due to higher energy input in the workpiece material. Also, larger kerf width can be expected in situation when cutting height is higher because of plasma jet deflection.
- Higher gas pressure at cutting speed: 2000 mm/min, arc current: 100 A and cutting height: 2 mm results with narrower cut (lower top kerf width) due to more focused and regular plasma jet.
- Gas pressure doesn't have visible effect on the bottom kerf width.
- Based on conducted experimental research and created fuzzy logic model preferable cutting conditions that lead to optimal top and bottom kerf width are: gas pressure: 7 bar, cutting speed: 6000 mm/min, arc current: 100 A, cutting height: 1 mm.
- This work serves as a base for further experimentations with the aim to upgrade developed fuzzy logic model with additional data and to generate fuzzy expert system capable for prediction of kerf width responses in all analysed experimental space.

6. REFERENCES

[1] I. Peko; B. Nedić; M. Dunđer; I. Samardžić. Modelling of Dross Height in Plasma Jet Cutting Process of Aluminium Alloy 5083 Using Fuzzy Logic Technique. Tehnički vjesnik 27 (2020), pp.1767-1773

[2] I. Peko; B. Nedić; A. Đorđević; I. Veža. Modelling of Kerf Width in plasma jet

cutting process using ANN approach. Tehnički vjesnik 25 (2018), pp.401-406

[3] I. Peko; D.Marić; B.Nedić; I. Samardžić, Modeling and Optimization of Cut Quality Responses in Plasma Jet Cutting of Aluminium Alloy EN AW-5083. Materials 14 (2021), pp.5559

[4] K. Kadirgama; M.M. Noor; W.S.W. Harun; K.A. Aboue-El-Hossein. Optimisation of heat affected zone by partial swarm optimisation in air plasma cutting operation. Journal of Scientific & Industrial Research 69 (2010), pp.439-443

[5] I. Peko; B. Nedić; M. Dunđer; I. Samardžić. Taguchi optimization of bevel angle in plasma jet cutting process of aluminium alloy 5083. Journal of Production Engineering 23 (2020), pp.1-6

[6] A. Hamid; O. Novareza; T. Dwi Widodo. Optimization of process parameters and quality results using plasma arc cutting in aluminium alloy. Journal of Engineering and Management in Industrial System 7 (2019), pp.7-14

[7] S.B. Patel; T.K. Vyas. Parametric Investigation of Plasma Arc Cutting on Aluminium Alloy 6082. Proceedings of the International Conference on Ideas, Impact and Innovation in Mechanical Engineering, Pune, India, 1-2 June 2017, pp.87-93

[8] M. Dragičević; E. Begović; I. Peko. Optimization of dry turning process parameters using Taguchi method combined with fuzzy logic approach. Proceedings of the 16th International Conference on Tribology, Kragujevac, Serbia, 15-17 May 2019, pp.429-435

[9] M. Madić; Ž. Ćojbašić; M. Radovanović. Comparison of fuzzy logic, regression and ANN laser kerf width models. UPB Scientific Bulletin, Series D: Mechanical Engineering 78 (2016), pp.197-212

[10] M. Madić; M. Radovanović; Ž. Ćojbašić; B. Nedić; M. Gostimirović. Fuzzy Logic Approach for the Prediction of Dross Formation in CO_2 Laser Cutting of Mild Steel. Journal of Engineering Science and Technology Review, 8 (2015), pp.143-150

[11] P. Kovač; D. Rodić; V. Pucovsky; B. Savković; M. Gostimirović. Application of fuzzy logic and regression analysis for modeling surface roughness in face milling. Journal of Intelligent Manufacturing, 24 (2013), pp. 755-762

[12] K. Kusumoto; J. Wang; K. Nezu. A Study on the Cut Surface Quality of Mild Steel Plate by Oxygen Plasma Arc Cutting. Quarterly Journal of the Japan Welding Society, 17 (1999), pp. 201-208

[13] R. Adalarasan; M. Santhanakumar; M. Rajmohan. Application of Grey Taguchi-based response surface methodology (GT-RSM) for optimizing the plasma arc cutting parameters of 304L stainless steel. International Journal of Advanced Manufacturing Technology, 78 (2015), pp. 1161-1170

Capability of round testing measurements for wrinkling monitoring of thin sheets

R. Sándor [a], G.J. Béres [b]

[a] GAMF Faculty of Engineering and Computer Science, John von Neumann University, Izsáki street 10, 6000 Kecskemét, Hungary, sandor.roland@gamf.uni-neumann.hu

[b] GAMF Faculty of Engineering and Computer Science, John von Neumann University, Izsáki street 10, 6000 Kecskemét, Hungary, beres.gabor@gamf.uni-neumann.hu

Abstract

Evaluating the wrinkling potential of a thin sheet metal during the press forming process is a cornerstone issue for a long time. Some analytical formulas were developed in the past, but the most useful equipment is the finite element simulation today. Both have the common disadvantage that deciding whether wrinkling is dangerous or not is based on the user's experience. With other words, there is still not clearly defined what we consider to wrinkling and by what property do we characterise it. This study presents the applicability of round test measurements in this topic, through the examples of three types of automotive, high strength steels. In the knowledge of these results a quantitative wrinkling criterion might become definable in the future that could show how close we are to the wrinkling risk in the production.

Keywords: Wrinkling of thin sheets, round testing measurements, high strength steels.

1. INTRODUCTION

The main failure mechanisms during the sheet metal forming operations are the fracture and the necking as well as the geometrical defects like wrinkling and springback [1]. However, the exact definition for necking limit with its own drawbacks and advantages were developed more than 50 years [2], other limit curves that may be able to include the wrinkling risk, is still not determined.

Besides, the wrinkling occurrence of the clamped surfaces (e.g. sheet under the blank holder) even depend on the normal pressure, i.e. the blank holder pressure [3]. Thus, the common interpretation of in-plane limit strains or stresses, no longer valid in this case. This means an additional difficulty on one hand, but for some reason, wrinkling is an under-researched area anyway. The most promising theory for the buckling instability is developed by Hutchinson and Neale [4], but the application of their criterion is not user-friendly. Among many other research, Wang and Cao [5] already improved an analytical formula for the direct connection of the binder pressure and the critical compressive stress arisen in the workpiece, but the use of their theory still remains in the background. Moreover, prior going to define the frames of a new wrinkling criterion, e.g. a wrinkling limit diagram, we shall lie down how to distinguish the flat shape from the wrinkled shape. Nowadays, it is the responsibility of the operator and/or the manager, i.e. the quality assurance is strongly affected by human-influenced factors, if an element is vulnerable for wrinkling.

Having regard the above shortcomings, in this paper we deal with the possible application

of the round testing measurement method to characterize the wrinkled form of the sheet flange. Before that, deep-drawing operations were carried out on circular flat blanks with variable blank holder forces to produce different wrinkled shapes. Our results show that although the procedure has drawbacks related to the size limit of the workpiece, the wrinkles are able to be classified based on their wave length and amplitude, too.

2. METHODS AND MATERIALS

In this subsection, the methodology of the deep-drawing tests as well as the round shape measurements are explained.

2.1. Deep-drawing operation

An ERICHSEN 142-40 type universal sheet metal tester equipment was applied for the deep-drawing investigations. The punch speed was constant 20+0.2 mm/min, and all the investigations were continued until we reached a limit cup height value. Finally, 20+0.2 mm drawing depth was applied due to the clamping facilities of the round tester equipment. The blank holder forces were varied between 4 and 8 kN, with a scatter of +0.2 kN. In Fig. 1., a wrinkled and a non-wrinkled cups can be seen after the drawing process. As it is visible, the wrinkles were formed on the flange area, depending on the applied normal force.

Fig. 1. Wrinkled and smooth flange cups after drawing with 4 kN and 7 kN blank holder forces respectively.

In order to reduce the friction between the sheet and the tool elements, a so-called sandwich lubrication was used (oil and polyethylene foil) on the die side of the blank. The punch side remained untreated as it is proposed for deep-drawing by Altan and Tekkaya [6]. The thickness of the polyethylene foil layer was approximately: 0,05 mm, and the lubricant type was BWS HK-280 deep drawing cold forming EP level lubricating oil. The average quantity of oil on each blanks was 87,85 g/m^2.

2.2. Round testing measurements

For the purpose of the quantitative determination of the wrinkling behaviour, a Mitutoyo RA-1500 round tester equipment was used. The number of the measuring points were 7200 per round. The measuring lines were lied as close as possible to the edge of the specimen, but a maximum of 2 mm far from that.

2.3. Applied materials

Three types of high strength steels that are widely used in the automotive industry were applied in this study. The commercial names of these steels are following: DP600, DP800 and DP1000. These are originated from the dual phase (DP) microstructure as well as the tensile strength of the materials.

Thanks to the benefit mixture of the ferrite-martensite phases in the microstructure, these steels can exhibit relatively good formability next to those increased strength. Naturally, the higher the strength, the lower the elongation as it is expected, but even the DP10000 material has a uniform elongation of approximately 6%. Since these steels have higher strength than the usual cold-forming steels, these are more exposed to the risk of wrinkles and springback. In the same time it means that producing wrinkle-free product is associated with the bigger challenge at these steel grades. That is the reason why we have chosen this steel family for wrinkling investigations.

The average value of some basic material properties of the mentioned materials (defined by tensile tests) are listed in Table 1. Here UTS refers to the tensile strength, YS to the yield strength, and A_{80} is the total, while A_u is the uniform elongation of each material. The r-value is considered as the Lankford coefficient.

Table 1. Some basic properties of the applied steels.

Material type	UTS (N/mm^2)	YS (N/mm^2)	A_{80} (%)	A_u (%)	r (-)
DP600	656	444	20.6	12.8	0.803
DP800	879	570	16.0	10.2	0.654
DP1000	1099	758	10.6	6.7	0.702

3. RESULTS AND DISCUSSION

3.1. DP600 material

In this subchapter the geometry obtained by the round tests of DP600 cups are drawn. Two blank holder forces are highlighted to introduce the measurements capability, namely the values of 5 kN and 7 kN. Fig. 2. shows the former case, in which both the peaks of hills and valleys as well as the basic geometric profile is depicted. It follows that the quantitative monitoring of wrinkling can only be successful, if the basic shape error would be separated from the error represented by the wrinkles.

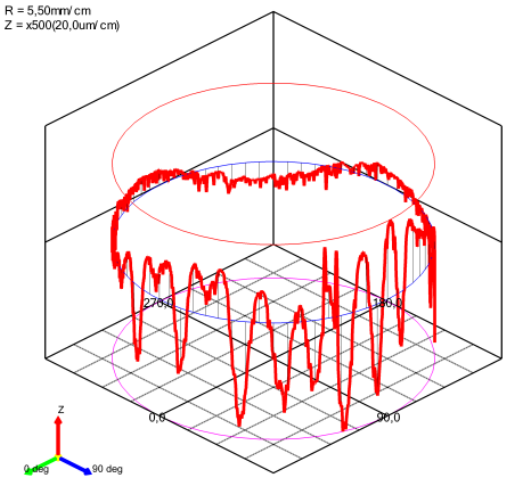

Fig. 2. Wrinkling made visible with the round testing measurement for DP600, next to 5 kN blank holder force.

To reach this goal, first we studied the results of the harmonic analysis (Fig. 3.) and define the limit shape error values, which are not related to wrinkling. After several attempts we have filtered the values that fall below 15 μm, and rise above 1500 μm.

The lower limit decision can be explained by the fact the values under 15 μm relate to the magnitude of the surface roughness. While, above 1500 μm shape deviation, the error is not locally, thus it cannot refers to the wrinkles.

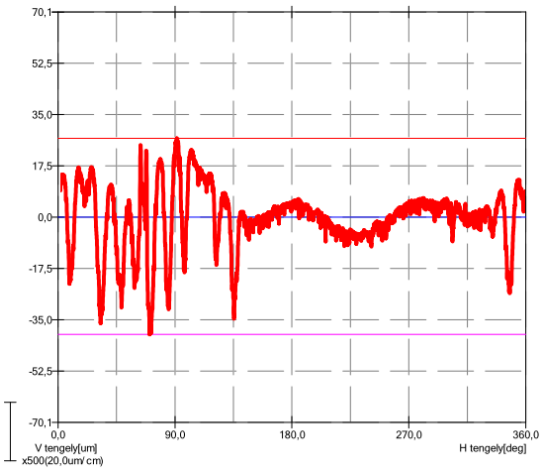

Fig. 3. Harmonic analysis of the round testing measurement for DP600, next to 5 kN blank holder force.

After sorting the signs according to the defined filters, the wrinkles become well-visible and characterisable: Fig. 4. depicts almost purely the wrinkling (except the values under 15 μm), and Fig. 5. signs the general shape error (which can be considered as the earing phenomenon of the cups).

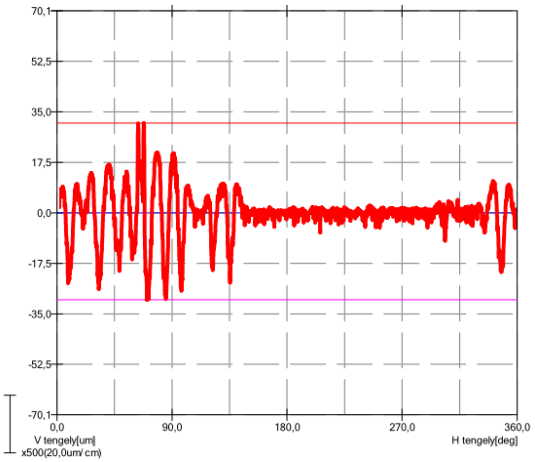

Fig. 4. Harmonic analysis filtered to x<1500 μm; DP600, 5 kN.

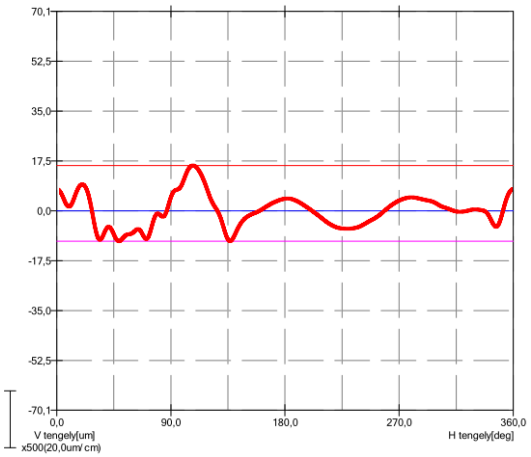

Fig. 4. Harmonic analysis filtered to x>1500 µm; DP600, 5 kN.

Using this method it can be observed that the biggest distance between the peaks is 67 µm, which can be interpreted as the maximum amplitude of the wrinkling. The number of the wrinkles is ~28 that means an average value of 4 mm in the wrinkling wave length, approximately. Besides, the non-symmetrical deformation of the workpiece is also visible.

Increasing the blank holder force up to 7kN, the extent of the wrinkling was decreased as it can be seen in Fig. 5. Here, all of the the measured points after the filtering process, which excluded the values above 1500 µm, fall in the magnitude of the surface roughness. In other word, apart form the global shape error, the remained signs can not to be considered as wrinkles.

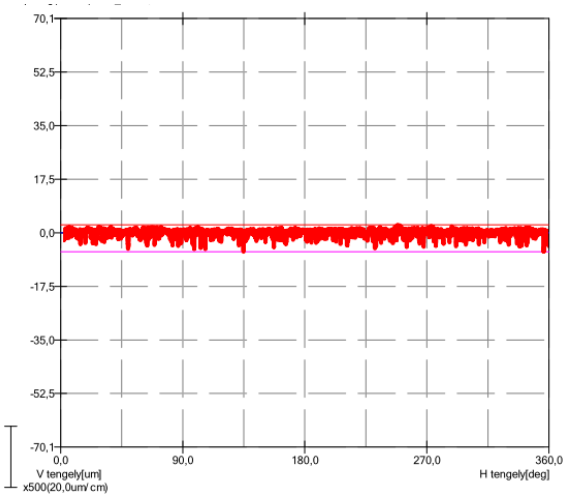

Fig. 5. Harmonic analysis filtered to x<1500 µm; DP600, 7kN.

3.2. DP800 material

The increase of the blank holder force caused similar results at this material, too. Fig. 6. shows the harmonic signs of the DP800 blank for 6 kN blank holder force. The maximum distance between the peak values is 47 µm. The wrinkle formation is not symmetric just like before. Apparently, the wrinkles are stronger eliminated at 8 kN, as depicted in Fig. 7. However, the maximum peak distance is still 34 µm (higher than the surface roughness), the most of the points are under 15 µm, thus we cannot talk about wrinkles.

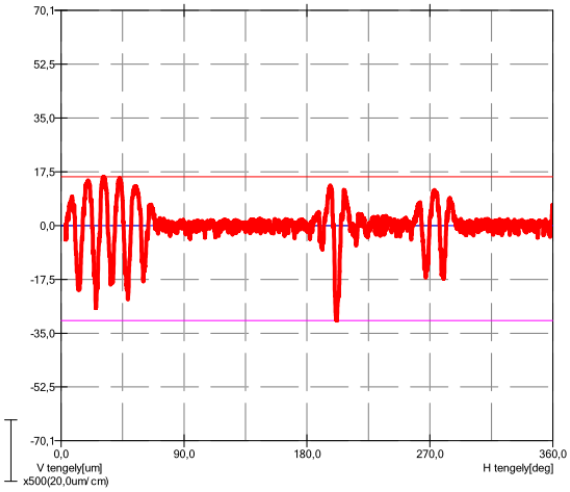

Fig. 6. Harmonic analysis filtered to x<1500 µm; DP800, 6 kN.

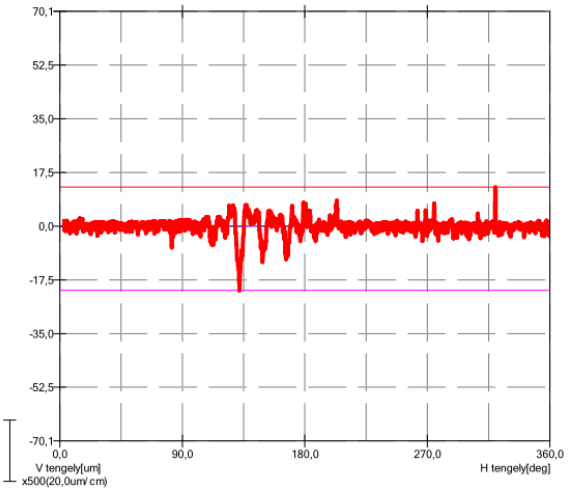

Fig. 7. Harmonic analysis filtered to x<1500 µm; DP800, 8 kN.

3.3. DP1000 material

With the increase of the tensile strength of the material from approx. 800 N/mm^2 to approx.

1000 N/mm^2 (exact values are in Table 1.), a most powerful wrinkling is visible at the same blank holder forces. Comparing Fig. 6. and Fig. 8., wrinkles with higher amplitude appeared at the DP1000 sheet. The highest amplitude is 76 µm, and the average wave length is about 5 mm. The cup flange is definitely wrinkled.

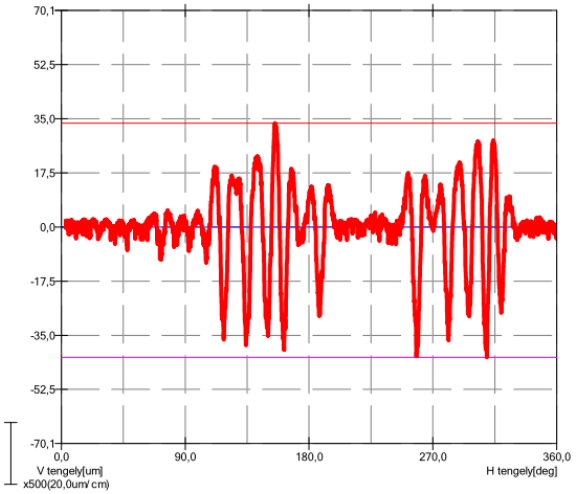

Fig. 8. Harmonic analysis filtered to x<1500 µm; DP1000, 6 kN.

However, similar to the DP800, 8 kN blank holder force was enough to eliminate the wrinkling, as it is depicted in Fig. 9. All of the points are under the condition that means the border of the surface roughness (15 µm). The highest amplitude is lower than 15 µm.

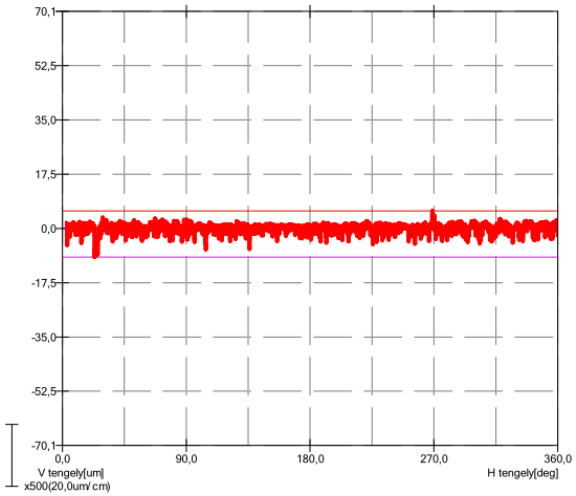

Fig. 9. Harmonic analysis filtered to x<1500 µm; DP1000, 8kN.

4. CONCLUSIONS

In this paper Authors discussed the possibility of the round testing measurements to characterize the wrinkling phenomenon of thin sheets. However, the main drawback of the measurement method is the size limit of the workpiece, it is well-used to define the amplitude and the number (and thus the frequency) of the wrinkling. Using these results, our main object in the future is to create a wrinkling limit condition parameter, which is able to refer how close we are to the wrinkling risk in a real deformation process. Besides, the evaluation habit of the wrinkling, which is basically happens by visual inspection nowadays, could be replaced by this method that can provide quantitative numbers about the wrinkling characteristic.

5. REFERENCES

[1] D. Banabic; H.J Bunge; K. Pöhlandt; A.E. Tekkaya, Formability of Metallic Materials. Springer-Verlag, Berlin-Heidelberg, (2000), pp.173-178.

[2] S.P. Keeler; W.A. Backofen, Trans ASM 56 (1963), pp.25-48.

[3] S. Geleji, A fémek képlékenyalakításának elmélete. First Edition, Publisher of Hungarian Scientific Academy, Budapest, (1966).

[4] W. Hutchinson; K. W. Neale, Wrinkling of curved thin sheet metal. Proceedings of International Symposium on Plastic Instability, Paris, France (1985) pp.1841–1914.

[5] J. Cao; X. Wang, An analytical model for plate wrinkling under tri-axial loading and its application. International Journal of Mechanical Sciences 42 (2000), pp.617-630.

[6] T. Altan; A.E. Tekkaya, Sheet Metal Forming Fundamentals. First Edition, ASM International, Materials Park, OH 44073-0002 USA, (2012).

Protection of exercise equipment by electrostatic powder coating

M.Stoić [a], M. Blažević[a], K. Horvat [b], A. Stoić [a]

[a] University of Slavonski Brod, Trg I.B.Mažuranić 2, 35000 Slavonski Brod, Croatia, mstoic@unisb.hr, mblazevic2@unisb.hr, astoic@unisb.hr

[b] Strojarska tehnička škola F. Bošnjakovića, Konavoska 2,10000 Zagreb, Croatia, horvat.katarina.93@gmail.com

Abstract

The paper describes the plasticization of exercise equipment that is intended for use in outdoor conditions and is subject to various external influences such as rain, snow, solar radiation, freezing, etc., which contribute to the formation of corrosion processes. The process of metal plasticization aims to ensure the longevity of the material and protection, as well as the longevity of the aesthetic appearance. After the plasticization process, the thickness of the plasticized layer is controlled using a device for measuring the surface layer, which should be from 60 μm to 80 μm. Three necessary methods for quality control were also carried out: "scratch" method, bending test and impact test. During the execution of the methods, it was observed that the plasticized layer meets all conditions and that the devices are ready for assembly and use.

Keywords: metal plasticization, electrostatic application, corrosion protection

1. INTRODUCTION

The primary function of all coatings is corrosion protection. A secondary function can be the improvement of some physical properties of the surface, protection against mechanical wear, aesthetics, repair of corroded surfaces, etc. Through plasticization processes, coatings of polymer materials with a thickness of 0.2 mm to 5 mm are applied to various metal and non-metal products. The increased use of polymer coatings was also influenced by the trend of environmental protection, given that during plasticization procedures, there is no evaporation of the volatile solvent that pollutes the environment. Plasticization procedures are applied for the protection of unalloyed carbon steels, additional protection of hot-dip galvanized steels (so-called duplex protection systems) or for coating non-ferrous materials such as aluminum. [1]

Powder coating technology is not a new way of protecting construction materials. This technology was funded as a project of the U.S. Environmetal protection Agency. A history of powder coatings starts at 1950. The coatings were applied using fluidized bed process with vynil or epoxy powder. [2]

Since 2000., the metal plasticization process has been increasingly used and also the number of polymers that are using for coating.

2. METAL PLASTICIZATION

The most important procedures for applying polymer coatings are: gluing and coating, hot spraying, melting, fluidization and electrostatic spraying. [1]

2.1. Electrostatic powder coating

Electrostatic powder coating is one of the most common methods of applying polymer coatings. It works on the principle that particles of polymer powder are electrostatically charged and thus attracted to the metal surface.

There are two ways:

- "classical" electrostatic charging of particles (so-called corona processes), by passing the powder through the high-voltage electric field in the spray gun, or

- particle compaction due to friction (so-called tribo-systems), in which electrostatic particle compaction occurs as a result of powder friction against the insulating walls of the spray gun.

Advantage of this method is uniformity of the surface. The sprayed particles are generating repulsive force against each other so that the coating thickness does not increase over a certain thickness. [3]

Factors that affect coating include applied voltage, the properties of powder particles, spraying distance, air pressure, and time [3]

After electrostatic application of the powder, the objects are processed by baking at temperatures from 180 °C to 250 °C, during which a coating is formed from the powder by melting. The process of creating the coating takes place in three stages: powder melting, bonding and spreading. [1]

The economic advantages of electrostatic powder coating are:

- even 99% of the powder that did not adhere to the surface can be reused

- costs of material loss compared to liquid coating systems are minimal

- the powder provides coverage in one layer without additional work on the finished piece

- it is not necessary to apply a primer

- the development of the components of the powder made it possible to use smaller ovens, lower the temperature and shorten the baking time

- there is no need to mix and add solvents, which reduces environmental pollution

- if we take into account the price of protection of one square meter and compare it with the price of classic coatings, in most cases the price of powder protection is lower compared to classic coating systems. [4]

2.2. Equipment for electrostatic powder coating

The working station in which the powder is applied consists of:

- two guns for electrostatic spraying

- a control panel,

- a powder collector,

- a suspension conveyor,

- a fluidizer, and

- oven.

Control panel (Figure 1.) consists of two parts: one for setin the spray gun parameters and the second part of the control panel that regulates the oven, the parameters of the cyclones that draw in the powder, and the speed and direction of the conveyor On the control panel, the desired parameters are set, which depend on the material and the powder that is applied to the metal.

Fig. 1. Control panel [5]

On Figure 2. a powder collector is shown.

Fig. 2. Powder collector [5]

On Figure 3. is shown switched off powder collector, where the powder is all around the working station, while on Figure 4. the powder collector is switched on and there is no powder to see in the working station. During spraying the powder it is important that the powder collector is switched on.

Fig. 3. Switched off powder collector [5]

Fig. 4. Switched on powder collector [5]

The fluidizer (Figure 5.) is a container into which the powder is poured, which should be very clean. It needs to be sifted additionally in order to remove all the impurities (Figure 6.) that can damage the metal, lead to corrosion on those parts and spoil the aesthetic appearance. This device works on the principle of blowing air into the container so that the powder does not stick to the wall of the container and so that it is evenly consumed. The powder in it looks like a liquid. Considering that compressed air enters, it is necessary to use condensate separators so that the condensate does not mix with the powder.

Fig. 5. Fluidizer [5]

Fig. 6. sieving powder [5]

The suspension conveyor must be kept clean in order to better conduct electricity (Figure 7.)

Fig. 7. Cleaning the suspension conveyor [5]

3. PLASTIFICATION OF EXERCISE DEVICES

The exercise equipment is made of structural steel (Figure 8.), and the task is to plasticize it in black.

Fig. 8. Devices made of structural steel, without protection [5]

3.1. Process of plasticization

Before starting plasticizing, it is necessary to prepare the surface for each part to be plasticized:

- Grinding
- Degreasing
- Preheating

Grinding is a mechanical treatment of metal that removes corrosion that has already occurred on the surface. Surface after grinding

The surface after grinding is shown on the Figure. 9.

Fig. 9. Grinding surface [5]

Degreasing should remove all grease from the surface of the material caused by touching the material with fingers or various objects that leave greasy marks. This chemical process is important because otherwise, in all places where fat remains, the texture of the plasticized layer will be worse, thicker, and spots may appear during baking.

Process of degreasing is shown on Figure.10.

Fig. 10. Degreasing [5]

Preheating is done to remove all impurities. The powder is baked at temperatures from 180℃ to 200℃, and preheating is done at a temperature of 100℃. In this way, the fats, if they are left after degreasing, come out. If there are some greasy spots or stains or any traces of impurity, re-chemical treatment and re-preheating of the metal is required. If the material is clean, the applying of powder can start.

Segments enter the station using a suspended conveyor. The powder is applied manually, with a spray gun. After the first layer is attracted to the metal surface, it acts as an insulator and stops attracting dust in that place. In this way, we can regulate the thickness of the applied powder. In the case that the powder is mistakenly applied to a surface that we do not want to plasticize, the powder can be easily removed from the metal using compressed air.

On Figure 11. the application with spray gun is shown.

Fig. 11. Application with spray gun [5]

Before baking, the texture of the applied powder is checked (Figure 12.)

Fig 12. Texture and check of applied powder before baking [5]

The powder-coated parts are placed in the oven. The powder is baked at 200℃ for 20 minutes. The oven has a built-in timer that starts counting down the time when the temperature in the oven is 200℃. Gas is used to heat the oven.

After 20 minutes, the segments are removed from the oven, cooled for 30 minutes in the air and are ready for assembly.

After cooling and before assembling it is necessary to check the texture visual. (Figure 13.)

Fig. 13. Cooling and visual check of texture [5]

3.2. Quality control of the applied layer

A well plasticized surface is 60 µm to 80 µm thick. Before measuring, it is necessary to calibrate the device with which the thickness will be measured. (Figure 14.)

Fig. 14. Calibration of the device for measuring the thickness of the plasticized layer [5]

CONTROL OF THE THICKNESS OF THE APPLIED LAYER

After calibration, the measurement is carried out at several different places on the material. The device records the number of measurements, the minimum, maximum and average thickness (Figure 15.)

Fig. 15. Achieved thickness of plasticized layer [5]

"SCRATCH" METHOD

The surface of the plasticized material is scraped with a sharp object and must not touch the surface of the metal. (Figure 16.)

Fig. 16. "SCRATCH" test [5]

BENDING TEST

The sample bends and the plasticized layer must not crack. (Figure 17.)

Fig. 17. Bending test [5]

IMPACT TEST

The method is performed by strong blows of a hammer at the surface of the sample. If a piece of the plasticized layer that is torn off is larger than the surface it is hit with, the test is not successful.

The performing of the test is shawn at Figure 18.

Fig. 18. Impact test [5]

4. CONCLUSIONS

Plasticization is one of the methods of protecting metals from corrosion. This procedure is gradually being applied more and more for a number of reasons, the most important of which is environmental acceptability. There are no harmful substances that end up in the atmosphere and that harm nature, and there are no harmful substances that have a bad effect on human health. The efficiency of this process is very high because all the powder, which is not applied to the metal,

can be collected by the powder collector and can be reused. When applying the plasticizing layer, it is not necessary to apply a protective layer beforehand, which reduces the protection time. Plasticization is characterized by the quick performance of the surface layer, which provides high quality and an aesthetic appearance. The electrostatic sputtering method is used in the work. Mechanical and chemical treatment of the metal surface is necessary to ensure better adhesion of the powder.

Protecting exercise equipment is very important due to the aggressive effects of the environment, as the equipment is intended for outdoor use, but also due to the very large amount of grease that is applied during exercise and possible impacts. In addition to the necessary protection, an attractive aesthetic appearance is desirable, which are also some of the advantages of plasticization.

Quality control is carried out to establish the quality and thickness of the layer. Using a device for measuring the thickness of the surface layer, it was established that the thickness of the surface layer meets the conditions. After the thickness of the surface layer was satisfied, three necessary methods of testing the strength and quality of the surface layer were performed: "scratch" method, bending method and impact resistance.

It can be safely said that the material is protected against corrosion processes for a long time. Further analysis and control can be carried out if corrosion occurs on the material.

5. REFERENCES

[1] Mehanizmi zaštite od korozije, https://bib.irb.hr/datoteka/749414.Mehanizmi_zatite_od_korozije_-_skripta_2015.pdf, last access 07/06/2022

[2] Powder Coating Technology update, https://p2infohouse.org/ref/23/22398.pdf, last access 07/06/2022

[3] A Study on the Exploration of Electrostatic Powder Coating Materials Suitable for 3D Scanning (matec-conferences.org), https://www.matec-conferences.org/articles/matecconf/pdf/2016/03/matecconf_icmes2016_01004.pdf, last access 25/06/2022

[4] Tomislav_Bosec-Diplomski_rad.pdf, http://repozitorij.fsb.hr/1832/1/28_06_2012_Tomislav_Bosec-Diplomski_rad.pdf, last access 25/06/2022

[5] M. Blažević, final paper 2022, Metal plasticization, University of Slavonski Brod, Technical department

Impact of worn plasma gun parts on cut quality

M.Stoić [a], M. Seifert[a], M. Čuletić Čondrić[a], K. Horvat [b], A. Stoić [a]

[a] University of Slavonski Brod, Trg I.B.Mažuranić 2, 35000 Slavonski Brod, Croatia, mstoic@unisb.hr, mladenseifert@gmail.com, mccondric@unisb.hr, astoic@unisb.hr

[b] Strojarska tehnička škola F. Bošnjakovića, Konavoska 2,10000 Zagreb, Croatia, horvat.katarina.93@gmail.com

Abstract

The paper investigates the influence of worn parts of plasma cutter torch on quality cut. Plasma cutting of structural steel S235JR+N was carried out on a CAT CNC EON 30160 3X HD plasma cutter. Two thicknesses of sheet material, 10 mm and 25 mm, were cut with new and worn parts of plasma cutter torch and with different current strengths for each thickness. The aim of the experiment was to prove that the worn parts of plasma cutter torch have a big influence on quality of cut. The other parameters were optimally chosen and kept constant during the experiment. The result showed that it is extremely important to maintain and replace consumable parts of the torch in order to reduce the costs of possible subsequent processing.

Keywords: plasma cutter torch, nozzle wear, plasma cutting parameters

1. INTRODUCTION

Cutting as a metal processing procedure is present in all industrial branches in order to obtain smaller metal parts either from sheet metal or some volumetric shape.

Plasma, laser, water jet and similar cutting procedures are often used for cutting parts from sheet metal. Nowadays, the thickness of material that can be cat with plasma jet ranges from very thin, few millimetres, up to 200 millimeters thick material that makes the plasma cutting more used process. [1]

Ranges of cutting area limits of Cr-Ni steel for plasma, laser and water jet are shown at Figure 1. Plasma process has the widest range of thicknesses in this comparison with laser and water jet.

Plasma is used for cutting aluminum and aluminum alloys, stainless steel, copper and copper alloys and all electrically conductive materials.

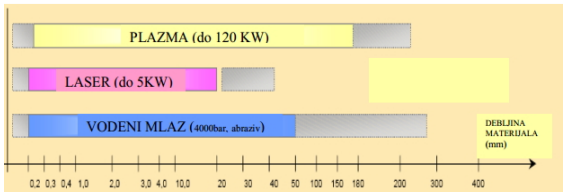

Fig. 1. Cutting area of Cr-Ni steel [1]

2. METHODS AND MATERIALS USED FOR RESEARCH

Plasma jet cutting is an nonconventional manufacturing process based on metal melting and partial vaporization of particles under the action of high temperatures that reach up to 20,000 ˚C. [2]

During the process, plasma gas flows through the electric arc established between a non fusing tungsten electrode that works as the catode and working piece – anode as shown in Figure 2. [3] This is the most frequently used solution – connection with a transferred arc. The

connections can also be done with a non-transferred arc, when arc is established between an electrode and a nozzle. [2]

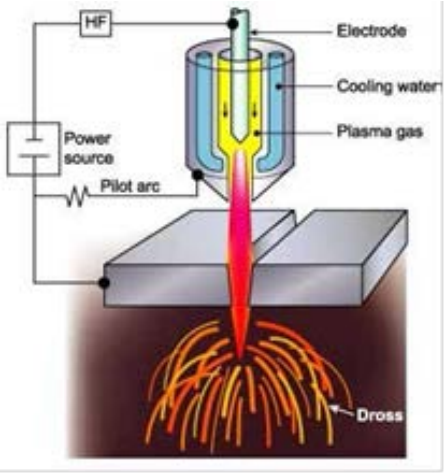

Fig. 2. Plasma Arc Cutting Process [3]

Technical gases used for plasma cutting are oxygen, nitrogen, argon, hydrogen and mixture thereof, which gives the optimal result for all metals. There is also a possibility for using air.

The paper investigates the influence of worn parts of the plasma gun on the quality of the cut.

2.1. Parameters of plasma cutting

The parameters that impacts on the quality of cutting surface using plasma arc are:

Gas selection - not only that certain gases are recommended for certain materials, but the purity of the gas is also important.

Cutting speed - has an impact on the width of the cutting kerf, surface quality, and on the size of the heat-affected areas.

Current strength - thicker materials requires a higher current strength.

Gass pressure - the gas pressure directs the plasma arc. It is necessary to determine the optimal pressure in order to achieve a smaller arc at the outlet.

Height of torch - to achieve an almost perpendicular cut, a setting of the torch hight is important.

Proper assembly of the torch - it's important to use the correct combination of parts in accordance of the thickness of material and the proper current strength.

The cutting parameters depending on the type and thickness of the material are selected from the table.

An example of such a table is given in Figure 3.

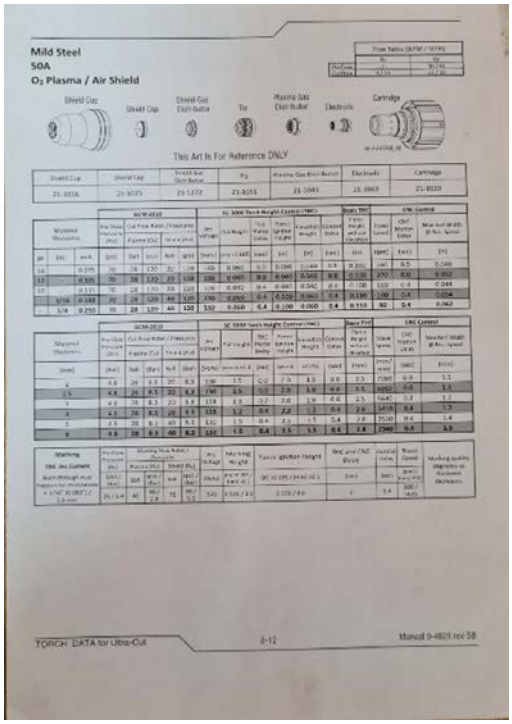

Fig. 3. Cutting parameters [4]

2.2. Plasma cutter torch

The parts of plasma cutter torch listed below, and showed on Figure 4 are from the CAT CNC EON 30160 3X HD cutter on which the experiment was performed.

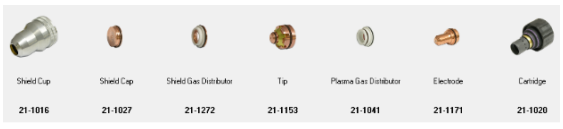

Fig. 4. Parts of plasma cutter torch [4]

Electrode

The electrode is the first part that is placed in the Cartridge, Figure 5. As the main contact point for the plasma arc, the electrode gets very hot. During operation, it can reach 3000 degrees Celsius. For this reason, most plasma cutting electrodes are liquid cooled. [4]

Fig. 5. Electrode [4]

Nozzle

On the outside of the nozzle there is a small round opening, the shape of which is an indicator of the nozzle's wear. (Figure 6). After some time of work, that circular opening widens and turns black around the edges.The inner bore of the nozzle is equally important. It is normal to have a white or gray residue in the bore, along with black or gray marks. Black or gray marks are usually carbon marks formed during arc initiation.

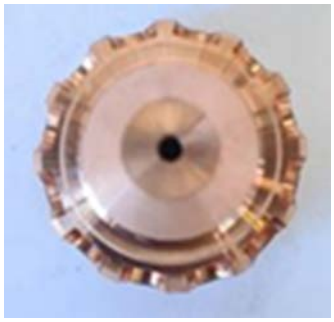

Fig. 6. Nozzle [4]

Protective cap

The cap protects the nozzle from double arcing from the workpiece during piercing or in case of contact during stationary cutting. It also helps to cool the nozzle and control the squareness of the cutting edge. For optimal cutting edge angle, the cap's main opening must be perfectly centered in relation to the nozzle's main opening. Damage to the cap can occur for several reasons. Problems most often arise when the machine punches too close to the workpiece, so it is important to follow the manufacturer's parameters for setting the punching height and punching time. Caps can also fail when the electrode itself is allowed to work more than recommended, i.e. to work in a worn condition, thus affecting the condition and wear of the cap.

The protective cup is shawn on Figure 7.

Fig. 7. Protective cup [4]

Plasma Gas Distributor

It controls the gas flow through the nozzle opening in a way that improves the cutting edge angle, dropping non-ionized gas molecules to the edges of the nozzle opening, increasing nozzle life. The ring also aligns the nozzle opening with the electrode emitter and electrically isolates the negatively charged electrode from the positive nozzle.

The distributor can be made of several materials. It is often the case that companies produce plasma gas diffusers from composites or ceramics. (Figure 8).

Fig. 8. Plasma gas distributor [4]

2.3. Material

The material used in experiment is structural steel S235JR+N.

S235 is a series of non-alloy structural steel with good strength, plasticity, resistance, weldability, good cold pressing and cold bending performance.

They are used to make connecting rods, pins, shafts, screws, nuts, rings, brackets, building structures, bridges, etc. They also have high tensile strength.

Meaning of the steel mark:

S235 – structural steel with a specified strength of 235 MPa.

JR – Impact test below 20 °C.

N – normalized

The tensile strength is Rm=340 N/mm^2

Plasticity limit R_{p02}=225 N/mm^2

Modulus of Elasticity E=2.1x10^5

2.4. Experiment

The paper investigate the impact of worn parts on the plasma cutter torch on the quality of cut.

Plasma cutting of structural steel S235JR+N was carried out on a CAT CNC EON 30160 3X HD plasma cutter.

For the experiment were used sheet plates dimensions 150 mm x 100 mm with two thicknesses: 10 mm and 25 mm.

The thickness of 10 mm was cutted by current strength of 100 A, and the thickness of 25 mm was cutted by current strength of 200 A. In both cases there were used new and worn parts.

To avoid the impact of speed and gas pressure on the quality surface [3], both have been kept constant during the experiment. For example, for current strength of 100 A, the speed was 2286 mm/min, and the gas pressure was 0,5 MPa when cutting with new and with worn parts. The plasma gas was oxygen and as preflow gas shield fluid was used air. The choosen parameters on CNC plasma machine are shawn on Figure 9.

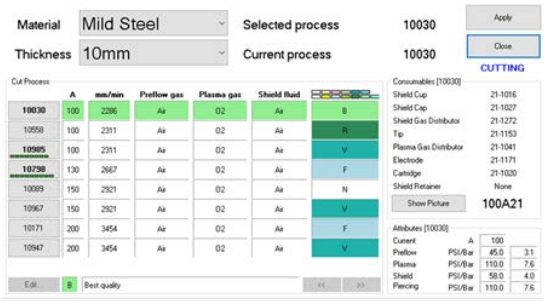

Fig. 9. Parameters on CNC machine [4]

2.5. Wear of plasma nozzle

The parameters that affects to nozzle wear during plasma cutting are: cutting speed, plasma gas pressure and current strength. [5]

Beside them there are several more things that impact the nozzle wear:

- purity of gas used during plasma cutting
- cutting height and dross performing –if the height is not set optimal there will be more dross performed. The bigger the dross perform, the greater the wear (Figure 10.)
- a large amount of rust – more rust, more dross
- the amount of slag on the slats of the machine – the more the slag on the slat, the greater the wear of the nozzle (Figure 11. and 12.)

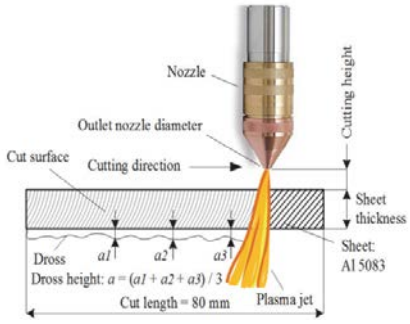

Fig. 10. dross height measurements [5]

Fig. 11. Big amount of slag on the slat of the machine

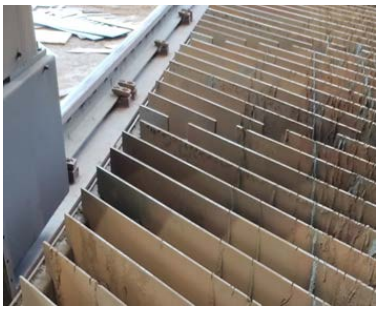

Fig. 12. Clean slats of the machine

3. RESULTS AND ACHIEVEMENTS

3.1. Experiment 1

Cutting with 100 A of current strength and with new parts of plasma cutter torch (Figure 13.) results with proper and neat cut with an unnoticeable bit of sliver in some places.(Figure 14.)

Fig. 13. New parts of plasma cutter torch for 100 A [4]

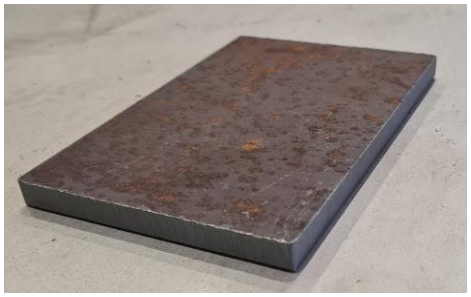

Fig. 14. Position 10 mm cut with new parts [4]

Cutting with 100 A of current strength and with worn parts of plasma cutter torch (Figure 15.) results with a cutted position with a big amount of dross and oblique cut on one and the other side of the board (Figure 16. and Figure 17.).

Fig. 15. Worn parts [4]

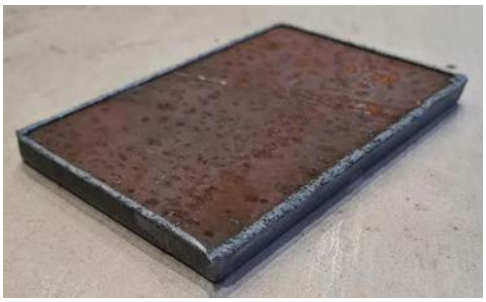

Fig. 16. Position with a lot of dross [4]

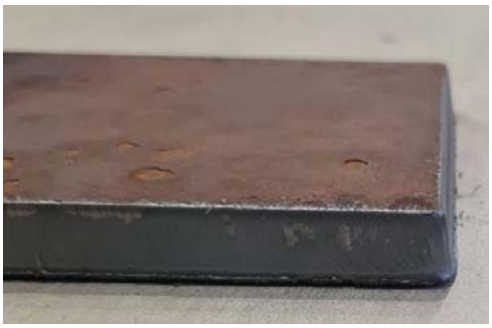

Fig. 17. Oblique cut [4]

3.2. Experiment 2

Cutting with 200 A of current strength and with new parts of plasma cutter torch (Figure 18.) results, as in the experiment 1, with proper and clean cut (Figure 19.).

Fig. 18. New parts of plasma cutter torch for 200 A [4]

Fig. 19. Position 25 mm cut with new parts [4]

Cutting with 200 A of current strength and with worn parts of plasma cutter torch (Figure 20.) results with a cutted position with a big amount of dross and oblique cut on one and the other side of the board (Figure 21.).

On a thicker plate of 25 mm the formation of a large amount of slag on the bottom side of the plate is even more noticeable than at the one of 10 mm, as well as the deviation of flatness on the sides.

The beveling of the edges is a problem because there is a deviation from the given dimensions and the cut position represents a scrap.

Even if the position could fit dimensionally within the required tolerance area, it is necessary to invest additional time and energy in order to remove the large amount of dross.

Fig. 20. Worn parts of plasma cutter torch for 200 A [4]

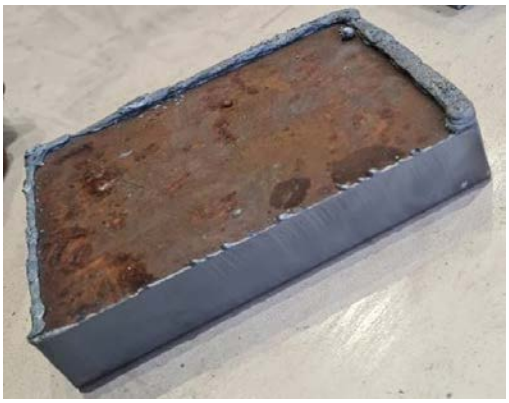

Fig. 21. Position of 25 mm with a lot of dross and oblique cut [4]

4. CONCLUSIONS

In the experimental part, plasma cutting of structural steel S235JR+N was carried out on a CAT CNC EON 30160 3X HD plasma cutter. Two thicknesses of sheet material, 10 mm and 25 mm, were cut with different plasma torch current strengths. Position dimensions of 150 mm x 100 mm were selected for all tests. The aim of the experiment was to prove the influence of worn parts on the quality of the cut.

To avoid impact of other parameters that could influence the quality of cut, all the parameters have been kept constant, both, by cutting a plate of 10 mm thickness and the same by cutting the plate of 25 mm thickness.

Also, the position of the plates was the same, at the clean side of the table of plasma cutting machine.

For the first experiment, the cutting process was performed with a current of 100 A and with new, unused parts of the plasma torch and with worn parts The result with new, unused parts is an extremely clean and flat surface of the cut and imperceptibly little burr in certain places. The result with worn parts was a large amount of slag on the lower surface of the cut and a noticeably slanted cut, which is by no means acceptable.

The same procedure was repeated for cutting a sheet of 25 mm, which requires a current of 200 A. On thicker sheets, the influence of worn parts on the amount of slag and the quality of the cut is even more noticeable. The experimental part has proved that using worn parts of the plasma torch greatly affects the quality of the cut. Therefore it is extremely important to maintain and replace consumable parts of the torch in order to reduce the costs of possible subsequent processing.

5. REFERENCES

[1] Plazma rezanje nehrđajućih čelika, https://servus.hr/strucni-clanci/plazma-rezanje-nehrdajucih-celika-dio-1/,last access 27/ 6/ 2022.

[2] M. Merta; L. Kudrna, Influences on plasma cutting quality on CNC machine. https://sciendo.com/pdf/10.2478/mape-2019-0011, last access 1/ 7/ 2022.

[3] The impact of plasma cutting speed and pressure on surface quality, conference proceedings, TEAM 2016, pp 147 – 150, https://teamsociety.org/_Data/Files/161026135057690.pdf, last access 30/ 6/ 2022.

[4] Influence of plasma gun parts wear on cut quality, M. Seifert, final paper 2022. SuSB, Technical department

[5] Investigating Parameters That Effect to Wear of Plasma Nozzle; Investigating Parameters That Effect to Wear of Plasma Nozzle (matec-conferences.org), last access 27/ 6/ 2022.

Simulation of First Layer Adhesion Errors in 3D printing

I. Šantak [a], M. Duspara [a], J. Cumin [a], B. Kovačević [a], L. Maglić [a], A. Stoić [a]

[a] Strojarski fakultet u Slavonskom Brodu, Trg Ivane Brlić Mažuranić 2, 35000 Slavonski Brod, mduspara@unisb.hr

Abstract

The main purpose of this paper is to explore parameters that affect first layer adhesion to print bed by simulating errors. Research was conducted on modified Velleman K8200 3D printer. Prior to research, 3D model of low surface area object was made. Parameters used for research were : temperature of the nozzle, temperature of heated bed, 3D printing speed and nozzle height. After the research, it is concluded that higher nozzle and heated bed temperatures affects first layer adhesion in a positive way. Lower nozzle height and speed also increase first layer print quality.

Keywords: First layer adhesion, 3D printing, 3D print quality, calibration, optimal 3D printing settings

1. INTRODUCTION

3D printing industry is rapidly growing, especially sector of low cost printers available to general public. Every day, there are more people involved in 3D printing. These people buy their first 3D printer thinking it's a plug'n play system in which you download a model, press the button and after a few hours get a final product. However, it is far from the truth since the lower the cost of 3D printer is, the more work is needed for setting up the printer. The amount of work needed for achieving consistent, high quality prints with low cost printer is tremendous. These printers have metric lead screws, low quality extruders and are built on the cheapest processors. Heat bed connected to the weak power supply can take up to 20 minutes to reach the heat set for printing. [1]

In this paper, errors in low cost 3D printers will be examined. One of the most common errors for beginners in 3D printing is detachment of first layer to heat bed. It is connected with a type of material that is placed over heated bed, temperatures' values, printing speed and nozzle offset from heated bed surface. Parameters will be examined one by one to get the approximate data of what works and what doesn't.

For controlling the 3D printer, Simplify 3D software will be used. For 3D modelling of printing object, Solidworks software will be used.

Settings that are used for succesful 3D printing in this paper should work on every other Fused Deposition Modeling printer. The only requirement is that the printer is well calibrated. It needs to have level heated bed, firmly secured extruder unit and Kapton tape glued over heated bed surface.

2. METHODS AND MATERIALS USED FOR RESEARCH

For this research, low cost equipment will be used showing results that can be achieved using highly available low cost printers. After 3D

modelling of low surface area body, it is imported in Simplify 3D printing software. Default parameters used for printing are listed in table 1. During error simulation, only one parameter will be changed while the rest will remain the same as the ones in the table.

2.1. 3D Printer

3D printer used for this research is modified Velleman K8200. Extruder, lead screw, separated heated bed power supply and control board are replaced from the original version. The reason was to achieve better quality and more reliable prints.

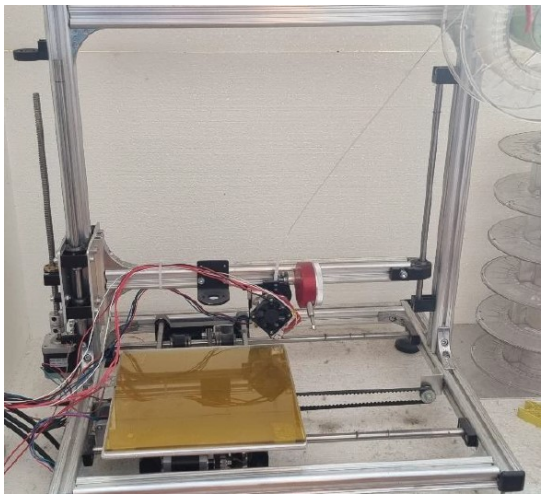

Fig. 1. Velleman K8200 3D printer

Heated bed plate is made from 3 mm tempered glass and is covered with Kapton tape. Extruder used for this research is E3D Titan Aero with 0.4 mm nozzle. It can deliver consistent filament flow which is important for this research. Material used is polylactide (PLA), thermoplastic polyester from “Devil Design” manufacturer. PLA was chosen as it is the most common 3D printing material. Manufacturer recommends hotend temperature of 200-235 °C and heated bed temperature of 50-60 °C.[2]

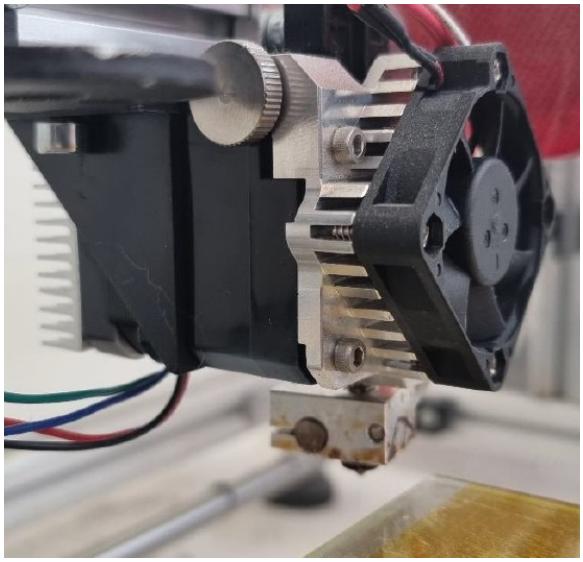

Fig. 2. E3D Titan Aero extruder

2.2. Calibration

Before simulating any errors, it is crucial that printing bed plate is horizontal (level). Failing to achieve this can lead to wrong results as plate leveling is directly connected to first layer adhesion. For this purpose, dial indicator is used. Every corner of printing bed plate was measured and it was assured they are on the same distance from the nozzle. Dial indicator used for this research has 10 mm range and 0.01 mm resolution. It is mounted on z-axis aluminium profile next as close to nozzle as possible.

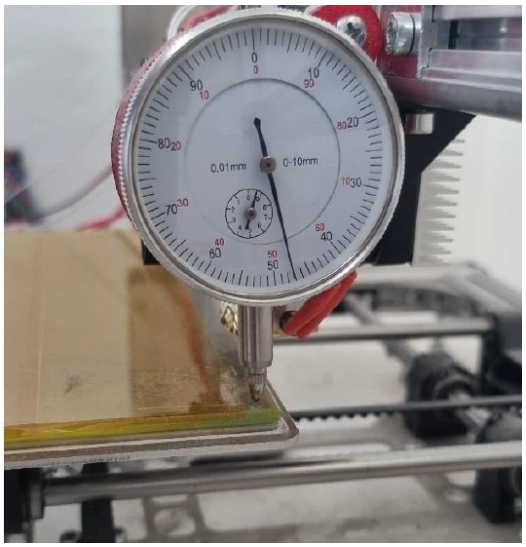

Fig. 3. Dial indicator

2.3 3D modelling software

3D model of print objects was made in Solidworks software. During design of objects, variable adhesion surface was of highest priority. On the image below, top view is presented. Objects are located close to one another to ensure that they are as close to the same nozzle height and heated bed temperature as possible. Calibration of heated bed plate was made but we can't predict how movement of heated bed will change levelness in sub milimeter evel. We also cannot predict whether the temperature field inside heated bed is constant over the whole area.

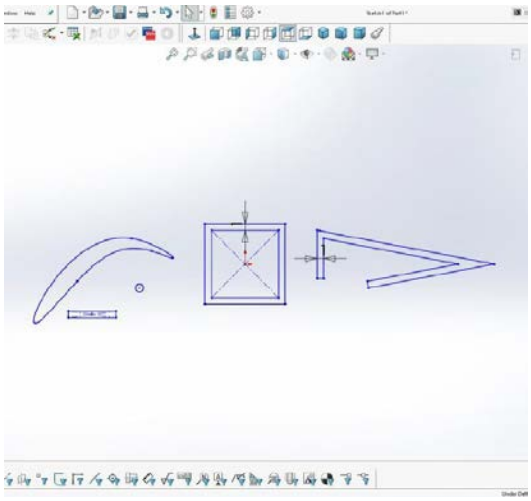

Fig. 4. Printing object top view [3

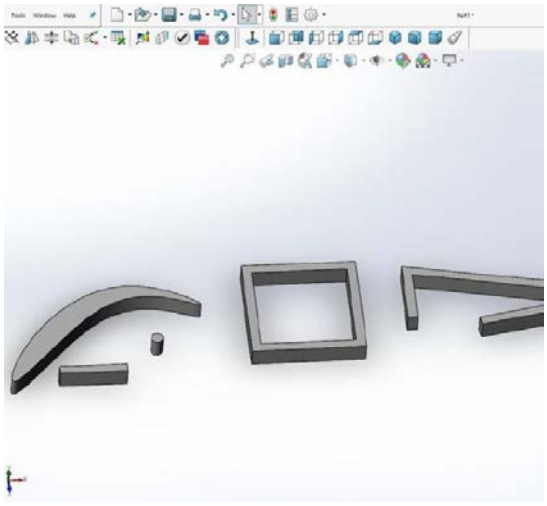

Fig. 5. Final printing object [4

2.4 3D printing software

For this research, 3D printing software Simplify 3D is used. Simplify 3D is highly configurable software that is ideal for this kind of research. In the following table, settings used for default printing will be shown. Settings will include extruder, layer and nozzle settings. .All prints are done without filament cooling because air flow measuring device was not available at the time the research was made. Room temperature was 26° C.

Table 1. Simplify 3D extruder settings

No	Setting	Value	Description
1.	Nozzle diameter	0.4mm	Diameter of brass nozzle connected to hotend
2.	Extrusion multiplier	1.01	Coeficcient that multiplies extrusion flow in order to fill gaps in material or to remove excess material
3.	Extrusion width	Auto	Width of extrusion that exits nozzle.
4.	Ooze control retraction distance	0.5mm	Distance by which the extruder will pull filament in reverse direction once it is done with extruding.
5.	Retraction speed	1800 mm/min	Speed at which the extruder will pull the filament in reverse direction.

Table 2. Simplify 3D layer settings

No	Setting	Value	Description
1.	Primary layer height	0.3mm	Height of each layer
2.	Top solid layers	4	Number of layers at the top of printing object
3.	Bottom solid layers	2	Number of layers at the bottom of printing object, beginning at first layer.
4.	Outline/perimeter Shells	2	Number of lines following perimeter of an object
5.	Outline Directionspeed	Inside-Out	Option that specifies how the outlines will spread.
6.	First layer height	110%	
7.	First layer width	100%	
8.	First layer speed	50%	
9.	Start points	Optimize for fastest printing speed	Option that specifies where nozzle will start printing. Start points can be optimized for speed or aestethics.

Table 3 Simplify 3D default heat, and nozzle settings

No	Setting	Value	Description
1.	Heated bed temperature	1. layer 70 2. layer 70 Remaining layers 50	Temperature of heated bed, which can be specified for each individual layer. Last layer sets the value for the rest of layers.
2.	Nozzle temperature	1.layer 230 Remaining layers 210	Temperature of 3D printing nozzle. Can be specified for each layer separately. Last layer sets the temperature for the rest of the lazers.
3.	Z-axis offset	0.05mm	Distance from lowest point of nozzle to the heated bed. Positive value brings nozzle furthers from the heated bed.

3. RESULTS AND ACHIEVEMENTS

3.1 Nozzle offset

In this error simulation, impact of nozzle offset from surface was examined.Calibration of nozzle zero height was done in the following way. Between the nozzle and the heated bed, thin foil was placed and nozzle was lowered till foil couldn't be pulled. First print was made with default offset of 0.05 mm from the surface.

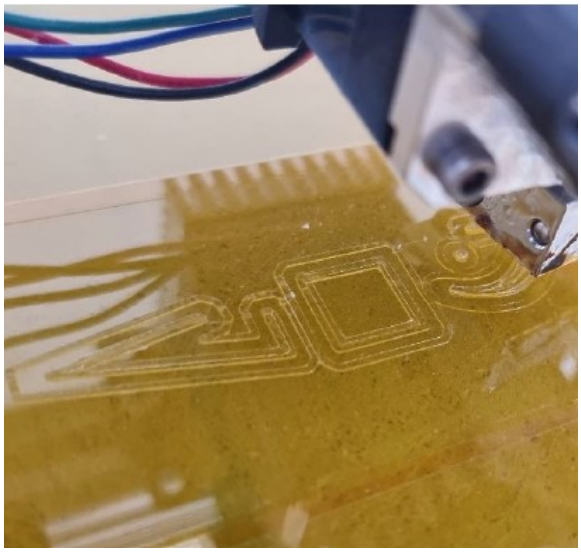

Fig. 6. 0.05 mm first layer

Fig. 7. 0.05 mm final layer

It can be seen that first layer and the whole print were completed successful. The first layer adhesion was excellent.

Next print was done with 1 mm nozzle height.

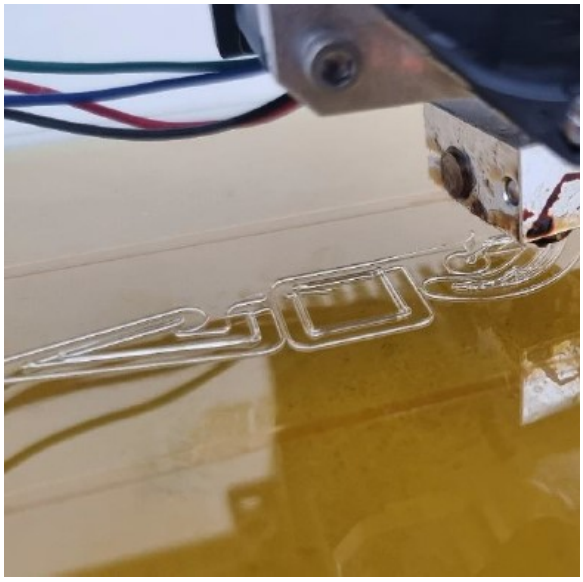

Fig. 8. 1 mm first layer

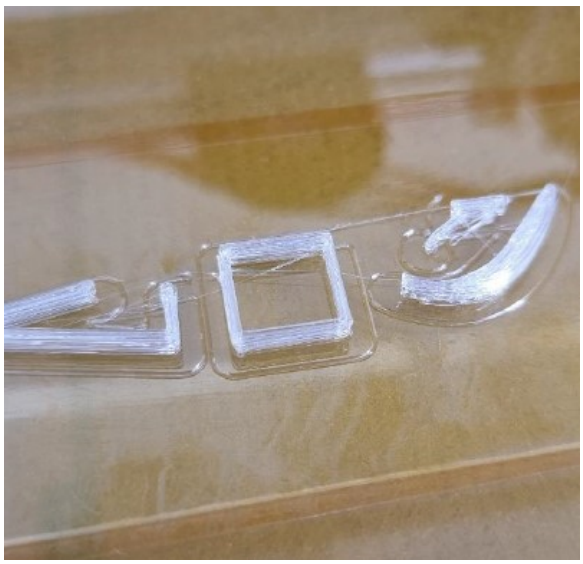

Fig. 9. 1 mm final layer

First layer adhesion was very weak and final print resulted in low quality product.

3.2 Heated bed temperature

This time adhesion layer was simulated for errors by changing heat bed temperature. First temperature was set to be 30°C. The temperature of heat bed will apply for the first and second layer. For remaining layers it is set to 50°C which is the manufacturer's recommendation.

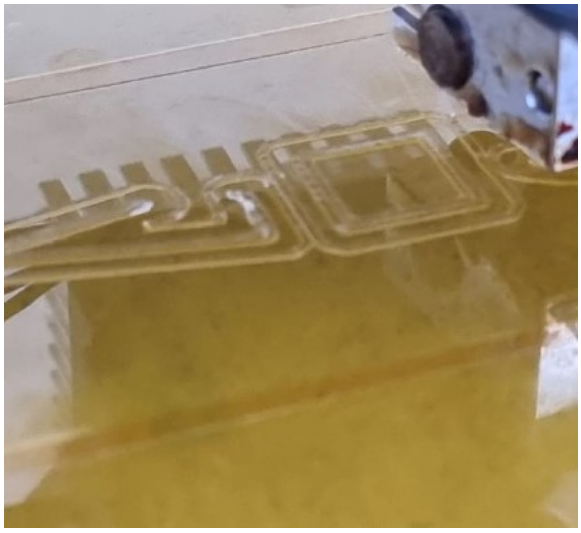

Fig. 10. 30 °C first layer

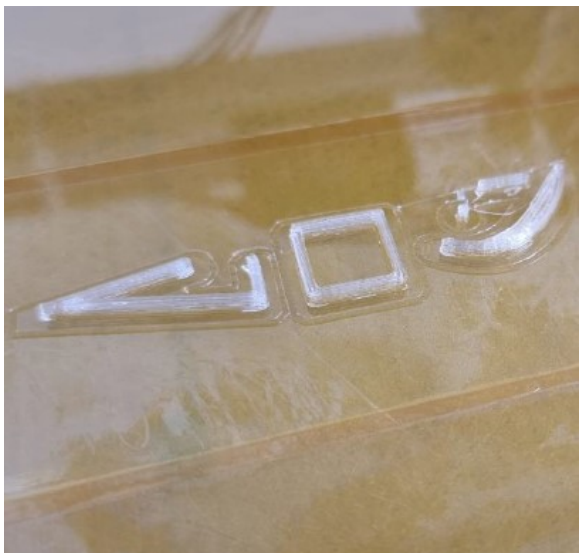

Fig. 11. 30 °C final layer

After first layer was printed, it can be seen that adhesion wasn't very good. The main indicators were places that are more white than the others meaning they didn't stick to the surface.

Final product had same shape as the original one, but the quality of places that were detached was not very good.

Next print was done with heated bed temperature of 70°C.

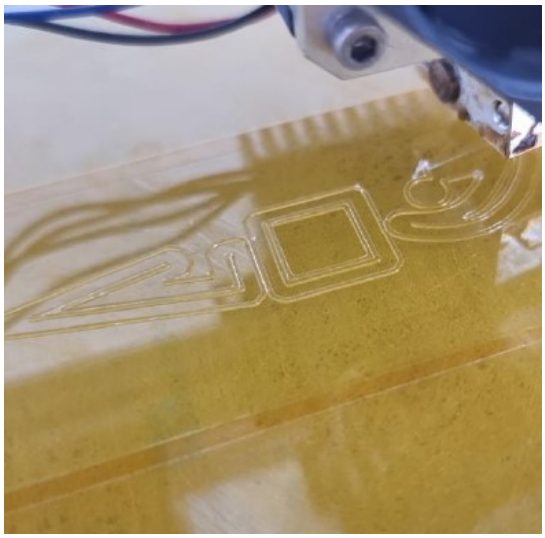

Fig. 12. 70 °C first layer

Fig. 13. 70 °C first layer

Now the print quality of first layer and final product was excellent.

3.3 Nozzle temperature

In this error simulation, nozzle temperature was changed to see how it affects first layer. Nozzle temperature will change only for first layer, after first layer is printed, temperature will return to default value of 210°C.which is in the

middle of manufacture's recommended range.[2]

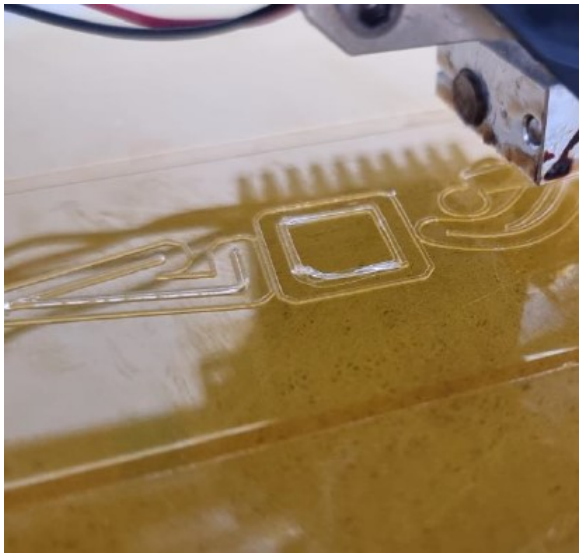

Fig. 14. 190 °C first layer

Fig. 15. 190 °C first layer

After simulation, it can be seen that with defaut settings and nozzle temperature of 190°C, print quality of first layer was very bad. There are many detached areas. It also affected final print lowering its quality.

Next step was to increase the temperature of the nozzle to 230°C. Once the first layer is printed, the temperature will change to 210 °C as it can be seen in table 3.

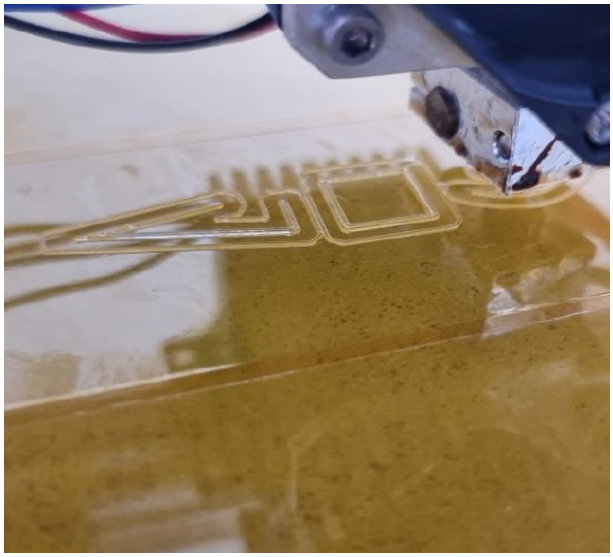

Fig. 16. 230 °C first layer

Fig. 17. 230 °C final layer

Results of first layes and final print were much better than with 190°C.

3.4 Print speed

In this simulation, print speed was changed. It is important to mention that the first layer speed was set up to 50% of printing speed. On the images, the value of printing speed for whole print without first lazer is shown. First print is

done with 2500 mm/min. First layer of the first print is printed with the speed of 1250 mm/min.

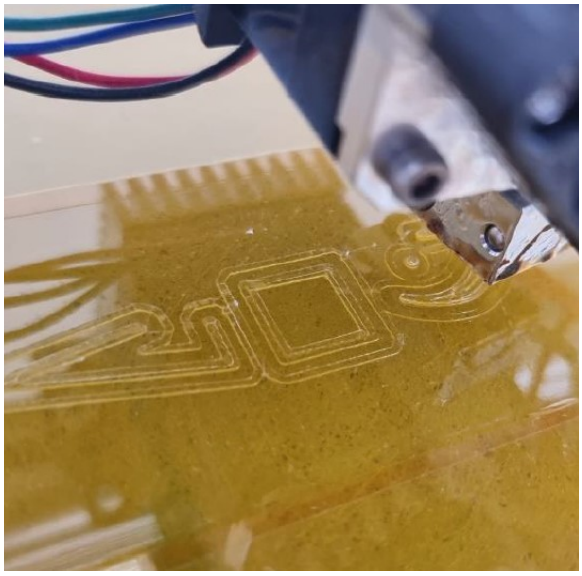

Fig. 18. 2500 mm/min first layer

Fig. 19. 2500 mm/min final layer

Quality of both first layer and final print is high. Next print is done with the speed of 5000 mm/min with first layer speed of 2500 mm/min.

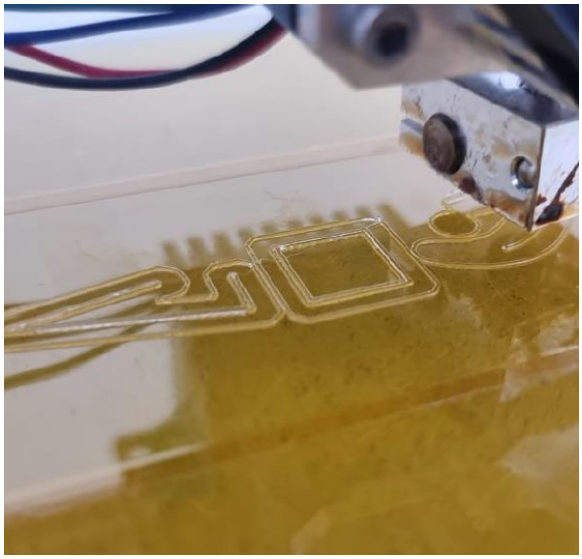

Fig. 20. 5000 mm/min first layer

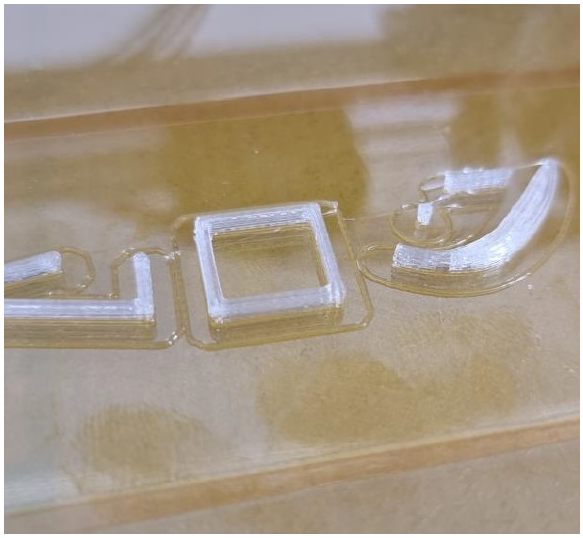

Fig. 21. 5000 mm/min final layer

4. CONCLUSION

After research was done, it can be noticed that the quality of the first layer greatly affects the rest of the print. General conclusion is that the higher the temperature, the better the first layer quality will be. Also, lower speed will increase first layer adhesion and quality. All simulations were done with only one parameter as a variable. It is possible that different combinations of changed parameters will result in different outcomes. For example, increasing the speed but lowering the nozzle could produce excellent results even with lower nozzle temperatures. Suggestions for further research

are to connect AI neural networks to printer with a camera. It would be empowering to see how 3D printer changes its own parameters based on the photos taken after every parameter change.

5. ACKNOWLEDGEMENTS

Special thanks to the Faculty of Mechanical Engineering for providing knowledge that made this research possible.

6. REFERENCES

[1] Michael Petch, the future of 3d printing – additive manufacturing experts forecast the next decade, 2022, https://3dprintingindustry.com/news/the-future-of-3d-printing-additive-manufacturing-experts-forecast-the-next-decade-202831/ (4,7,2022)

[2] Devil Design PLA product card, https://devildesign.com/download/PLA_-_product_card.pdf (4,7,2022)

[3]Simplify 3D,https://www.simplify3d.com/

[4]Solidworks. https://www.solidworks.com/

ROI Analysis of Implementing UV-C, Bi-oxygen or Plasma Ion Decontamination Technologies to Improve Logistic Process Efficiency

Á. Tóth [a], T. Ferenczy [b]

[a] John von Neumann University, 10. Izsáki út, 6000 Kecskemét, Hungary, toth.akos@gamf.uni-neumann.hu

[b] John von Neumann University, 10. Izsáki út, 6000 Kecskemét, Hungary,

Abstract

As a result of Coronavirus, both supply chain processes and internal logistics processes at factories have changed a lot. In many areas the effectiveness of the logistic processes has declined because of the restrictions, which have been implemented against the virus. One of the options to increase the efficiency of the logistics sector is to use UV-C, Bi-oxygen or Plasma Ion decontamination technologies. These decontamination processes can create a safe indoor environment. The authors compare the examined technologies with ROI analysis. The results of the analysis demonstrate, which decontamination application is the most efficient one to reset the efficiency of the logistic processes.

Keywords: logistics, efficiency, Coronavirus, decontamination, UV-C technology, Bi-oxygen technology, Plasma Ion technology, return of investment

1. INTRODUCTION

The social and economic environment has changed because of Coronavirus. Introducing protection measures at the national, regional, and institutional levels, which impact the internal logistics processes of the supply chain and companies.

In the first part of the study, based on practical experience, we describe the logistics areas where protection measures had to be incorporated into the production and work processes and Coronavirus-related protection measures.

The impact of these measures on the efficiency of logistics processes is explained in a separate chapter.

The theoretical methodology used to examine the change in efficiency will be described in the third chapter.

In the fourth part of the study, we show how effectively UV-C Bi-oxygen and Plasma Ion technologies can fight against Coronavirus in the field of surface and air sterilization.

We also list the logistical work processes where cycle times can be reduced with air and surface disinfection, thereby increasing cost-effectiveness so that protection against the virus is also solved.

In the main chapter of the study, we demonstrate the return of investment of the 3 examined technologies. We show which technology is the most competitive both from decontamination effectiveness and financially.

Our hypothesis is that with the help of UV-C Bi-oxygen and Plasma Ion technologies, it is possible to compensate the decrease in efficiency of internal logistics processes caused by Coronavirus.

2. THE IMPACT OF CORONAVIRUS ON LOGISTICS PROCESSES

From the outbreak of Coronavirus in 2019 until July 2021, one of the study's authors worked in logistics. So he has first-hand knowledge of the restrictive measures that affected certain logistics processes. In all cases, the cycle times used in the pre-virus period increased, which resulted in a clear increase in costs. The quality of logistics services has also decreased in many areas. The following are examples of changes in the company's internal logistics processes:

- Due to employee illnesses, the number of shifts has decreased, fewer people had to do the same amount of work.
- Disinfection of the surface of production equipment during production processes decreased productivity.
- Quarantine and disinfect incoming goods for a period of 10 working days resulted slower access to raw materials.
- Wearing a mask and fogging glasses further reduces productivity of logistics workers.
- Complete isolation of shifts changed the work order.
- Non-contact packaging of finished products, storage, and loading onto trucks were implemented.

All these previously listed restrictions resulted productivity decline and increased cycle time at the same time.

In the next chapter, we present the 3 selected air cleaning technologies.

3. DECONTAMINATIN TECHNOLOGIES TO FIGHT AGAINST CORONAVIRUS

The purpose of this chapter is to describe the effectiveness of UV-C, Plasma Ion and Bi-oxygen technologies in dealing with viruses and bacteria, to explain the areas in which these technologies can be used, and finally to describe the possibilities of using these technologies in logistics.

3.1. UV-C Technology

As soon as airborne viruses are formed, they can be destroyed directly. When used at close range, bactericidal ultraviolet light at 254 nm can harm the skin and eyes [1] [2].

On the other hand, UV-C light (207–222 nm) destroys pathogens without harming human tissue [1] [2].

Previous research has shown that 222 nanometres of UV-C light can inactivate airborne influenza viruses. In addition, they examined whether far UV-C light radiation could effectively kill alpha HCoV-229E and beta HCoV-OC43 human Coronaviruses. The results show that low UV-C doses of 1.7 and 1.2 mJ/cm^2 kill 99.9% of airborne coronavirus types 229E and OC43 [1] [2].

Since all human-dangerous Coronaviruses are similar in size and structure, the researchers hypothesize that far UV-C light may show similar neutralizing effectiveness against other human-harmful Coronaviruses, including SARS-CoV-2. In addition to the current accepted official radiation limit value of 3 mJ/cm^2/hour, continuous far UV-C radiation destroys 95% of viruses in 11 minutes, 99% in 16 minutes, and 99.9% in 25 minutes [1] [2].

Thus, by complying with the current ones and staying within the frequency limits, the regulation of low-speed, distant UV-C light radiation can effectively, safely and at the same time significantly reduce the concentration of the airborne Coronavirus in public spaces.

Advantages of UV-C technology [3]:

- It is effective against the majority of nosocomial pathogens.
- The duration of disinfection is short (approximately 15 minutes), but in the case of Clostridium difficile, a longer exposure is necessary (approximately 50 minutes).
- There is no need to close the room as well as the heating, ventilation, and air conditioning system.
- As a result of disinfection, no toxic by-products remain in the environment.
- Costs include only tangible assets, there are no consumables.
- As a result, it diffuses throughout the entire room.

Disadvantages of UV-C Technology [3]:

- During the disinfection process, nobody is permitted to stay in the room.
- Suitable only for final disinfection.
- There is a high investment cost.
- Its effectiveness is influenced by the parameters of usage (e.g. wavelength, UV-C dose, exposure time).
- The equipment and tools must be moved away from the walls.

Overall, it is a widely used technology with good performance rates.

3.2. Bi-oxygen Technology

An ionization process caused by atomic collisions is the basis for Bi-oxygen technology. A space fed by an oscillating electric field collides with fast moving particles. The collisions cause atoms to lose one or more electrons, thereby transforming them into positive ions. In contrast, atoms that gain one or more electrons are transformed into negative ions [4].

Researchers have developed a special electric capacitor that creates controlled ionization of oxygen, water vapor and nitrogen molecules in the air. This ionization process initiates reactions on volatile organic compounds, thereby reducing contamination in the air and on surfaces. This ionization process damages the cell membranes of microorganisms and at the same time inhibits their vital functions [4].

Until now, indoor air quality has been controlled (mechanically) with filters. Thanks to Bi-oxygen technology, air disinfection is now possible independently of mechanical filters or, if necessary, in combination with them. The use of Bi-oxygen technology in any environment reduces chemical, organic and microbial contamination in the air and on surfaces. Bi-oxygen technology differs from technologies that use air filtration and/or purification in the classical sense. The essence of Bi-oxygen technology is that active ions are able to break the bonds of chemical compounds, transforming them into simpler and easier-to-handle basic elements. As for volatile organic compounds, the Bi-oxygen technology "cuts" the main compounds into simpler molecules, which can then be oxidized. In addition, it is possible to completely oxidize the bonds during the process [4].

As with UV-C technology, Bi-oxygen technology sterilizes the air as well. Bi-oxygen is a natural technology that improves indoor air quality. This process eliminates bacteria, airborne dust, odours, and many other chemical contaminants. Besides removing airborne microbes, Bi-oxygen’s technology reduces volatile organic compounds in the air and on surfaces. It can be used in all areas where it is necessary to prevent and reduce chemical and biological contamination (healthcare, food industry, residential and commercial buildings).

There are several advantages of using the Bi-oxygen system [4]:

- There is less maintenance required.
- The heat exchanger coils and nozzles are less likely to be attacked by algae.
- To eliminate algae and microbes, which cause pipeline damage, far fewer chemicals are required.
- The tower's heat exchanger efficiency does not decrease with time.

For bacteria and general viruses, as well as bacteria occurring in the food industry, the results show an effectiveness of over 99%, with no negative effect on food quality [5] [6].

Bi-oxygen technology's effectiveness against Coronavirus, however, is no longer as convincing as UV-C technology. In the case of two different tests, only the 60-minute air purification resulted in a 95% result. Even 30- and 45-minute air purification gave successful results in one test, but in the other test, 30- and 45-minute air purification failed [5] [6].

3.3. Plasma Ion Technology

Ions can also be found in nature, both positive and negative. Plasma Ion technology also uses positively and negatively charged ions found in nature. The technology was developed in the early 2000s, and it has continued to develop since then [7].

Using Plasma Ion technology, machines produce hydrogen and oxygen molecules with positively and negatively charged ions. In the presence of voltage, positive hydrogen ions are produced in the water, while positive oxygen ions are generated in the air [7].

Water molecules in the air surround these electrically charged particles. Due to their extremely strong oxidation effect, these water molecules extract hydrogen from viruses and other microbes found in the air and on various surfaces, thus destroying them. Structure destruction also results in the death of these organisms. As a result of the chemical reaction, neutral-charged water molecules are formed [7].

As part of the industrial application of Plasma Ion technology, the equipment for generating plasma ions is connected to the equipment for exchanging air (air conditioning, air circulation, etc.). The equipment itself is situated in a separate room [7].

A variety of air cleaning procedures are performed during air cleaning, including deodorization, pollution reduction, and sterilization.

This is without a doubt one of the most effective technologies for the prevention of Coronavirus infections. The Plasma Ion technology can clean the air in 10-15 minutes with 99.99% efficiency, whereas UV-C technology can do it in 25 minutes. In comparison to Plasma Ion and UV-C technologies, Bi-oxygen technology cannot even come close to disinfecting within 45 minutes with only 95% efficiency [7].

The comparative analysis of the previously introduced technologies show that the Plasma Ion technology has the highest sterilisation performance against Coronavirus.

In the next chapter, we present how return of investment can be an effective way of analysing which decontamination technology should be used from economic point of view to reduce the negative effects of Coronavirus on production.

4. ROI ANALYSIS OF UV-C, BI-OXYGEN AND PLASMA ION TECHNOLOGIES

Companies are constantly exploring opportunities for improvement to maintain their competitiveness. Many of these require investment, often with capital requirements that exceed the resources available. Therefore, it is necessary to demonstrate the economic and financial impact of investments, which provides a basis for evaluating and ranking investments competing for resources.

Investments can be grouped according to their nature into tangible and intangible, productive and non-productive. Depending on the organisational objectives, each may be justified. The investment objectives are different, but all need to be examined in terms of their economic viability, which affects the enterprise's ability to generate income. This can be most easily determined for tangible and productive investments (e.g. investing in production equipment), while for non-productive and intangible investments (e.g. management software) the impact on income is more difficult to show.

All the investment appraisals use return on investment indicators. These can be static or dynamic indicators. Static indicators are only appropriate for investments with a short lifetime and lower capital requirements. They do not consider the temporality of money and do not apply time preference.

Dynamic rates of return distinguish between amounts of money at different points intime and determine their present value (PV) or future value (FV). In both cases, a chosen imputed interest rate is used to calculate values for the same point in time.

When determining the imputed interest rate, we need to take several factors into account. The minimum requirement is the deposit rate, which can be adjusted by the expected interest rate on the equity and debt capital employed. Another factor that increases the interest rate is the estimated risk of the investment. The magnitude of the value of the interest rate applied is more critical when comparing investments with different objectives and less relevant when comparing substitute investments.

The variables used in the ROI analysis are:

- Purchase price (EUR)
- Depreciation (Linear) (EUR) 5 years
- Installation costs (EUR)
- Annual maintenance costs (EUR)
- Energy consumption (W/H)
- Energy consumption costs (EUR)
- Production cycle time (H)
- Number of shifts (pcs)
- Annual production output during the time saved with machine decontamination (pcs)
- Price per product (EUR)
- Decontamination time machine (H)
- Decontamination time (H) manual
- Overhead (%)

Table 1: ROI Analysis of UV-C, Bi-oxygen and Plasma Ion Technologies

	UV-C	Bi-oxygen	Plasma Ion
Purchase price (EUR)	1250	500	1250
Depreciation (Linear) (EUR)	250	100	250
Installation costs (EUR)	1000	1000	1000
Annual maintenance costs (EUR)	1000	500	500
Energy consumption (W/H)	70	10	20
Energy consumption costs (EUR)	2187,5	562,5	375
Overhead (%)	10%	10%	10%
Total costs (EUR)	6256	2929	3713
Production cycle time (H)	0,0083	0,0083	0,0083
Number of shifts (pcs)	3	3	3
Annual production output during the time saved with machine decontamination (pcs)	13125	5625	16875
Price per product (EUR)	2	2	2
Decontamination time machine (H)	0,42	0,75	0,25
Decontamination time (H) manual	1	1	1
Total Revenue	26250	11250	33750
Profit (EUR)	2625	1125	3375
ROI (years)	**2,383**	**2,603**	**1,100**
W cost (EUR)	0,1	0,1	0,1
EUR/HUF exchange rate	400	400	400
Number of annual working days	250	250	250
Profit rate %	10%	10%	10%

Source: own calculations

The results of the ROI analysis (Table 1) show that the Plasma Ion technology is the best choice from economic point of view.

The Plasma Ion technology has advantages with its low purchase price, low energy consumption, low maintenance costs and fast air cleaning efficiency. All these factors have strong positive influence on that the ROI is 1,1 years for Plasma Ion technology.

The ROI of UV-C and Bi-oxygen technologies are quite close to each other (2,8-2,6 years), but far behind the Plasma Ion one. However, the air cleaning performance of UV-C

technology is far better (see chapter 3.). Although Bi-oxygen technology is far cheaper, but its cleaning efficiency much lower and the time needed for this process is much longer.

5. CONCLUSIONS

In this study we introduced how Coronavirus has changed the processes of logistics. In general, the changes caused increasing costs and longer production times in the factories.

We assume that various decontamination technologies can help in getting closer to those production performance rates, which were standards before the Covid crisis.

First we showed the main technological characteristics of the examined UV-C, Bi-oxygen and Plasma Ion technologies, then compared their air cleaning efficiency. In the main chapter of the study, we tested with mathematical calculations the ROI of the 3 technologies.

The overall winner of both the air cleaning and ROI analyses is the Plasma Ion technology.

6. ACKNOWLEDGEMENTS

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7. REFERENCES

[1] D. VanOsdell, K. Foarde, Defining the Effectiveness of Uv Lamps Installed in Circulating Air Ductwork. ARTI-21CR/610-40030-01 (2002)

[2] M. Buonanno, D. Welch, I. Shuryak, D. J. Brenner, Far-UVC light (222 nm) efficiently and safely inactivates airborne human coronaviruses. (2021) www.nature.com/scientificreports

[3] R. Szabó, L. Szigetiné Málics, I. Barcs, Környezethigiéné: innovatív dekontaminációs technológiák. Környezetészségügy – Összefoglaló Közlemény, Egészségtudomány / Health Science (2020) 3.

[4] https://www.bioxigen.com/gb/cos-e-la-ionizzazione. last access 12.08.2022

[5] https://www.big-box.net/data/e6j56tsj/relazioni-universit%C3%A0_it.pdf. last access 12.08.2022

[6] https://www.big-box.net/data/e6j56tsj/bioxigen_testcovid-19_it.pdf. last access 12.08.2022

[7] https://global.sharp/pci/en/about_pci/. last access 12.08.2022

Economic-ecological analysis of a photovoltaic system for own consumption

N. Veljić [a], R. Lujić[b], J. Jukić [c]

[a] Tehnički odjel Sveučilište u Slavonskom Brodu, Trg Ivane – Brlić Mažuranić 2, 35000, Hrvatska, nveljic@unisb.hr

[b] Strojarski fakultet Sveučilište u Slavonskom Brodu, Trg Ivane – Brlić Mažuranić 2, 35000, Hrvatska, rlujić@unisb.hr

[c] Tehnički odjel Sveučilište u Slavonskom Brodu, Trg Ivane – Brlić Mažuranić 2, 35000, Hrvatska, jjukic@unisb.hr

Abstract

We are experiencing major climate changes every day, one of the causes of which is the use of energy from fossil fuels. To mitigate them, one of the solutions is the use of energy from renewable sources. In this paper, an economic and environmental analysis of electricity generation by a photovoltaic system connected to the power grid is presented. Four photovoltaic systems with power from 3.84 kW to 5.76 kW for self-consumption on a single-family house were analyzed and the optimal solution was selected. The input data were the annual reference power consumption leased from the utility and the annual solar radiation. The Geographical Information System for Photovoltaics was used to calculate and optimize the amount of electricity generated. The installation of a photovoltaic system on a single-family house contributes to the Republic of Croatia achieving the national goal of using energy from renewable sources in the energy sector.

Keywords: photovoltaic system, economic-ecological analysis, electricity

1. INTRODUCTION

Every day we see pollution from fossil fuel use increasing, fossil fuel prices rising, and energy supplies becoming more and more inadequate. These are the main reasons for the increasing use of renewable energy sources. In recent years, there has been a trend in the Republic of Croatia to install photovoltaic systems on residential buildings in order to increase the share of electricity generated from renewable energy sources and at the same time reduce air pollution.

By the Decision of the Parliament of the Republic of Croatia of December 8, 2021, the Act on Renewable Energy Sources and High-Efficiency Cogeneration was promulgated, and Directive 2018/2001 of the European Parliament and of the Council of December 11, 2018 on the promotion of the use of energy from renewable sources was incorporated into Croatian legislation.

The implementation of the following European Union legal acts is also ensured:

- Regulation (EU) 2018/1999 of the European Parliament and of the Council of 11 December 2018 on the management of the Energy Union and climate action, amending Regulation (EC) No. 663/2009 and (EC) No. 715/2009 of the European Parliament and of the Council, Directives 94/22/ EC, 98/70/ EC, 2009/31/ EC, 2009/73/ EC, 2010/31/EU,

2012/27/EU and 2013/30/EU of the European Parliament and of the Council, Council Directives 2009/119/ EC and (EU) 2015/652 and repealing Regulation (EU) No. 525/2013 of the European Parliament and of the Council, in the part related to the participation of the Republic of Croatia in the European Union financial mechanism for energy from renewable sources, and Regulation (EC) No. 1099/2008 of the European Parliament and of the Council of 22 October 2008 on energy statistics [1].

By using energy from renewable energy sources, the interests of the Republic of Croatia in the field of energy, which are set out in strategic energy and climate policy documents, laws and other regulations for the implementation of energy activities, are realized, especially with regard to achieving the national goal of covering at least 36.6% of gross final energy consumption in the Republic of Croatia with energy from renewable energy sources by 2030 [1].

2. ENERGY ANALYSIS

The system of electricity supply in buildings refers to the components located behind the point of electricity collection in the building to the end user. This segment describes data related to:

- the voltage level of the current collection,

- the power distribution

- uninterruptible power supply systems.

Power consumption systems are defined as groups of consumers, i.e. all consumers of electricity. When performing an energy inspection, all major individual consumers of electricity are located and divided into individual systems according to their purpose. The following data is typically collected and displayed for individual loads:

- Technical characteristics (rated power, power factor, efficiency, if applicable),

- Operating characteristics (operating mode, consumption and performance data related to operating mode segments, control methods, if applicable),

- Equipment condition (wear, quality of maintenance) [2].

The final results of the energy analysis performed:

- Unit prices for electricity (according to the last available bill),

- Reference electricity consumption (at annual and monthly level),

- Distribution of electricity consumption to individual consumer groups, i.e. to individual purposes (result of modelling).

According to the regulations for building energy audits and energy certification, the energy audit includes, among other things, an analysis of consumption and costs of all forms of energy, energy sources and water for the period of the last three calendar years [3].

The consumption of energy, energy products and water is directly related to the behavior of the end user of the building.

For the building in question, the data on electricity consumption was taken from the energy audit report, Table 1. In the building there is a billing point no. 10000784425 (consumption category: household; tariff model: household white).

The consumption is calculated semi-annually summer consumption 3-9 months and winter consumption 9-3 months.

Table 1: Analysis of electricity consumption from 2018 to 2021.

	2018		2019		2020		2021	
	HT	LT	HT	LT	HT	LT	HT	LT
Winter (9-3) month	1381	490	1118	489	1117	422	1204	411
Summer (3-9) month	1828	684	1425	584	1435	531	2065	938
Totally:	3209	1174	2543	953	2552	953	3269	1349
HT+LT (kWh/year)	4383		3616		3505		4618	
Account (HRK)	4357,44		3560,92		3513,14		4529,53	

The average annual consumption in the period from IX /2017. to IX /2021. years was used for the reference electricity consumption:

- annual reference electricity consumption high tariff (HT): 2893.25 kWh/year

- annual reference electricity consumption low tariff (LT): 1137.25 kWh/year

- annual reference electricity consumption is: 4030.50 kWh/year

- monthly reference electricity consumption is: 335.88 kWh/month

- annual reference cost of electricity is:

3990.26 HRK/year including VAT

- monthly reference cost of electricity is:

332.52 HRK/month including VAT

- average consumption in winter:

1658 kWh/6 months = 266,33 kWh/month

- average summer consumption:

2372.5 kW/6 months = 395.42 kWh/month.

Figures 1 to 4 show the reference power consumption in a diagram.

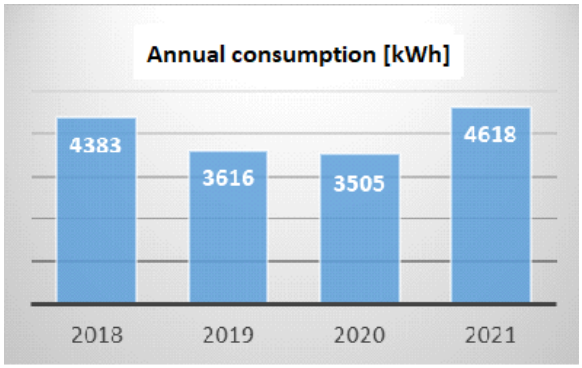

Figure 1. Diagram of total electricity consumption 2018-2021

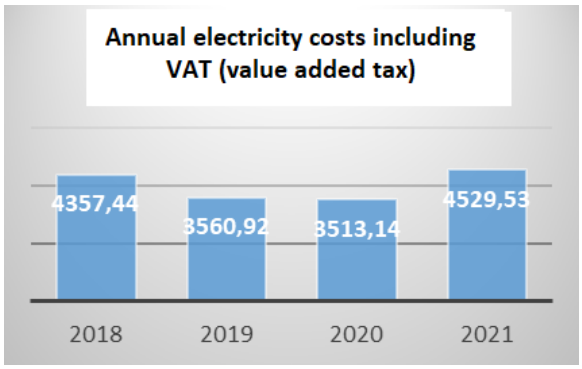

Figure 2. Diagram of costs for electricity 2018-2021

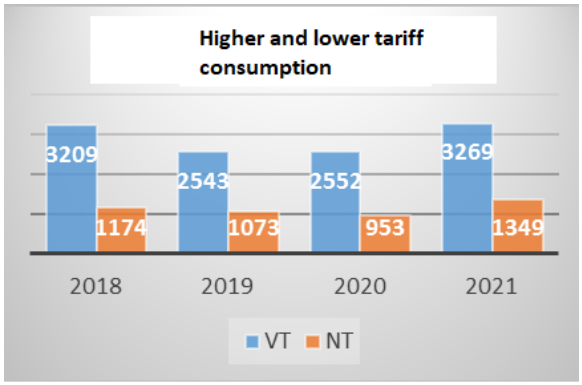

Figure 3. Diagram of electricity consumption 2018-2021 higher and lower tariff

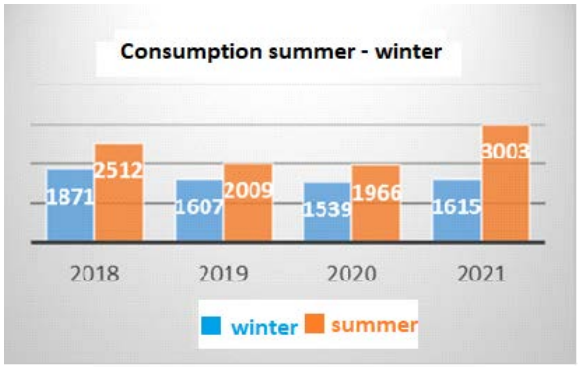

Figure 4. Diagram of electricity consumption 2018-2021 summer-winter

According to the "Law of Renewable Energy Sources and High-Efficiency Cogeneration", Article 51, paragraph (9), the billing period for the electricity received and delivered is one month. During the billing period, the price and, of course, the generation and consumption of electricity in the higher (HT) and lower daily tariff (LT) differ. Table 2 and Figure 5 show the reference electricity consumption for the building in question, reduced to a monthly level.

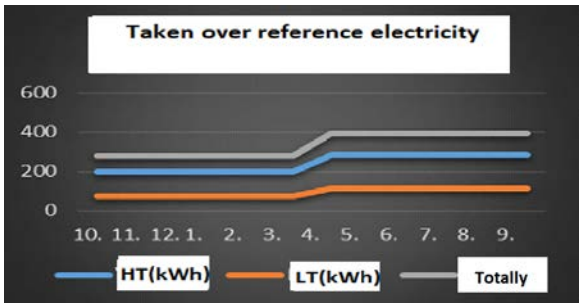

Figure 5. Taken over (reference consumption) of electricity

Table 2. Taken (reference consumption) of electricity

Month	HT (kWh)	LT (kWh)	Totally (kWh)
10.	**200,83**	**75,5**	**276,33**
11.	**200,83**	**75,5**	**276,33**
12.	**200,83**	**75,5**	**276,33**
1.	**200,83**	**75,5**	**276,33**
2.	**200,83**	**75,5**	**276,33**
3.	**200,83**	**75,5**	**276,33**
4.	**281,38**	**114,04**	**395,42**
5.	**281,38**	**114,04**	**395,42**
6.	**281,38**	**114,04**	**395,42**
7.	**281,38**	**114,04**	**395,42**
8.	**281,38**	**114,04**	**395,42**
9.	**281,38**	**114,04**	**395,42**
Totally	**2893,26**	**1137,24**	**4030,5**

The price of the last billing period (6 months), Table 3, was used as the reference price for the electricity taken over by the consumer.

Table 3. Electricity price structure

Ord. numb.	Structure	Unit price without VAT (kn/kWh)	Unit of issue
1.	Electricity higher daily tariff (HT)	0,84	kWh
2.	Electricity lower daily tariff (LT)	0,41	kWh
3.	Fee for settlement and supply	17,40	month
4.	Compensation for encouraging production from renewable energy sources	0,105	kWh

3. AVERAGE ANNUAL IRRADIATION

The sun is the most important source of electromagnetic radiation penetrating the atmosphere and an inexhaustible source of renewable energy. Considering that the sun releases more energy in just one second than our civilization has consumed in the course of its development, the study of solar energy and the conversion of solar radiation into useful forms of energy takes on a whole new dimension with a great possibility of solving the problem of the energy crisis that is becoming more and more rampant in the world [4].

To determine the amount of electricity generated by the photovoltaic system, it is necessary to define the amount of solar radiation that falls on the photovoltaic system during the day. The duration of solar radiation depends on the number of hours of sunshine, which depends on the geographical location and the season. These data are usually given as average values. Figure 6 shows the average annual irradiance of the horizontal surface by the total solar radiation in the Republic of Croatia.

The building for which the photovoltaic system was analyzed is located in Slavonski Brod with coordinates 45.166 north latitude and 18.012 east longitude.

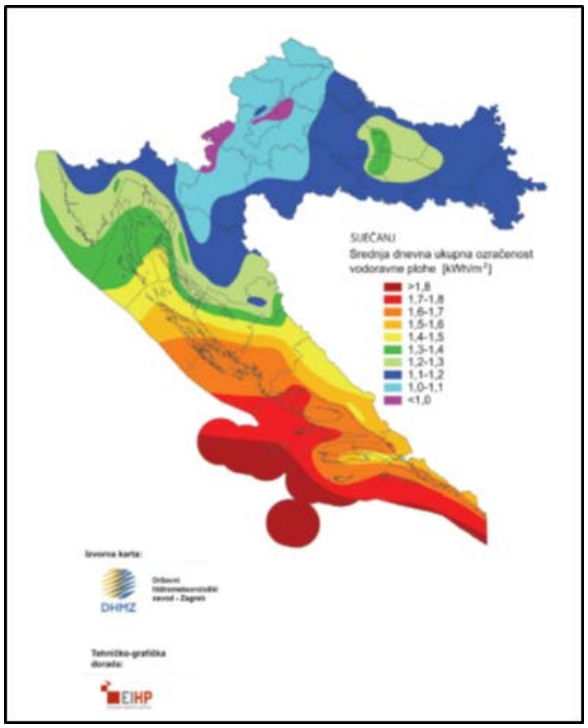

Figure 6. Mean annual irradiance of the horizontal surface by total solar radiation, data from DHMZ [5]

4. ASSESSMENT OF MONTHLY AND ANNUAL ELECTRICITY PRODUCTION

According to the law [1], Article 4, the term is defined: A self-generating end-user is an end-user of electricity whose facility is connected to a production facility for the generation of electricity from renewable energy sources or high-efficiency cogeneration, which meets the needs of the end-user and has the possibility of feeding surplus generated electricity into the transmission or distribution network.

Article 51, of the aforementioned Act, defines the conditions that a power generation facility must meet. Among other things, one is that the connected load of an end user with self-generation or a user of a self-generation facility in the direction of feeding electricity into the grid may not be higher than the connected load of an end user with self-generation or a user of a self-generation facility in the direction of drawing electricity from the grid.

The maximum connected load of the final customer in the analyzed system is 7.5 kW, and therefore the installed power of the photovoltaic system is also limited. The techno-economic analysis was performed for the following peak powers of the photovoltaic system:

- Peak power of 3.840 kW (12 modules)
- Peak power of 4.480 kW (14 modules)
- Peak power of 5.120 kW (16 modules) and
- Peak power of 5.760 kW (18 modules)

The individual power of the offered photovoltaic modules is 320 W.

The Photovoltaic Geographical Information System (PVGIS) [6] was used to estimate the electricity generated by each photovoltaic system. All the necessary solar radiation intensity data for estimating the power generated by the photovoltaic system were taken from the PVGIS tool database.

The roof of the building in question, on which the installation of the photovoltaic system is planned, is oriented in a north-south direction. Therefore, a field with 50% photovoltaic modules will be placed on the northern part of the roof and on the southern field with 50% photovoltaic modules. The ground plan of the roof and the position of the photovoltaic system is shown in Figure 7. The angle of inclination of the photovoltaic system is 14°, which represents the rotation of the module in relation to the horizontal. The azimuth of the southern part of the roof is 0° and the northern part of the roof is -180°, where 0° is the reference to the south. Figure 7 shows the position of the building or roof. The azimuth represents the rotation of the photovoltaic system in relation to the sides of the world.

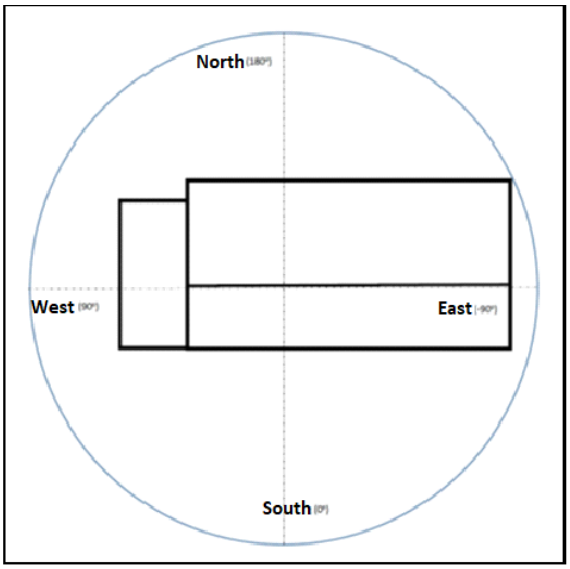

Figure 7. The position of the building in relation to the sides of the world

The photovoltaic system is installed next to the roof of the building, resulting in losses due to increased temperature of about 15.2%. The reason for the losses in systems installed next to the roof is the lack of ventilation, which leads to an increase in temperature and thus a decrease in the maximum power of the module. In addition to losses due to increased temperature, there are also losses due to reflection, heat exchangers and cables. It was assumed that the reflection losses are about 2.4% and the losses due to heat exchanger and cables are about 4%.

The calculation in the PVGIS tool was performed separately for each part of the roof, and then the obtained energies were added.

$$E_{m,tot} = E_{m,south} + E_{m,north} \quad [kWh] \tag{1}$$

Table 4 and Figure 8 show data on the average monthly electricity production of each photovoltaic system and the average annual production.

Table 4. Average monthly and annual electricity production

Month	P_1=3,84 kW	P_2=4,48 kW	P_3=5,12 kW	P_4=5,76 kW
1.	116,50	135,90	155,30	174,80
2.	159,60	186,20	212,70	239,40
3.	300,10	350,20	400,20	450,20
4.	416,40	485,70	555,20	624,60
5.	490,70	572,60	654,40	736,10
6.	528,50	616,60	704,80	792,80
7.	561,20	654,70	748,20	886,80
8.	498,50	581,60	664,60	747,70
9.	346,50	404,20	462,00	519,70
10.	243,30	283,80	324,40	364,90
11.	132,90	155,20	177,30	199,50
12.	94,70	110,50	126,20	142,10
∑	3888,90	4537,20	5185,30	5878,60

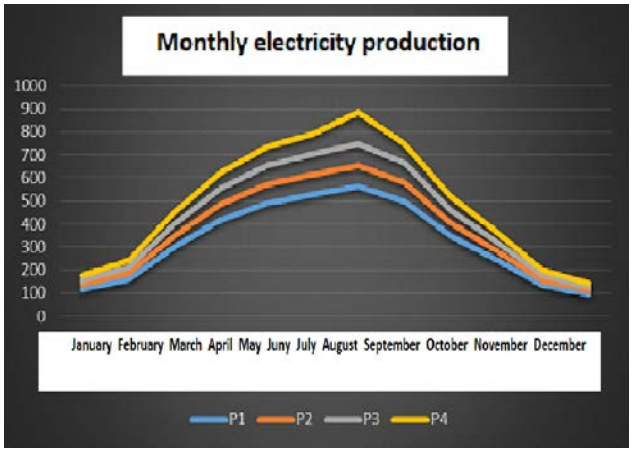

Figure 8. Average monthly electricity production

5. TECHNICAL - ECONOMIC ANALYSIS

The price of small and medium-sized photovoltaic systems is significantly higher than that of other technologies that generate electricity from fossil fuels. Large photovoltaic systems require large open spaces, so smaller systems that can be installed on smaller surfaces such as house roofs, facades, and porches are preferred. Such surfaces, on which smaller

photovoltaic systems are installed, retain their original function.

Photovoltaic systems then become integrated components of individual building elements, which reduces construction costs.

The advantage of such systems is that the electricity is generated at the point of consumption, so the actual price is the same as the retail price and the generation is the same as any other conventional system. The users of such systems have a direct (microeconomic) benefit resulting from the incentives to supply energy from renewable sources. The use of such systems reduces the import of fossil fuels and electricity and results in a reduction of greenhouse gas emissions.

Electricity suppliers are required to enter into a supply agreement that includes provisions for the purchase of surplus electricity from the production facility upon request from end users with their own production to which they supply electricity or from users of self-supply facilities within 30 days of the request, and are required to purchase surplus electricity from end users.

For the electricity purchased by the electricity supplier, the law determines the value of the electricity purchased by the final customer with its own generation Pd in the calculation period as follows [1]:

If it is:

$$E_r \geq E_d \rightarrow C_i = 0{,}9 \cdot PKC_i \quad (2)$$

If it is:

$$E_r < E_d \rightarrow C_i = 0{,}9 \cdot PKC_i \cdot E_r/E_d \quad (3)$$

E_r - the total amount of electricity that the customer has taken from the grid during the billing period, expressed in kWh.

E_d - the total amount of electricity fed into the grid by the customer's production facility during the billing period, expressed in kWh.

AP_d - the average unit price of electricity paid by the customer to the supplier for electricity sold during the billing period, excluding grid usage charges and other fees and taxes, expressed in HRK/kWh.

P_d - the value of electricity purchased by the final customer from its own production, expressed in HRK/kWh.

In each billing period extending over one month, the electricity supplier shall reduce the bill for the electricity supplied to the final customer from its own generation by the amount billed.

Based on the reference consumption and the electricity price structure, the average unit price was calculated and amounts to:

$$AP_{dLT} = 0{,}4195 \text{ HRK/kWh}$$

The photovoltaic system produces electricity exclusively during the day, i.e. a higher (daily) tariff (HT) when surplus electricity is supplied to the supplier, while at night all the energy required is taken from the supplier (lower LT tariff).

$$E_d = E_{rHT} - E_{rLT} \quad (4)$$

Table 5 shows the data on electricity purchased and supplied by the supplier and the amount by which the bill was reduced for each billing period for the photovoltaic system with a power of P_1=3.84 kW.

Table 5. Data on electricity received and delivered by the supplier

Month	Referent consumption (kWh)			E_d (kWh)	E_r (kWh)	E_{dp} (HRK)	P_d (HRK/kWh)	Account reduction (HRK)
	HT	LT	Totally					
10.	200,83	75,5	276,33	42,47	75,5	56,28	0,3776	16,03
11.	200,83	75,5	276,33	0	143,43	120,48	0,0000	0,00
12.	200,83	75,5	276,33	0	181,63	156,58	0,0000	0,00
1.	200,83	75,5	276,33	0	159,83	135,97	0,0000	0,00
2.	200,83	75,5	276,33	0	116,73	95,24	0,0000	0,00
3.	200,83	75,5	276,33	99,27	75,5	56,28	0,2871	28,51
4.	281,38	114,04	395,42	135,02	114,04	76,13	0,3189	43,06
5.	281,38	114,04	395,42	209,32	114,04	76,13	0,2057	43,06
6.	281,38	114,04	395,42	247,12	114,04	76,13	0,1742	43,06
7.	281,38	114,04	395,42	279,82	114,04	76,13	0,1539	43,06
8.	281,38	114,04	395,42	217,12	114,04	76,13	0,1983	43,06
9.	281,38	114,04	395,42	65,12	114,04	76,13	0,3776	24,59
∑	**2893,96**	**1137,24**	**4030,5**	**1295,26**	**1137,24**	**1077,62**		**284,40**

Table 5 shows that the price per kWh of electricity supplied decreases when it is higher than the quantity received.

E_{dp} - The amount of electricity purchased from the supplier

E_{dp} = Purchased EE in VT x price of VT + Purchased EE in NT x price of NT + fee for settlement office and delivery + (fees for promoting the production of RES x total amount EE received).

Table 6 shows the data on the delivered surplus of electricity generated by the photovoltaic power plants for P_1, P_2, P_3, and P_4, as well as the monthly and annual savings.

The calculation of electricity consumption and grid usage charges, as well as charges for renewable energy and high-efficiency cogeneration, takes into account the difference between the electricity purchased and the electricity supplied in a given tariff. If, at the end of the billing period, the amount of working electricity fed into the grid in a given tariff is greater than the amount purchased, the supplier is obliged to pay for the excess electricity produced at the price of:

$$P_{dHT} = 0{,}8 \cdot P_{rHT} \quad (5)$$

$$P_{dLT} = 0{,}8 \cdot P_{rLT} \quad (6)$$

where is:

P_{rHT}- the price of all electricity taken from the grid by the final customer during the billing period for the duration of the higher daily tariff, expressed in HRK/kWh

P_{rLT} - the price of all electricity taken from the grid by the final customer within the billing period for the duration of the lower daily tariff, expressed in HRK/kWh

P_{dHT} - the price of all electricity, fed into the grid by the final customer's generation facility within the billing period for the duration of the higher daily tariff, expressed in HRK/kWh

P_{dLT} - the price of all electricity fed into the grid by the final customer's generation facility within the billing period for the duration of the lower daily tariff, expressed in HRK/kWh.

According to actual accounts:

$$P_{rHT} = 0{,}84 \text{ HRK/kWh}$$

$$P_{rLT} = 0{,}41 \text{ HRK/kWh}$$

The utility is obligated to purchase the excess electricity produced at the price:

$$P_{dHT} = 0{,}8 \cdot P_{rHT} = 0{,}8 \cdot 0{,}84 = 0{,}672 \text{ HRK/kWh}$$

$$P_{dLT} = 0{,}8 \cdot P_{rLT} = 0{,}8 \cdot 0{,}41 = 0{,}328 \text{ HRK/kWh}$$

Table 6. Data on the delivered surplus of produced electricity

Month	E_d (kWh) P_1=3,84 kW	Ušteda (kn)	E_d (kWh) P_2=4,48 kW	Saving (kn)	E_d (kWh) P_3=5,12 kW	Saving (HRK)	E_d (kWh) P_3=5,12 kW	Saving (HRK)
10.	42,47	189,78	82,97	189,78	123,57	189,78	164,07	189,78
11.	0	125,59	0	146,66	0	167,55	0	188,53
12.	0	89,49	0	104,42	0	119,26	0	134,28
1.	0	110,09	0	128,43	0	146,76	0	165,19
2.	0	150,82	0	175,96	11,87	189,78	38,57	189,78
3.	99,27	189,78	149,37	189,78	199,37	189,78	249,37	189,78
4.	135,02	265,90	204,32	265,90	273,82	265,90	343,22	265,90
5.	209,32	265,90	291,22	265,90	373,02	265,90	454,72	265,90
6.	247,12	265,90	335,22	265,90	423,42	265,90	511,42	265,90
7.	279,82	265,90	373,32	265,90	466,82	265,90	605,42	265,90
8.	217,12	265,90	300,22	265,90	383,22	265,90	466,32	265,90
9.	65,12	265,90	122,82	265,90	180,62	265,90	238,32	265,90
∑	1295,26	2450,99	1859,46	2530,46	2435,73	2598,34	3071,43	2652,78

In each billing period, the electricity supplier shall issue a bill to the final customer in the household category for the difference between the electricity purchased and the electricity supplied (kWh) in the higher daily tariff and the difference between the electricity supplied and the electricity purchased (kWh) in the lower daily tariff by the final customer with self-generation. The same quantities form the basis for calculating the grid usage charge and the charge for renewable energies and high-efficiency cogeneration.

5.1. Return to investment

The main indicator of the profitability of the installation of a photovoltaic system is the report of financial and economic benefits. The report contains estimates of investment costs, profits and maintenance during the useful life of the project. The profitability of a project for a photovoltaic system can be determined in several ways, and some of these methods are:

- Payback period method
- Net present value method
- Internal rate of return (IRR) method.

In this work, the payback period method was used. The payback period is the time needed to cover the total investment in the installed photovoltaic system. The total investment in each installed photovoltaic system and the return on investment are shown in Table 7. The investment includes: Solar modules, grid converters, roof supports, cables, connections and all other equipment, delivery, installation and commissioning. Today's market prices for the "turnkey" model range from HRK 7.00/W to HRK 9.00/W. The price of HRK 8.00/W was chosen for the analysis in this paper.

Table 7 shows the investment, savings, and return on investment for each photovoltaic system.

Table 7. Savings and return on investment in a photovoltaic system

Power PV	Investment	Annual production PV	Reference consumption	Totally saving (HRK)	Return to investment
P_1=3,84	**30.720,00**	**3888,9**	**4030,50**	**3320,99**	**9,25**
P_2=4,48	**35.840,00**	**4537,2**	**4030,50**	**3780,02**	**9,48**
P_3=5,12	**40.960,00**	**5185,3**	**4030,50**	**4235,15**	**9,67**
P_4=5,76	**46.080,00**	**5878,6**	**4030,50**	**4716,78**	**9,77**

It is also obviously from aforementioned table that the shortest return on investment for the photovoltaic system is P_1=3.84 kW, which is shown in the diagram in Figure 9. For the project to be acceptable, the investment return period must be shorter than the life of the project. The shorter the investment return period is, the greater the economic profit of the project is.

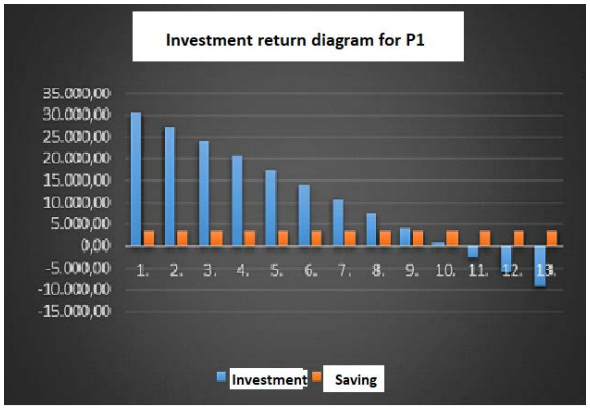

Figure 9. Investment return diagram for P_1

Available data show that the life span of such projects is about 20 years.

5.2. Ecological analysis

At its session on June 2, 2021, the Croatian Parliament adopted Low-carbon Development Strategy of the Republic of Croatia until 2030 with a look at the year 2050 with the aim of initiating changes in Croatian society that will contribute to the reduction of greenhouse gas emissions and enable the decoupling of economic growth from greenhouse gas emissions. As part of the EU, Croatia shares the climate policy ambitions expressed in the European Commission's European Green Plan (2019), according to which the EU should be climate neutral by 2050. When all the implications of the common EU target to reduce greenhouse gas emissions by - 55% by 2030 and the 2050 climate neutrality target of sectoral policies are known, it will be possible to complete the zero emissions scenario for Croatia [7].

Table 8 shows data on current CO_2 emissions and emissions reductions after the installation of the photovoltaic system. The CO_2 emission factor was taken from the methodology of the Energy Inspection of Buildings and is 0.23481 kg CO_2/kWh year for electricity.

The table shows a reduction of CO2 emissions from 64.4% for P1 to 69.7% for P_4, i.e. depending on the power of the installed photovoltaic system.

Table 8. CO_2 emission and emission reduction

Reference comsuption (kWh)	CO_2 emission (t/year)	P_1- consumption	CO_2 emission (t/year)	P_2	CO_2 emission (t/year)	P_3	CO_2 emission (t/year)	P_4	CO_2 emission (t/year)
4030,5	0,946	1436,86	0,337	1352,76	0,318	1280,93	0,301	1223,33	0,287
% reduc.			64,4		66,4		68,2		69,7

6. CONCLUSION

In the paper, an economic-ecological analysis of the photovoltaic system for own use of a single-family house was carried out. Four photovoltaic systems were analyzed with the following powers: P_1=3.84 kW; P_2=4.48 kW; P_3=5.12 kW and P_4=5.76 kW. The photovoltaic system power was selected based on the annual reference consumption and the installed (leased) electricity capacity. The shortest payback period of the investment without subsidies is 9.25 years for the photovoltaic system with a capacity of P_1= 3.84 kW. The estimated production of the photovoltaic system P_1 is 3888.90 kW/year and the annual savings is 3320.99 HRK/year. The annual CO_2 emissions would decrease by 64.4% compared to the current emissions. The analysis was performed without planning subsidies for the investment, which would certainly shorten the payback period of the investment and contribute to the highest possible share of renewable energy sources.

The work concludes that the optimal power of the installed photovoltaic system would be the one that generates electricity close to the consumption.

7. REFERENCES

[1] NN 138/2021 (15.12.2021.), Zakon o obnovljivim izvorima energije i visokoučinkovitoj kogeneraciji

[2] Metodologija provođenja energetskog pregleda zgrada, Zagreb, 2021.

[3] Pravilnik o energetskom pregledu zgrade i energetskom certificiranju („Narodne novine“ broj 88/17, 90/20, 1/21, 45/21)

[4] Majdandžić, Lj.: Solarni sustavi, 2010, Sveučilište Josipa Jurja Strossmayera u Osijeku

[5] https://meteo.hr/klima.php?section=klima_hrvatska&param=k1_9&el=Y6190&it=sunce

[6] https://joint-research centre.ec.europa.eu/pvgis-photovoltaic-geographical-information-system_en

[7] NN 63/2021 (7.6.2021.), Strategija niskougljičnog razvoja Republike Hrvatske do 2030. s pogledom na 2050.godinu

The Impact of Digitalization on Logistics Today

A. Boldizsár [a,b], F. Mészáros [a], B. R. Busa [b]

[a] Budapest University of Technology and Economics, Műegyetem rkp. 3., H-1111 Budapest, Hungary, boldizsar.adrienn@edu.bme.hu

[b] John von Neumann University, Izsáki út 10., H-6000 Kecskemét, Hungary, boldizsar.adrienn@gamf.uni-neumann.hu

Abstract

The emergence of autonomous mobility will lead to significant changes in road freight transport. In the modern "data age", companies are increasingly digitizing their resources, taking advantage of the potential of the „smartened" assets. The assets are continuously monitored and managed through cloud-based services, including the goods vehicles. These disruptive technologies fundamentally change the demands of freight transport activities. Thus both the operators of the transportation system and the companies in production and service provision are interested in making the most of the benefits from technology development. This research focuses on exploring, analyzing and evaluating the potential for interacting with technologies and the resulting direct benefits and synergies. The research results will make the process of changing to autonomous vehicles at the companies more smooth and efficient.

Keywords: *autonomous mobility, freight transport, enterprise resources*

1. INTRODUCTION

Transporting goods by road is essential and a top priority in the supply chain. Just think that the vast majority of the objects around us are very likely, even for a short while, to have turned around in the cargo compartment of at least one freight road vehicle. The same is true for multimodal transportations, as in the first and last few kilometres, with a few exceptions, it is inevitable that goods will be transported by road. It should also be noted that despite the rapid pace of technological development, the increase in environmental awareness, the proliferation and increasing pressure of regulations, restrictions and guidelines, no other transport sub-sector is sufficiently competitive with road transport. [1] Transport is rapidly changing, becoming digital, interconnected and autonomous. With the advancement of vehicle technology and the automation of vehicles, autonomous road freight is appearing. This paper contributes to a better understanding of the gains of autonomous vehicles in the road freight sector and seeks possible pathways for the responsible parties.

The Fourth Industrial Revolution, which is still underway, has already brought about change in many areas of the economy, from agriculture to food to the car industry, affecting virtually all industrial sectors. Automation is becoming more and more widespread, including the use of robot technology and self-driving vehicles [2]. The main reason for this is the explosion of information technology and the spread of digitalisation in all supply chain elements, opening up many new opportunities in the economy and logistics sectors [3]. Logistics is increasingly expected to introduce new technologies throughout the supply chain worldwide. Increasing digitalisation offers many

opportunities for innovation, including sustainability, which has become a key issue in recent times, particularly in logistics and freight transport [4]. One after the other, Internet platforms is appearing, linking logistics companies, international freight forwarders, warehouse operators and hauliers electronically [5]. International freight forwarding and transport activities can be tracked continuously through barcode systems and mobile phone applications, making it easy to monitor the movements of vehicles and the work of drivers. Most companies currently use GPS-based fleet and goods tracking systems for international and domestic transport [6]. These systems can also suggest the most favourable transport route from the warehouse to the consignee based on cost, journey time or environmental impact. Industry 4.0 is thus also affecting the logistics sector and international transport and is based on automation and digitalisation. This raises the question of how digital development, logistical development and social indicators relate to each other and what they can tell us about the situation in a country, particularly in the light of recent events.

2. REVOLUTION IN THE ROAD FREIGHT SECTOR

Alongside self-driving, intelligent vehicles, in freight transportation, intelligent cargo also appeared. Those goods or cargo are intelligent and have information about themselves, their environment and location and are linked to information services. This helps companies with logistical and administrative rules for transporting goods, regardless of cargo size. Its benefits contribute to achieving more efficient transport, including more energy-efficient transport.

Future vehicle technology requires a sophisticated, widely used onboard vehicle device, which means practically considering using an integrated onboard unit capable of handling all intelligent vehicle-specific functionality consistently. Establishing such a system is possible with single, top-down legislation. Although the tachograph specification is already part of the legal system, the other hand, the OBU (On-Board Unit) tools do not yet have a mature concept for transposition into legal frameworks. It is already clear that the future implementation of such an "integrated OBU" has legal and regulatory barriers rather than technological barriers.

Fig. 1. Integrated OBU functions [Own editing]

OBU is an acronym for "On Board Unit" (OBU), which means "board unit". Generally speaking, any electronic device can be defined as an OBU that performs some or all of an automated task in a vehicle - driver (vehicle operator) infrastructure relation (e.g. auto identification, toll payment, driver assistance, vehicle diagnostic services, etc.). With the advancement of technology, onboard devices are being replaced by integrated, intelligent onboard computers. The onboard units communicate with the central server over a mobile network, allowing real-time tracking and subsequent evaluation of data stored at the headquarters. The use of onboard computers is needed to improve the driver's working conditions, ensure the traceability of truck performance, and meet the extensive information needs of any transport company [7].

Besides the use of autonomous vehicles, real revolutionary innovation and radical change can be brought by the incorporation and use of information technology. This means that in

addition to the fact that computer-controlled cars will be on the road, the infrastructure, the smart transport network, networked and communicating with each other, contributes to increasing the efficiency and safety of Mobility. Using such an integrated intelligent transport system can increase the efficiency of passenger and freight transport and contribute to safe and environmentally friendly transport. The system also opens doors to new services and new business models.

Fig. 2. System components of a smart infrastructure [8]

Smart roads and smart car cooperation mean smart transport, for which shared knowledge and a continuous and secure network connection between systems is essential. Intelligent cars are expected to be fully integrated as components of an intelligent transport system and will be critical players in sensing and transmitting the information [9].

It is essential to mention the concept of IoT, which has become a crucial area concerning Industry 4.0. The Internet of Things (IoT) concept is that the personal computer is becoming increasingly overshadowed in specific applications, and intelligent objects are replacing its role and tasks. The Internet of Things also refers to the interconnection of physical objects and devices in a structure similar to the Internet. Smart devices communicate with each other using 5G technology, e.g. the washing machine starts when the electricity is the cheapest, depending on the power supply load. In a certain sense, auto-identification with RFID, which is widely used in logistics, is considered the core of IoT. However, many other encoding makes it possible to identify the devices [10].

The Connectivity as a Service (CAAS) is based on elements that are part of the IoT linking services to enable you to take advantage of the benefits of connectivity. The CaaS model provides simple, cost-effective, high-quality, and secure network data connectivity. The data connection network is based on an IoT platform and provides access to the model's features through a cloud-based service [11].

Another central concept of intelligent transport systems is Mobility as a Service (MaaS), where proprietary transport means and modes are increasingly being pushed into the background and service-based, community-based mobility solutions are gaining ground. The trend is driven by the proliferation of new, innovative community mobility services, primarily due to the development of the information technology tools and applications described above. Such MaaS services also include different modes of transport sharing, such as community cars, bicycles, and roller skating. MaaS can improve travel conditions and provide new mobility options for users. Most MaaS services positively impact social values, improve the efficiency of the transport network, and typically favour environmentally conscious solutions [12].

In the following, we examine the validity of the requirements for the general freight and logistics system described above in terms of the capabilities of the above-mentioned autonomous technology, automated IT system upgrades, and networking of mobile devices.

3. ENTERPRISE INFORMATION TECHNOLOGY AND AUTOMATION DEVELOPMENTS

The structure of information systems that support logistics processes is closely related to logistics management tasks. In addition to operational tasks, planning is a prerequisite for

competitive logistics. During the planning process, the goals and the frameworks are defined for which the specific processes occur. In order to ensure continuous development, there is a need to measure the actual performance of the operation, analyse and feedback on the results obtained, and review and redesign critical points in the system. The transactional and decision support systems supporting operational and planning processes are two essential, necessary and closely related parts of the logistics information system. Below we examine the validity of the general freight and logistics system requirements. The opportunities offered by autonomous technology are previously mentioned in terms of the automated information system development and networking of mobile devices [13].

Table 1. Prerequisites for autonomous road freight transport against the logistics information system of a company [13]

Requirements	Conventional vehicles	Autonomous vehicles	Gains	Challenges
Quality of information	Based on conventional architectures and software, accessible to process	Based on the communication of high-level and automated equipment and the application of innovative software	More reliable information, up-to-date data management	Investment and higher-level operational knowledge are in need
Extent of information	The general extent of data interchange	The greater extent of data interchange	Complete monitoring and process control	Improvement of informatics system, need for more extensive data storage capacity.
Location of information	Far from the origin	Close to the origin	Accurate and updated data management	Improvement of information and communication technology solutions
Lead time	Longer	Shorter	Rapid intervention	Holistic infrastructure development is in need
Data security	Normal level security	High-level security	Secure, protected communication channels	Need for involving high-level IT service provider
Human-machine interaction	Human-human and human-machine interactions	Human-machine and machine-machine interactions	Process automation	Current equipment needs upgrading or replacement
Integration to partner systems	Low level	High level	Up-to-date information on all involved parties	Need for cooperative and synchronised developments at all involved parties
Level of digitalization	Paper-based and digital information	Mainly digital information	Reducing data process failures	Time-consuming transition
Online accessibility	Only partly online	Mainly online	Cloud-based data management	Emerging risk in abuse of data
Remote monitoring	Low level, minimal number of applied mobile devices	High level, the high number of applied mobile devices	No spatial or time limit for access	Internet of Things and mobile data interchange system improvement is in need.

In the table, we emphasized the examination of claims for which the use of innovative technology is a particular degree and identified benefits. We have highlighted the points where the application of autonomous solutions may require reinterpretation or modification in the application of technology. From the perspective of many freight companies, all of these properties exploit the benefits arising from the use of autonomous vehicles.

4. ANALYSIS AND RESULTS

Following an examination of the use of autonomous vehicles, the correlations between the well-known indices from the international literature were explored to determine whether the results of the literature research can be mapped to the correlation of the applied development indicators. To perform linear regression, it was necessary to narrow down the range of indicators to be examined. For the analysis, indicators were chosen for which the comparison results can be interpreted with certainty, do not rely on similar pillars in the way they are defined, and therefore the linear regression results are interpretable. A further criterion in the selection was that the indices should relate to European countries and the logistics sector. The selected indicators are: the Logistics Performance Index (LPI) [14], the Global Competitiveness Index (GCI) [15], the Digitalisation Index (DiGiX) [16].

Table 2. Summary of selected indicators

	Index	Short description	Gains
LPI	*Logistics Performance Index*	Based on the communication of high-level and automated equipment and the application of innovative software.	An interactive benchmarking tool created by the World Bank to help countries identify the challenges and opportunities they face in trade logistics and what they can do to improve their performance.
GCI	*Global Competitiveness Index*	Economic competitiveness indicator.	It includes: infrastructure, health, education, goods market efficiency, labour market efficiency, technological development.
DiGix	*Digitalization Index*	A composite index summarising relevant indicators on the digital performance of 100 countries.	t is built around six main dimensions: infrastructure, households, business adoption, costs, regulation and content.

The indicators aim to determine the correlation between the logistics situation and the digital development of a country and whether the examination of these indices allows any conclusions to be drawn. The analyses were based on online international databases, from which the most recent (the year 2018) complete data sets for 36 countries in the European Economic Region were extracted. The analysis results are presented in Figures 3., 4. and 5.

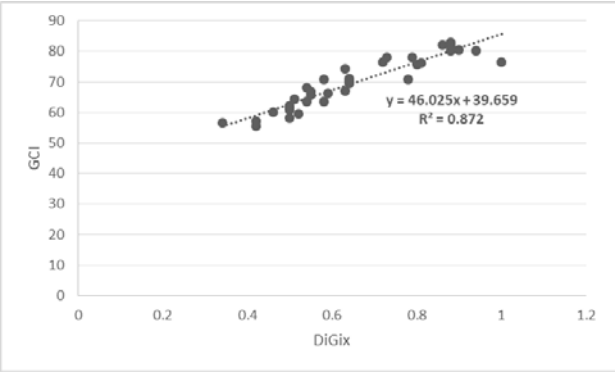

Fig. 3. The link between GCI and DiGix

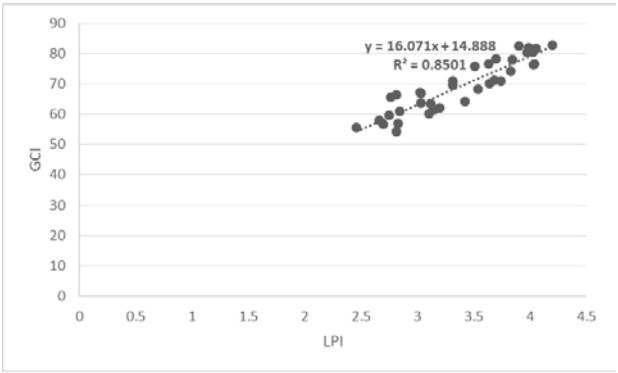

Fig. 4. The link between GCI and LPI

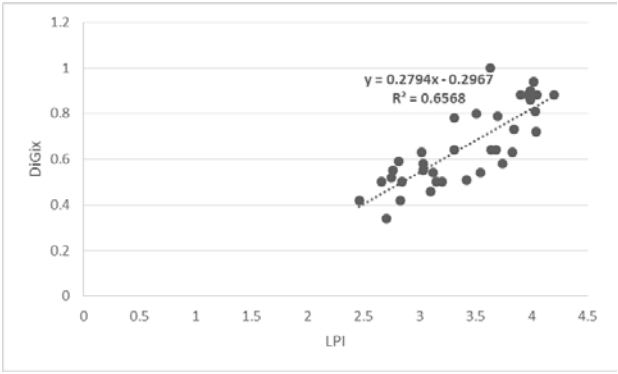

Fig. 5. The link between DiGiX and LPI

As can be seen from the graphs, the Global Competitiveness Index is closely correlated with the Digitisation Index (R^2 = 0.872), as well as with the Logistics Performance Index (R^2 = 0.8501). This shows that a country can be the most competitive in the market if it leads in all other indicators and vice versa. If the Indexes in each area are strengthening, this is positively related to competitiveness, where strengthening is also expected. The better a country's logistics performance and the more willing it is to embrace digitalisation to work with new technologies, the more competitive it can become. A surprising result is that the R^2 value of the Digitalisation Index and the Logistics Performance Index is 0.6568, which means there is not a very strong correlation between the two indices. Thus, the analysis shows that each indicator is the most likely to influence the competitiveness of a country.

5. CONCLUSIONS

Recent events (the Covid-19 epidemic and the Russian-Ukrainian conflict) have shown that a region's or country's economic position and competitive position can change enormously in a relatively short period. To make the right strategic decisions, it is crucial to have a clear picture of how different areas, such as the logistics industry or the digital development of a country, interact. In this analysis, social values have been included as an additional factor, as they are also critical to regions' long-term development.

Overall, the beneficial effects of using the potential of autonomous vehicles and smart roads for freight processes, corporate assets and infrastructure operations are safer, more reliable and more efficient. Thanks to this technology, driver errors can be reduced to virtually zero. The traffic load on the road network can be optimized, congestion can be reduced, and infrastructure maintenance simplified and streamlined. Several points require further study and research in connection with the subject area. Integrating autonomous vehicles into the concept of Industry 4.0 is also an open issue, with the vision of automating the entire supply chain from manufacturing to end-users while minimizing human labour requirements.

The linear regression calculation showed that a country is most competitive today with an excellent digital level, can provide good logistical performance in the market, and can meet social expectations and human development. Combining all these factors will undoubtedly help a country gain a better position and competitive advantage in the market. In the long term, further research questions may arise as to whether a region wishes to improve or maintain its economic competitiveness, how and from what perspective each area should be developed, and whether neighbouring countries, for example, show a link in terms of spatial mobility.

6. ACKNOWLEDGEMENTS

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7. REFERENCES

[1] IRU report, Tracking Driver Shortage in Europe, https://www.iru.org/resources/iru-library/tackling-driver-shortage-europe, (2019), Last access: 07.04.2022.

[2] C. Fritschy; S. Spinler, The impact of autonomous trucks on business models in the automotive and logistics industry–a Delphi-based scenario study, Technological Forecasting and Social Change, Volume 148, (2019), 119736, ISSN 0040-1625, https://doi.org/10.1016/j.techfore.2019.119736.

[3] O. Kovács O. Az ipar 4.0 komplexitása – II., Közgazdasági Szemle, LXIV. évf., (2017), (970–987. o.), https://doi.org/10.18414/KSZ.2017.9.970

[4] M. Zoldy; M.S. Csete; P.P Kolozsi; P. Bordas Á. Torok, Cognitive Sustainability. Cognitive Sustainability. 1, 1 Mar, (2022), https://doi.org/10.55343/cogsust.7.

[5] M. Holubčík; G. Gabriel Koman; J. Soviar, Industry 4.0 in Logistics Operations, Transportation Research Procedia, Volume 53, (2021), Pages 282-288, ISSN 2352-1465, https://doi.org/10.1016/j.trpro.2021.02.040.

[6] G. Pauer; T. Sipos; Á. Török, Statistical analysis of the effects of disruptive factors of driving in simulated environment. Transport, (2019), 34 (1), 1-8. https://doi.org/10.3846/transport.2019.6724.

[7] M. Petracca; P. Pagano; R. Pelliccia; M. Ghibaudi; C. Salvadori; C. Nastasi C, Onboard Unit hardware and software design for Vehicular Ad-hoc Networks. CNIT - National Laboratory of Photonic Networks, Italy, (2012)

[8] Alan R Earls, IoT Smart Roads: Paving the way Downloaded: https://www.smart-industry.net/iot-smart-roads-paving-the-way/, (2018), (Last downloaded: 07.07.2022.)

[9] TNET: Smart Road Intelligent Transport System, https://www.tnet.it/en/smart-road-and-intelligent-transportation-system/ Last access: 20.06.2022.

[10] J.H. Nord; A. Koohang; J. Paliszkiewicz, The Internet of Things: Review and theoretical framework; Expert Systems With Applications, (2019), https://doi.org/10.1016/j.tra.2019.01.025

[11] B. Edmound, Connectivity as a Service for Designing, Ordering and Managing Enterprise Networks, https://www.slideshare.net/Global_Capacity/slide-share-connectivityasservice, (2015), Last access: 17.06.2022.

[12] Half-Cooked Research Reports, Mobility as a Service Market Research Report-Forecast 2023, (2019), https://www.marketresearchfuture.com/reports/mobility-as-a-service-market-3109, Last access: 19.06.2022.

[13] A. Boldizsár, F. Mészáros, Synchronization of transportation and enterprise resources with the emergence of autonomous road freight; 7th CERS Conference Sopron, (2020), 671 p. pp. 557-566., 10 p.

[14] https://lpi.worldbank.org/, Last access: 20.02.2022.

[15] https://www.weforum.org/reports/the-global-competitveness-report-2018, Last access: 20.02.2022.

[16] https://www.bbvaresearch.com/wp-content/uploads/2019/04/Digix_v7-1.pdf, Last access: 20.02.2022.

The occurrence of kinesiophobia in the rehabilitation of locomotor system injuries

T. Crljenko [a], S. Jelica [b] M. Kunac [b] T. Kokić [c,d]

[a] Proprio centar Zadar, Ante Starčevića 7A, 23000 Zadar, Hrvatska

crljenko.toni@gmail.com

[b] Veleučilište Lavoslav Ružička u Vukovaru, Županijska 50, 32000 Vukovar, Hrvatska

stjepan.jelica@gmail.com mkunac@vevu.hr

[c] Medicinski fakultet Osijek, Sveučilište Josipa Jurja Stossmayera u Osijeku, Josipa Huttlera 4, 31000 Osijek

tkokic@gmail.com

[d] Opća županijska bolnica Vinkovci, Zvonarska 57, 32100 Vinkovci, Hrvatska

Abstract

Puropose: In this research, the goal was to explore the occurrence of kinesiophobia in people rehabilitating from injuries of the locomotor system and to measure the level of kinesiophobia. Kinesiophobia or fear of movement is a common occurrence in the locomotor system rehabilitation process. It plays a major role in the transition of acute pain to chronic pain and also affects the outcomes of rehabilitation. The term arose within a model that describes the avoidance of movement due to the fear of pain or re-injury. **Design**: This cross-sectional study (N=53) was conducted in Zadar in 2020. The level of kinesiophobia was measured using the Tampa questionnaire, which was composed of 17 statements about pain, beliefs about pain and physical condition, and about exercise. **Results**: The results showed that the level of kinesiophobia is higher in men compared to women, in older people compared to younger people, as well as in participants who are not active.

Keywords: kinesiophobia, rehabilitation, locomotor system.

INTRODUCTION

In the context of musculoskeletal biomechanics, we define injury as damage caused by physical trauma, suffered by muscle, bone or connective tissue[1].

Globally, in 2019, 2.41 billion people had certain medical conditions, of which 1.71 billion were musculoskeletal diseases, which at one point in the duration of the disease would benefit from rehabilitation and and its influence would be positive in the further course of the disease[2]. Kinesitherapy is a branch of physical therapy that applies movement in the prevention and treatment of injuries, body deformations or diseases. It is the initial step of the rehabilitation process in which the goal is to achieve complete recovery after damage to the body, and the individual with it achieves the most natural continuation of life. Often skipped in the rehabilitation process, but regardless extremely important for recovery and prevention of future injuries are the psychological factors of the injury that can affect the person before, during and after the injury and rehabilitation. Many theories have been proposed that identify psychological state as a predisposing risk factor

for injury. In addition, the psychological state after injury greatly affects rehabilitation and recovery [3]. Among the many biopsychosocial factors that contribute to the experience and impact of pain, the negative or acute phase becomes chronic in some individuals, and the reason why pain persists after healing of damaged tissue. In this context, the fear-avoidance model (fig.1) is the model that has received the most empirical attention to the explaination of the development and persistence of disability after an episode of acute musculoskeletal pain. People affected overreact to the real or potential threats, developing behavioral models where they avoid actions or movements that could trigger new or repeated injury and, consequently, pain [4].

The connection between fear and pain is described through several conceptual terms, including: pain-related fear, fear-avoidance model, fear of movement, and kinesiophobia [5]. Kinesiophobia, also known as fear of movement, is defined as an excessive, irrational and debiliating fear of physicalmovement due

Fig.1 . Fear-avoidance model.[6]

to a sense of vulnerability created during a painful experience caused by an injury or fear of re-injury [7]. Both constructs are very similar and have the same clinical significance. While kinesiophobia is usually measured by the Tampa Scale for Kinesiophobia, there is no specific tool for measuring the fear of movement [8].

2. METHODS

The aim of the research is to measure the degree of kinesiophobia in people who were rehabilitating from locomotor system injuries. The research was conducted in April 2021 at the Proprio Center for Physical Rehabilitation in Zadar. Fifty-three subjects (N=53) aged between 22 and 62 who were rehabilitating from an injury to some part of the locomotor system took part in this cross-sectional study. Out of 53 participants, 43 were women and 10 were men. A questionnaire was created based on the English version of the Tampa questionnaire for kinesiophobia, which consists of 17 statements (Likert 1-4).

Scoring ranges from 1 to 4. Answers 1,2,3,5,6,7,9,10,11,13,14,15,17 were scored normally, while answers 4,8,12,16 do the scored inversely.

A high score on the Tampa Kinesiophobia Questionnaire indicates a high level of kinesiophobia, while a score of 37 or higher is a reference value on a number line that establishes a high level of kinesiophobia and predicts poorer health outcomes [8]

In accordance with the objectives of the research, we set the following hypotheses:

H1- Females will have a higher score on the Tampa questionnaire than males.

H2 - Older people will have a higher score on the Tampa questionnaire than younger people.

H3 - People who are not physically active will have a higher score on the Tampa questionnaire than people who are physically active.

The t-test for independent samples was used to test hypothesis (significance level was set at 0.05).

3. RESULTS AND ACHIEVEMENTS

The research included both males (18,87%) and females (81.13%). The participants were divided into two groups by age: from 22 to 40 years old and from 41 to 62 years old.

Between younger and older respondents there are statistically significant difference (p=0,04). Older respondents (age 41-62) had a higher score on the Tampa questionnaire (36.08±4.53) compared to younger respondents (33.15±5.97).

Table 1. Level of kinesiophobia

Participants N=53		Male	Female	Younger (22-40 years)	Older (41-62 years)	Physically active	Not physically acitve
	Kinesiophobia mean±SD	38,20 ±4,89	33,74 ±5,29	33,15 ±5,97	36,08 ±4,53	33,91 ±5,15	35,79 ±5,94
	Min/max Tampa score			21/44	22/62		
	P value vs. groups	0.019		0.040		0.234	

The average value of kinesiophobia in physically inactive subjects was (35.79±5.94), while physically active individuals showed a lower level of kinesiophobia (33.91±5.15) expressed through the result of the questionnaire but the difference was not statistically significant (p=0.234).

Comparision by gender showed that men had a higher degree of kinesiophobia (38.2 ±4.89) than women (33.74±5.97). There are significant statistical differences in the level of kinesiophobia between male and female subjects in favor of male subjects which scored higher for kinesiophobia (p=0.019). Thus, the first hypothesis was rejected.

Although available data on a significant difference are limited and inconsistent some studies have concluded that women catastrophize more than men when it comes to pain, but there is evidence that men show higher levels of kinesiophobia than women [9]. In both cases, significant differences are not always established, but to the authors' knowledge, no research has conducted ehere women showed a higher level of kinesiophobia than men [10]. In male and female participants, the results showed that men had a higher Tampa questionnaire score on average compared to women. Between younger and older respondents there are statistically significant differences in the level of kinesiophobia

(p=0,040), with the older respondents having a higher score on the Tampa questionnaire compared to younger respondents, which confirms the second hypothesis of the research, which states that the older group of respondents will have a higher score than the younger group. In a study [12] report that more pain catastrophizing is typically associated with younger age, while the relationship between age and fear of injury/re-injury is very small or non-existent. There is evidence from clinical and social research that the older population thinks and reacts more stoically to pain, regardless of differences in nociception and pain perception that should make older people more vulnerable to the negative impact of pain [12] [13].

Although the results showed that physically active individuals have a lower level of kinesiophobia than physically inactive individuals, there is no statistically significant difference in the level of kinesiophobia between these two groups, which partially confirms the third research hypothesis, although there is a difference in the results, which is not statistically significant (p=0.234) In a study 2016. [14] people with chronic neck pain achieved pain relief by participating in exercise programs and sports activities. In the study (15) conducted on 105 Polish perimenopausal women (from 48 to 58 years old) which investigated the impact of physical activity and exercise on the level of physical activity barriers (kinesiophobia), the results showed that the physical activity and abilities of the women

were significantly related to the level of kinesiophobia. The low level of physical activity and ability in perimenopausal women favors a kinesiophobic attitude and thus increases the level of barriers against engaging in physical activities, which also fits in with the results of this research. Thus, the third hypothesis was confirmed.

4. CONCLUSION

The data obtained in this research indicate that kinesiophobia is remarkably present in the rehabilitation of locomotor system injuries. Phenomenon of kinesiophobia should definitely be taken into account in every patient during rehabilitation-kinesitherapy and the Tampa questionnaire should be used to evaluate the level of kinesiophobia. There is the need to validate the Croatian version of the questionnaire in the near future.

5. REFERENCES

[1,3] Whiting, W.C., Zernicke R.F., Biomechanics of musculoskeletal injury, Second Edition, Human Kinetics, New Zealand (2008).

[2] Cieza, A., Causey, K., Kamenov, K., Hanson, S. W., Chatterji, S., Vos T. Global estimates of the need for rehabilitation based on the Global Burden of Disease study 2019: a systematic analysis for the Global Burden of Disease Study Lancet 396 (2021), pp.2006-2017.

[4] Luque-Suarez, A., Martinez-Calderon, J.,

Falla, D., Role of kinesiophobia on pain, disability and quality of life in people suffering from chronic musculoskeletal pain: a systematic review, British Journal of Sports Medicine, 53(9), (2019), pp.554-559.

[5,8] Lundberg, M., Grimby-Ekman, A., Verbunt, J. Pain-related fear: a critical review of the related measures. Pain Research and Treatment 2011 (2011), pp.1-26.

[6] Vlaeyen, J. W. S., Linton, S. J., Fear-avoidance and its consequences in chronic musculoskeletal pain: a state of the art. Pain, 85(3) (2000), pp.317-332

[7] Kori SH, Miller RP, Todd DD. Kinesiophobia: A new view of chronic pain behavior. Pain Management (1990), pp.3:35

[9,10] Racine, M., Solé, E., Sánchez-Rodrígue, E., Tomé-Pires, C., Roy. R., Jensen, M. P., Miró, J., Moulin, D. E., Cane, D., An Evaluation of Sex Differences in Patients With Chronic Pain Undergoing an Interdisciplinary Pain Treatment Program. Pain Practice, 20(1) (2020), pp.62-74.

[11] Bränström, H., Fahlström, M. (Kinesiophobia in patients with chronic musculoskeletal pain: Differences between men and women. Journal of Rehabilitation Medicine, 40(5), (2008), pp. 375-380.

[12] Cook, A. J., Brawer, P. A., Vowles, K. E. (2006) The fear-avoidance model of chronic pain: Validation and age analysis using structural equation modeling. Journal Pain, 121(3), (2006), pp. 195-206.

[13] Jong, H. H., Gibson, S. J., Horne, D. J., Helme, R. D., Development of a pain attitudes questionnaire to assess stoicism and cautiousness for possible age differences. The Journals of Gerontology: 56(5), (2001), pp.279–284

[14] Demirbüken, İ., Özgül, B., Kuru Çolak, T., Aydoğdu, O., Sarı, Z., Yurdalan, S.U. Kinesiophobia in relation to physical activity in chronic neck pain. Journal of Back and Musculoskeletal Rehabilitation 29(1), (2016), pp.41-47.

[15] Saulicz, M., Saulicz, E., Knapik, A., Linek, P., Rottermund, J., Myśliwiec, A., Wolny, T.Impact of physical activity and fitness on the level of kinesiophobia in women on perimenopausal age. Menopausal Review, 15(2), (2014), pp.104-111.

Exponential and logarithmic functions and their application in mechanical engineering

M. Čuletić Čondrić [a], M. Stoić [a], B. Grizelj [a], M. Srbalj [b]

[a] University of Slavonski Brod, Technical Department, dr. Mile Budaka 1, 35 000 Slavonski Brod, Croatia, mccondric@unisb.hr, mstoic@unisb.hr, bgrizelj@unisb.hr

[b] University of Slavonski Brod, Mechanical engineering faculty in Slavonski Brod, Trg Ivane Brlić Mažuranić 2, 35 000 Slavonski Brod, Croatia, msrbalj@unisb.hr

Abstract

The paper studies exponential and logarithmic functions that are mutually inverse functions. These functions appear throughout history from Archimedes who dealt with potencies to Euler who defined logarithm, and Napier who compiled the first logarithmic tables. Exponential and logarithmic functions are one of the elementary functions used in arithmetic operations and compositions of other elementary functions. The definition of exponential and logarithmic functions requires knowledge of their properties and graphical representation.

The application of exponential and logarithmic functions is very wide. There are many scope that apply exponential and logarithmic functions to solve their problem tasks from physics, geodesy, biology, economics to forensics. Through examples, the authors will show their application in problem tasks in the wider field of mechanical engineering. The importance and purpose of the Taylor equation in determining the stability of tools in machining will be presented. The properties of exponential and logarithmic functions will be applied through examples related to the elementary theory of plasticity, ie through the force of deformation, Sachs and Siebel equations to logarithmic deformation.

Keywords: exponential and logarithmic functions, mechanical engineering, Taylor equation, logarithmic deformation

1. INTRODUCTION

Since ancient times, people have been familiar with powers and applied them to represent certain phenomena and define them using known numbers and quantities. The first mathematician in history who used powers back in the 3rd century BC was Archimedes. Logarithms were first mentioned by a Swiss watchmaker in the 16th century. Euler is one of the most deserving people for the development of logarithmic and exponential functions and he was the first to define the logarithm. The first logarithmic tables were made by Napier in the 17th century, while the first decade logarithmic tables were made by Briggs. The logarithm of a number x, with respect to the base a, is the number y with which it is necessary to power the base, in order to obtain the number x. [1]

Exponential and logarithmic functions are mutually inverse functions. This property can be seen from the graphs of each individual function, because the graph of the exponential function can be constructed mirroring the y-axis from the graph of the logarithmic function. Graphs can also be used to explain the two concepts of exponential and logarithmic growth and decline.

In the first part of the paper, the exponential function, its definition, graph and properties are presented and explained, and the solution of exponential equations is shown on one example.

Then, in the second part of the paper, the logarithmic function, its properties and graph are described and defined, and an example of solving logarithmic equations is also shown. At the very end, there are several examples of exponential and logarithmic functions, showing the application of these functions in mechanical engineering, but also in other areas such as physics, geodesy, biology, economics, etc. The paper used a mathematical tool, i.e. the dynamic mathematics program GeoGebra, to display graphs of exponential and logarithmic functions.

2. EXPONENTIAL FUNCTIONS

The knowledge of powers goes back a long way, in the ancient Greek mathematician Archimedes mentions powers and was aware that to show the size of the universe he had to use large numbers, i.e. he would show the size of the universe with the help of powers. Thus, with his thinking, he came to the conclusion that the universe is filled with 10^{63} grains of sand. After him, the ancient Mayan Indian tribe also mentioned potencies to try to show how old the universe is, according to them the universe was 10^{29} years old. [1]

2.1. Potency

If it is set that $a > 0$ and is a member of the set $\mathbb{R}$, and n is a member of the set $\mathbb{N}$, it follows

$$a^n = a \cdot a \cdot a \cdot \cdots \cdot a \tag{1}$$

So some real number a is the base while some natural number n is the exponent of the power. The exponent can also be a negative number and a rational number, then it follows

$$a^{-n} = \frac{1}{a^n} \tag{2}$$

$$a^{\frac{x}{y}} = \sqrt[y]{a^x} \tag{3}$$

If x and y are some real numbers, then the properties of powers for addition, subtraction and exponentiation of exponents are valid, the properties of powers are as follows

$$a^x \cdot a^y = a^{x+y} \tag{4}$$

$$(a^x)^y = a^{x \cdot y} \tag{5}$$

$$(a \cdot b)^x = a^x + b^x \tag{6}$$

$$a^x : a^y = a^{x-y} \tag{7}$$

In addition to all the above, according to the agreement is valid $a^0 = 1$ and $a^1 = a$. [2]

2.2. Definition and graph of the exponential function

The function f defined by the formula:

$$f(x) = a^x, \qquad a > 0, \qquad a \neq 1 \tag{8}$$

we call it an exponential function with base a. [3] The domain of an exponential function is the set of all real numbers $\mathbb{R}$, and the codomain is the set $\langle 0, +\infty \rangle$. For $a > 1$ the exponential function is increasing, while for $0 < a < 1$ it is decreasing. Figure 1 shows the graphs of functions for which $a > 1$ and $0 < a < 1$ are valid. The variable x is chosen arbitrarily and by including it in the function $f(x) = 2^x$, the value $y = f(x)$ is obtained, and the coordinates thus obtained form the graph of the increasing function. In an analogous way, the graph of the function $g(x) = 2^{-x}$ for which $0 < a < 1$ where it can be seen that the function is decreasing. [1]

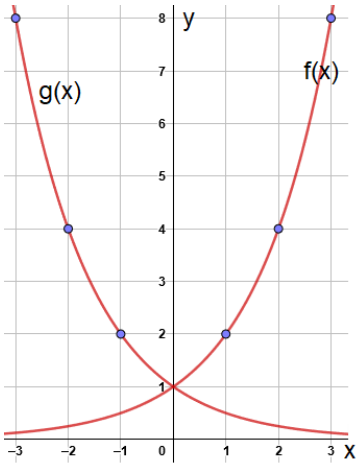

Fig. 1. Graphs of the functions $f(x) = 2^x$ and $g(x) = 2^{-x}$

The basic properties that apply to powers (4)-(7) also apply here, but the expression also applies

a) If it is $a > 1$, than it is $x_1 < x_2$ it's worth it $a^{x_1} < a^{x_2}$ and the function is increasing

b) If it is $0 < a < 1$, than it is $x_1 < x_2$ it's worth it $a^{x_1} > a^{x_2}$ and the function is decreasing

c) If it is $a^{x_1} = a^{x_2}$, than it is $x_1 = x_2$

All properties and rules of exponential functions can be proved very easily.

2.3. Exponential equations

The exponential function $f(x) = a^x$ is also associated with exponential equations of the form $a^x = b,\ b > 0$. The procedure for solving exponential equations will be explained through an example of a task from the field of economics. [3] The number e is also mentioned here, which is called Napier's number and is $e = 2.71815$.

Example 1. The market price of share C_t at time $t,\ t \geq 0$, is modeled using the exponential function $C_t = 130 \cdot e^{X_t}$, where $X_t = 0.05t + a,\ a = -5$. Calculate at what time t stock reached a price of $130e^2$?

Solution $X_t = 0.05t - 5,\ C_t = 130e^2$

$$130e^2 = 130 \cdot e^{0.05t-5}$$

$$e^2 = e^{0.05t-5}$$

$$2 = 0.05t - 5 \quad \Rightarrow t = 140$$

The share reaches the requested price at time $t = 140$.

3. LOGARITHMIC FUNCTIONS

The word logarithm is derived from the greek words *logos*, which means calculation, and from the word *aritmos*, which means number.

3.1. Definition and graph of the logarithmic function

The inverse function of the exponential function is called a logarithmic function and has the form:

$$f(x) = \log_a x, \qquad a > 0, \qquad a \neq 0 \tag{9}$$

The domain of the logarithmic function is $\langle 0, +\infty \rangle$, and the codomain is $\mathbb{R}$. It is strictly increasing for $a > 1$ and strictly decreasing for $0 < a < 1$. The logarithm of x with respect to the base a is equal to the exponent with which the base a should be raised to obtain x. [3]

The formula reads:

$$a^{\log_a x} = x, \qquad x > 0 \tag{10}$$

Logarithms with respect to the base $a = 10$ are called decade logarithms or Briggs logarithms and we write $\log_{10} x$ instead $\log x$. If $a = e$ then we call such logarithms natural or Napier logarithms and write $\log_e x$ instead $\ln x$.

The rules for logarithmization are:

$$\log_a a^x = x \tag{11}$$

$$log_a(xy) = \log_a x + \log_a y \tag{12}$$

$$log_a(\tfrac{x}{y}) = log_a x - log_a y \tag{13}$$

$$log_a x^y = y \log_a x \tag{14}$$

$$log_b x = log_a x \cdot \log_b a \tag{15}$$

Properties of the logarithmic function that also apply are:

a) For each number $a > 0$ and $a \neq 1$ it's worth it $\log_a 1 = 0$

b) If it is $a > 1$, and $x_1 < x_2$ than it is $\log_a x_1 < \log_a x_2$

c) If it is $0 < a < 1$, and $x_1 < x_2$ than it is $\log_a x_1 > \log_a x_2$

d) If it is $\log_a x_1 = \log_a x_2$, it's worth it $x_1 = x_2$

All properties and rules of logarithmic functions can be proved very easily. [4]

Since the exponential and logarithmic functions are inverse functions and their graphs are inverse, i.e. symmetrical with respect to the line $y = x$.

Figure 2 shows the mirroring with respect to the line $y = x$ and is valid for base $a > 1$.

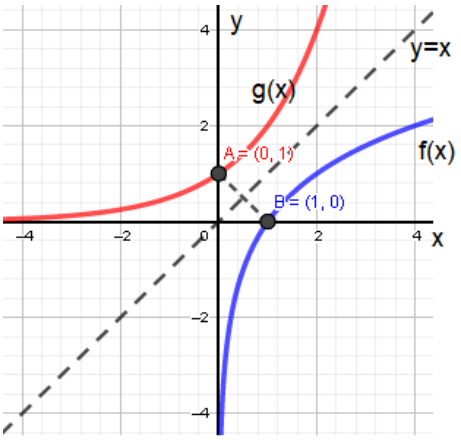

Fig. 2. Graphs of the functions $f(x) = \log_2 x$ *and* $g(x) = 2^x$ [5]

When $0 < a < 1$ is valid, then the logarithmic function appears as in Figure 3 and the axis of symmetry is also the line $y = x$, where you can see the exponential function with the same base $a = 0.5$.

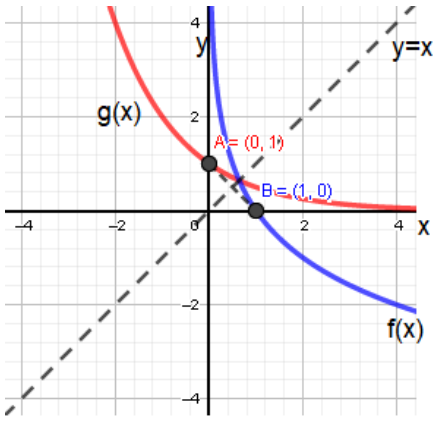

Fig. 3. Graphs of the functions $f(x) = \log_{0.5} x$ *and* $g(x) = 0.5^x$ [5]

From the graphs shown, it can also be concluded that the domain of the definition of the exponential function is the set of real numbers, while the set of values of the exponential function is limited to the set of positive real numbers. From the graphs of logarithmic functions, it can be concluded that the domain of definition of logarithmic functions is limited to the set of positive real numbers, while the set of values of logarithmic functions is the entire set of real numbers.

3.2. Logarithmic equations

Along with the already mentioned logarithmic function $f(x) = \log_a x$, there is also a logarithmic equation of the form $\log_a x = b$. The set of all values of the logarithmic function is the set of real numbers, and therefore this equation has solutions for any real number b. [1] Therefore, an equation that can be reduced to the following form is called a logarithmic equation

$$\log_a x = b\,, \qquad x > 0, \qquad b \epsilon \mathbb{R} \tag{16}$$

The following two examples will demonstrate the application of properties (11)-(15) in solving logarithmic equations and the connection with exponential equations. Before solving any logarithmic equation, it is necessary to check the domain of the function.

Example 2. Solve the equation

$$\log_x 81 = 4$$

Solution

$$x^4 = 81$$

$$x = \sqrt[4]{81} = \sqrt[4]{3^4}$$

$$x = 3$$

Example 3. Solve the equation [3]

$$\log x + \log(x - 3) = 1$$

Solution

Here is the logarithm to base $a = 10$ and $\log_{10} 10 = 1$ .Conditions are: $x > 0$, and $x - 3 > 0 \Rightarrow x > 3$

$$\log[x \cdot (x - 3)] = \log 10$$

$$x \cdot (x - 3) = 10$$

$$x^2 - 3x - 10 = 0$$

$$x_1 = 5, \; x_2 = -2$$

After the logarithmic equation is summarized to a quadratic equation with the help of a calculator, two possible solutions $x_1 =$

$5, x_2 = -2$ are reached, but because the logarithmic function for the solution $x_2 = -2$ is not defined, only one solution remains $x = 5$.

4. APPLICATION OF EXPONENTIAL AND LOGARITHMIC FUNCTIONS

4.1. Sound intensity

Sound intensity represents the energy that a sound wave transmits in a unit of time through a unit area perpendicular to the direction of sound propagation, i.e. the ratio of sound power to area. The sound intensity of $I_0 = 10^{-12}\, W/m^2$ represents the audibility threshold and other intensities are compared with it. Intensities of around $10\, W/m^2$ are at the threshold of pain. The ratio between the intensity of the strongest and the weakest sound is 10^{13}, so it is much simpler and more convenient to calculate with the logarithms of the intensity ratio than with the intensities themselves. For this reason, a new concept was introduced, the concept of sound level L, which can be expressed with the help of the following formula

$$L = 10 \cdot \log \frac{I}{I_0} \qquad (17)$$

where is L sound level, I sound intensity and I_0 is threshold of audibility. [1]

4.2. Taylor's equation

Another example of the application of exponential and logarithmic functions in mechanical engineering is the determination of tool stability during machining.

Durability research methods are usually divided into long-term methods (Taylor's research), which are also standard methods, and short-term methods (minute tests, tests with a continuous increase in cutting speed, tests with multiple penetrations). Long-term research methods are based on a typical wear curve. The typical tool wear curve (Figure 4) represents the amount of wear on the back surface of the tool as a function of processing time. The type curve is valid for the corresponding workpiece-tool combination under the given processing conditions:

$$A = a_p f = const., v_c = const. \qquad (17)$$

Where is a_p tool cutting depth, f is shift and v_c is cutting speed. [6]

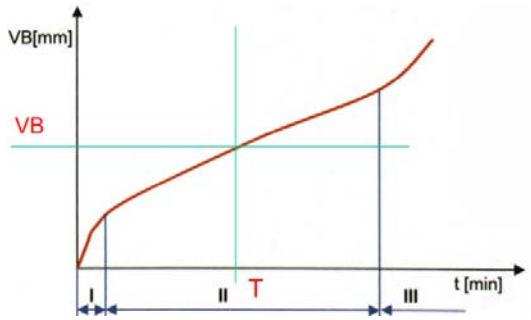

Fig. 4. Display of a typical tool wear curve [6]

In Figure 4, three periods are also important:

I – Running-in period (high intensity, but a small amount of tool wear)

II – Period of normal wear and tear (straight-line change of wear over time)

III – Period of sudden wear (large increase in wear – end of service life, catastrophic wear)

Taylor's method of determining tool blade life (Figure 5) is based on determining typical tool wear curves for different cutting speeds.

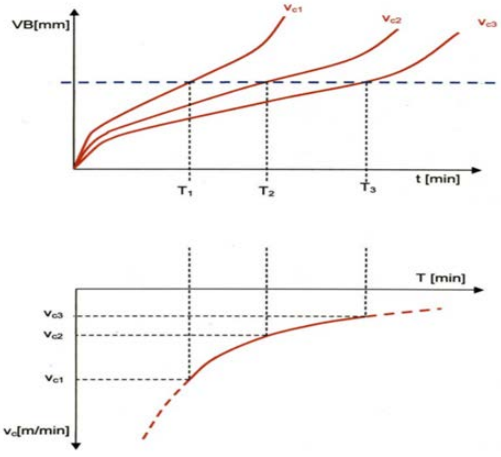

Fig. 5. Presentation of Taylor's method of determining blade life [6]

The durability of the tool represents the time during which the tool works efficiently. The definition of tool durability can be considered directly derived from Taylor's model of tool durability testing, where he expressed tool durability as the time spent by the tool in work. Taylor concluded that the time spent by the tool in the work depends on the cutting speed v_c and that this dependence can be shown:

$$v_c \cdot T^m = C_T \tag{18}$$

where is v_c cutting speed, T is durability of the tool, m is exponent of the Taylor equation, and C_T is Taylor's constant. [7]

Formula (18) can be logarithmized on both sides, expressions (12) and (14) are applied and it takes the form:

$$\log(v_c \cdot T^m) = \log C_T$$

$$\log v_c + m \log T = \log C_T$$

According to the Taylor equation in the $\log T - \log v_c$ diagram (Figure 6), it can be seen that the dependence of the cutting speed and tool life is linear.

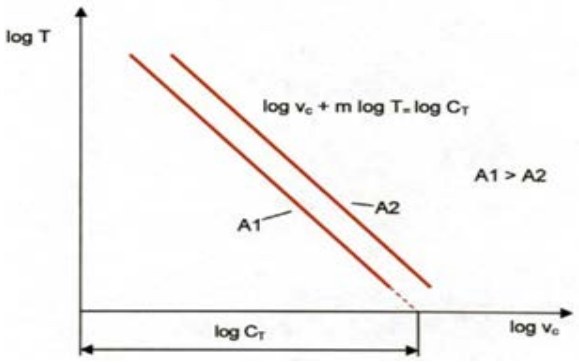

Fig. 6. Taylor's diagram [6]

4.3. Elementary theory of plasticity

The yield condition according to Tresca and von Mises aims to reduce the multiaxial stress state to the uniaxial stress state. The values thus obtained can be compared with the values of the plastic yield stress obtained for the uniaxially stressed state. One of the simplest examples of the use of the stress study of the elementary volume of the material is given in the case of compression of a prism, from which conclusions are then drawn about what happens in free forging and other operations where the material is reshaped by compression. Let there be a given prism of height h, width a, length b and let it be subjected to a compressive force F such that plastic deformation is induced. The expression for the force is:

$$F = 2\int_0^{a/2} p_x\, b\, dx = \frac{bh}{\mu} k_f \left(e^{\frac{\mu a}{h}} - 1\right) \tag{19}$$

where is p_x specific pressure, μ is contact friction factor, and k_f is plastic yield stress. [8]

From the previous expression and Figure 7, the relationship between the exponential and logarithmic functions can be seen.

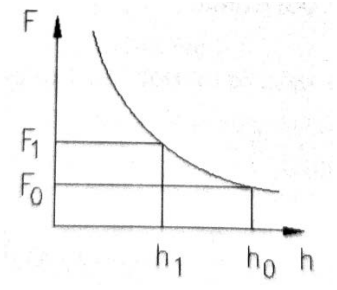

Fig. 7. Force diagram during compression [8]

Various bar materials in the form of round, square and polygonal bars, various profiles, strips, pipes and wires, produced by rolling, are often subjected to the second stage of production and the drawing process. Two equations are important for threading, namely the Sachs equation (20) and the Siebel equation (21), where you can also see the exponential and logarithmic functions and their properties. [8]

$$\frac{\sigma_a}{k_f} = \left(1 + \frac{tg\ \alpha}{\mu}\right)\left[1 - \left(\frac{D_a}{D_b}\right)^{\frac{2\mu}{tg\ \alpha}}\right] + \frac{\sigma_a}{k_f}\left(\frac{D_a}{D_b}\right)^{\frac{2\mu}{tg\ \alpha}} \tag{20}$$

$$\frac{\sigma_a}{k_f} = \varphi\left(1 + \frac{\mu}{\alpha} + \frac{2}{3}\frac{\widehat{\alpha}}{\varphi}\right) \tag{21}$$

The main formula for threading is of the form:

$$A_n = A_0(1 - \psi)^n \tag{22}$$

from which the value of n is obtained by logarithmization, which is the number of required sweeps or the number of required matrices.

$$n = \frac{\ln A_n - \ln A_0}{\ln(1-\psi)} \tag{23}$$

Logarithmic deformation is calculated using the expression: [8]

$$\varphi = 2\ln\frac{D_b}{D_a} = \ln\frac{A_0}{A_1} = \ln\frac{1}{1-\psi} \tag{24}$$

5. CONCULSION

Exponential and logarithmic functions are only two of the nine basic elementary functions in mathematics. They serve as a tool for solving equations with an unknown that is in the exponent of a power, in the base of the logarithm or in the logarithm. The use of these functions in combination with the use of calculators enabled the accurate and fast solving of problems that historically scientists had to calculate for weeks. Progress in the development of astronomy, biology, physics, navigation, geodesy, mechanical engineering and many other sciences was made possible precisely by the discovery and application of logarithmic and exponential functions, and today's modern science, especially in the aforementioned areas, is not possible without these functions.

In the fourth part of this paper, the formulas, definitions and their application in the field of mechanical engineering are shown, especially in processing by separation of particles and shaping of metals by deformation. Taylor's formula, as well as Siebel's and Sachs' equation are very important and it also shows how well it is necessary to know the exponential and logarithmic properties in these expressions in order to quickly and accurately find the unknown that is in the exponent or logarithm.

6. REFERENCES

[1] Exponential and logarithmic functions, M. Srbalj, final paper, (croatian) University of Slavonski Brod, Technical department, (2020).

[2] B. Dakić, N. Elezović, Mathematics 2, the second part, (croatian), Element, Zagreb, (2018).

[3] V. Halusek, B. Radišić, M. Špoljarić, Applied mathematics in economics, (croatian), Požega, (2017).

[4] S. Kurepa, Mathematical analysis, the first part, (croatian), Tehnička knjiga, Zagreb, (1975).

[5] https://www.geogebra.org/search/logaritamska%20funkcija, last access 01/07/2022

[6] Influence of cutting speed and tool wear on the shape of a separate particle when lathe, L. Novotni, final paper, (croatian), University of Slavonski Brod, Technical department, (2021).

[7] Š. Šavar, Particle separation processing, the first part, (croatian), Zagreb, (1978)

[8] B. Grizelj, Metal shaping by deformation, (croatian), Slavonski Brod, (2002)

History of teacher education in Slavonski Brod

J. Jagodar [a], I. Stipić [b]

[a] Department of Social sciences and Humanities of the University of Slavonski Brod, Ivana Gundulića 20, 35000 Slavonski Brod, Croatia, jjagodar@unisb.hr

[b] University Library of the University of Slavonski Brod, Ivana Gundulića 20a, 35000 Slavonski Brod, Croatia, istipic@unisb.hr

Summary

The beginnings of higher education in Slavonski Brod date back to the 18th century, when the Franciscans opened a study of philosophy in their monastery, which operated intermittently until 1831. In addition to the study of philosophy, from 1812 to 1843, the Provincial Study of Theology also operated in the monastery. From its abolition until the middle of the 20th century, no higher education institution is operational in Slavonski Brod.

After the law on compulsory eight-year education of 1951, there was a need to establish new studies for teacher education, as the number of students in schools increased greatly. In 1959, the Council of the Higher Pedagogical School in Zagreb adopted a decision on the establishment of the Teaching Centre for Part-time Studies in Slavonski Brod. The first students were enrolled in 1959. The following school year, study groups for music education and the Russian language were enrolled. The People's Committee of the District of Slavonski Brod adopted the Decision on the establishment of the Pedagogical Academy in Slavonski Brod, which worked from 1961 to 1972.

The aim of the work is to explore, consolidate and present data on the history of teacher education in Slavonski Brod until the seventies of the 20th century.

Keywords: higher education in the area of Slavonski Brod, education of teachers in Slavonski Brod, Franciscan College of Philosophy in Brod, Teaching Center Slavonski Brod, Pedagogical Academy in Slavonski Brod

1. INTRODUCTION

The Catholic Parish in Brod na Savi/Slavonski Brod was very successfully managed, even during the Ottoman rule, by the Franciscans of Bosnia of Srebrena [1]. Among other things, this is confirmed by the first printed book that we associate with the Slavonski Brod "Thesavrvs perpetvvs indulgentiarum seraphici ordinis sancti patris nostri Francisci" written in 1662 by a former Italian student, Bosnian friar and Slavonski Brod's parish priest fr. Ivan Ančić precisely during his parish priestship in the city still under the rule of the Ottomans [2]. After the liberation of the city in the 18th century, Brod na Savi/Slavonski Brod developed into a more important settlement of the Slavonian part of the Military Frontier. The most important role in the cultural and educational development of the city throughout the 18th and 19th centuries belongs to the Franciscans, and the central educational place consists of various forms of educational activity in the Franciscan Monastery on the coast of the Sava. The need to literate and educate the youth of Slavonski Brod was recorded through organized elementary and secondary school education probably in the premises of the Slavonski Brod's monastery already from 1709, because the

first special school building in Brod was built only in 1730, and even in this school until 1777 the students were taught by the Slavonski Brod's Franciscans [3,4,5]. In addition, the monastery itself organizes the education of future priests - novitiate. For the purposes of education in the Franciscan monastery in 1710, the Higher Philosophical College began its work. It worked with a short interruption until 1783. After the re-establishement of the Monastery in Slavonski Brod in 1806 the Franciscan brothers return to it. With their second beginning they are relaunching the philosophical study which lasts until 1831. In addition to studying philosophy, from 1812 the monastery also held the Provincial Study of Theology. After 1843, there were "no more philosophy nor theology studies in Brod." [6]

The training of teachers in the area of Slavonski Brod was initiated in the second half of the 20th century, primarily as a dislocated study of the Higher Pedagogical School in Zagreb, then as a independent study within the Pedagogical Academy in Slavonski Brod, which operated from 1961 to 1974 and was completed by more than 3000 students from the area of Slavonski Brod and the wider surroundings and the territories of Bosnia and Herzegovina and Serbia (as part-time students of dislocated studies in several places).

2. FRANCISCAN STUDY OF PHILOSOPHY AND THEOLOGY

2.1. Franciscans and Brod

The geographical location of Slavonski Brod at the beginning of the 18th century after the Great Viennese War, its leaning on the Sava River and neighbouring Bosnia, which is still under the Ottoman Administration, the need to educate its own clergy for pastoral, enlightening and pedagogical work in the community and the persistent Franciscan community made the Slavonski Brod's Monastery an ideal place for the organization of the Provincial Study of Philosophy. In 1710 the work of the Franciscan High Philosophical School began in Slavonski Brod.

Ignjat Alojzije Brlić, Josip Koprivčević, Rudolf Horvat, Tomo Matić, Franjo Emanuel Hoško, Paškal Cvekan, Andrija Zirdum, Eusebije Fermendžin, Mato Artuković, Dubravko Jelčić, Stribor Uzelac Schwendemann and others have been writing about the Franciscan College of Philosophy in Brod, and the proceedings from the scientific conferences "O Slavonskom Brodu" ["About Slavonski Brod"] from 1994 and "Franjevci u Slavonskom Brodu" ["Franciscans in Slavonski Brod"] have been published 2007. The most important source for the history of the Franciscans in Brod is the translated and published "Kronika Franjevačkog samostana u Brodu na Savi" ["Chronicle of the Franciscan monastery in Brod na Savi"]. The edition of the "Kronika" in four volumes covers the period from 1706 to 1932, and was published as a project of the Slavonski Brod's branch of Matica hrvatska from 1995 to 2003. The "Hrvatski franjevački biografski leksikon" ["Croatian Franciscan biographical lexicon"] is the best source for biographical data on significant Franciscans and professors of the Franciscan College of Philosophy in Brod. "Leksikon brodskih pisaca" ["Lexicon of writers from Slavonski Brod"] brings significant biobibliographic data on the Slavonski Brod's Franciscan written heritage.

2.2. Two Franciscan higher education starts in Brod

The Franciscan College of Philosophy in Brod was established by the decision of the administrative council of the Province of Bosna Srebrena on September 22, 1710 in Velika. The first teacher of the college was appointed Luka Pontić from Slavonski Brod, who, as a member of the Province of Bosna Srebrena, most likely completed his higher education in Italy. With the decision of the new provincial Petar Pastirović, after only two years, Pontić and his students were moved to Požega, and the

Slavonski Brod's monastery became a place of novitiate by the same decision, a place of upbringing for Franciscan recruits who began Franciscan life in it. But already in 1720, the newly elected provincial Andrija Kutjevčanin renewed the work of The Franciscan College of Philosophy in Brod. Since then, the college has been continuously active in Brod until 1757 under the auspices of the Province of Bosna Srebrena, and after that as part of the Province of St. Ivan Kapistran until 1783 due to the abolition of religious schools by Emperor Joseph II inspired by the ideas of the Enlightenment and reformed Catholicism or Jozefinism, he broke the allegiance of the Hasburg Monarchy to previously established teaching practice at Franciscan colleges across the empire [4,5]. Shortly after his studies, in 1787 the Slavonski Brod's monastery was abolished. The premises of the monastery were converted into school premises with teacher's apartments, for the city's salt storage, etc., and the monastery's inventory, together with the rich library, was taken by the remaining monks with them to monasteries in Našice and Đakovo [6]. In 1806 with the agreement between Fr. Marijan Lanosović and Antun Mandić, provincial and future bishop of Đakovo, on handing over the Franciscan monastery in the Đakovo diocese for the purposes of housing a theological seminary in exchange for the return of the temporarily occupied monastery in Brod, and with the approval of Emperor Francis II, the return of the Franciscans to Brod and the continuation of their activities was realized until today. Their return was wholeheartedly assisted by the citizens of Brod through their work and voluntary contributions. The same 1806 the College of Philosophy was renewed [5,6].

2.3. Students and curriculum

Back in 1708 with its decree, the Parliament of Bosna Srebrena requested for the alumni of Franciscan grammar schools, candidates for priests and future professors to be from good families, are 12 to 14 years old and that after three years in the monastery they can enter novitiate as a condition for continuing their studies in philosophy and theology [5,7]. Due to the political circumstances in which the Catholic Church in the Ottoman Empire was located "... The Franciscans of Bosna Srebrena had an important privilege and could send their students of philosophy and theology to all the provinces in The Order, and they had to receive them and educate them for free." Abroad, mostly in Italy, were those students who were destined for a professorship after their studies, and in order to continue their education, they had to have an excellent knowledge of the Latin language. As a condition of study, students had to undergo primary school material beforehand: read, write (They learned two scripts in parallel: Latin and Bosnian.), religious education, singing, then the so-called humanistic, grammatical gymnasium, *trivium* (grammar, rhetoric, dialectics) and *quadrivium* (arithmetic, geometry, music and astrology). Very demanding primary and secondary education lasted up to eight years. [7,8].

Through the full 65 years of the 18th century, until the forced abolition of studies in Brod, the Franciscans of Slavonski Brod, through an organized three-year study within their The Franciscan College of Philosophy, raised and educated a whole range of students. Many of them, having completed their studies in philosophy and continued their studies in theology, became distinguished professors not only in Brod, but also at many other universities throughout the Province. Professors, lecturers of philosophy were selected from the most excellent students with the obligation to take a very rigorous exam, and in order to teach theology they had to be previously vetted, excellent lecturers in philosophy. Given the need to continue studying theology, the number of Slavonski Brod's students was not large. The students were attached to their professor. As a rule, seven to eight students. To facilitate the transition of students from one course to another at any Franciscan college, the detailed, uniform curriculum laid down in the so-called Victorian constitutions was also the core curriculum throughout the life of the Franciscan college in

Brod. Lectures are organized in Latin according to the scholastic method twice a day for an hour and a half. It is interesting that for the sake of accuracy, the classrooms were equipped with a device for measuring time (hourglass). In case the lecturer was late, the students were not obliged to wait for him. In addition to regular attendance, students had the obligation of half-hour exercises in crossed material with the professor every night. The three-year school material included "a whole philosophical course, tj. Summulae (*logic minor*), logic (*logic maior*) physics, metaphysics, the doctrine of the soul, about emergence and decomposition, and if there is time left, then about heaven, the world and atmospheric circumstances." [8]

After the return of the Franciscans to Brod in 1806 the organization of philosophy studies continued in the monastery until 1831 when it ceased its work. In addition to studying philosophy from 1812 to 1843 the Provincial Study of Theology also operates in the monastery [6]. After that, until 1959, i.e. until the establishment of the Teaching Center for Extraordinary Studies in Slavonski Brod of the Higher Pedagogical School in Zagreb, there was not a single higher education institution.

2.4. Significant Slavonian franciscan professors and their heritage

With the duration of the study of philosophy and theology through the 18th and 19th centuries, the work of forty professors (lecturers) was recorded in Brod, many of whom distinguished themselves with their work in the field of education and culture. Their contribution is recognizable through the written legacy inherited by monasteries and libraries throughout Europe as well as through the extensive literature through which it is described [1,4,5,6,9]. By training students in both Croatian language and writing their papers in Latin and Croatian, they managed to resist the strong pressure of Germanization. His work on mass literacy, organization of ceremonial masses in folk, Croatian language and organization of theatrical life (The only preserved Croatian a school drama from the 18th century In Slavonia, "Judith, victrix Holofernis" was performed around 1770 in the Franciscan high school in Brod, and the famous Brod native Andrija Antun Brlić also acted in it.) they left a strong Pre-Illyrian stamp of the national peculiarity of the Slavonian, Croatian people. I. A. Brlić in his “Uspomene na stari Brod” [“Memories of the old Brod”] records the oldest preserved song on hrv. language "Isus, Isus, naša dika" [“Jesus, Jesus, our joy”] The song was sung on January 13, 1745 in Brod by Friar Petar Sabovljević from Vukovar. [11]

Preserved manuscript and printed material testifies to their extremely responsible approach in working with students. Blaž Šimić also compiled the first philosophy manual in Brod. The literature wrongly attributes him as being from Dubrovnik (Hoško, Frkin, etc.). Namely, the wrong reading of his place of birth, the Latin "a Dubovikki" as Dubrovnik instead of Dubovik near Slavonski Brod by one of the authors generated an incorrect attribution by others. After him, many other professors draw up similar manuals, and after the obligation of public defense, they also print the so-called thesis from philosophy, write pious texts, catechisms, etc. Among them, the work of four Slavonski Brod’s Franciscans should definitely be singled out:

- Antun Bačić,[1] the writer of the “Istina katoličanska” ["Catholic truth"], the Church Builder and the last provincial of the Province of Bosna Srebrena before the division of the monastery in Slavonia and Danube into a separate Province [9,10].

[1] Antun Bačić, scientist, priest and religious writer (Vrba near Brod na Savi, around 1690 – Našice, December 12, 1758) A scientific meeting about him was held in 2010 in Slavonski Brod and Našice, and in 2013 the Proceedings were published with of the subject set.

- Ivan Velikanović,[2] Bologna student, head of Osijek's general university, certified examiner and provincial of the Province of St. Ivan Kapistran [9,10].

- Marijan Lanosović,[3] a Buda's and Osijek student, as well as a Osijek and Slavonski Brod's professor of philosophy and theology, publisher of the first Croatian calendar in Buda (1763-1766), lexicographer and member of the spelling commission for the publication of Stulli's dictionaries, author of the oldest known regularly conducted Meteorological Diary (1769) with a rich scientific legacy [9,10].

- Marijan Jaić,[4] professor of dogmatics, moral and pastoral theology, translators, librarians, organists and music educators, dean of the Vukovar College of Theology and provincial of the Province of St. Ivan Kapistran. His pious written legacy and his work on promoting Croatian hymning marked him as a great national deserving person in the Pre-Illyrian and revival period of croatian histories [9,10].

Library of the Franciscan monastery in Slavonski Brod despite its historical adversity and two peasants: after the abolition of the monastery in 1787 from Brod to Našice and Đakovo and the return upon the restoration of the monastery in Brod in 1806, it kept a rich library material, manuscripted and printed, authored by professors and students of one of the, in the monastery of organized, studies [6]. The material in question is a real source for further research and valorization of the work of the Franciscan colleges in Brod. The beginnings of the library can be placed around the year 1700, and the "Kronika Franjevačkog samostana u Brodu na Savi" records the trace of its first librarian, from 1771 the director of the Franciscan grammar school in Brod and Brod professor Jerolim Bačić, and the specially arranged library space in 1772.

3. TEACHING CENTER SLAVONSKI BROD (1959-1961)

A more modern way of training teachers in the area of Slavonski Brod began in the second half of the 20th century. After the law on compulsory eight-year education, passed in 1951, there was a need to establish new studies for teacher education, because the number of students in schools increased greatly, and the number of untrained teachers was very large. Then the Higher Pedagogical School Zagreb established the Teaching Center for Extraordinary Studies in Slavonski Brod on March 30, 1959. The teaching center functioned as a dislocated study programme, and students were able to study in one of three study groups: mathematics and physics, Russian language and music education [12,13]. In the spring of 1959, 25 students from the area of Slavonski Brod, Nova Gradiška, Slavonska Požega and three students from other districts were enrolled in the group of mathematics-physics because the largest number of teachers of these subjects were missing. Marija Buzatović was appointed director of the Teaching Centre for Outstanding Study in Slavonski Brod [14,15], and during the functioning of the Teaching Center, employees organized and performed classes and exams for part-time students. The following school years (1960/1961) also enrolled study groups for music education (15 students) and Russian (20 students). In Slavonski Brod, all administrative, financial and personnel activities were conducted on behalf of the Higher Pedagogical School from Zagreb [16]. The teaching center

[2] Ivan Velikanović, scientist, priest and writer (Brod na Savi, August 7, 1723 – Vukovar, August 21, 1803). The 200th anniversary of Velikanović's death was marked with a scientific meeting under the auspices of HAZU in 2003 in Slavonski Brod.

[3] Marijan Lanosović, priest, linguist, religious writer (Orubica, June 12, 1742 – Brod na Savi, November 25, 1812).

[4] Marijan Jaić, scientist, priest, religious writer (Brod na Savi, July 4, 1795 – Buda, Hungary, August 4, 1858) A scientific conference organized in 1998 under the auspices of HAZU was dedicated to Jaić's work.

functioned until December 6, 1961, when the conditions were created for all jobs to be taken over by the newly established Pedagogical Academy, which has since secured all the conditions for taking over programs, students, inventory and other business and legal activities related to the training of teachers in the area of Slavonski Brod, which began in 1959. [17].

4. PEDAGOGICAL ACADEMY IN SLAVONSKOM BRODU (1961-1972)

4.1. Establishment of the Pedagogical Academy

Since the Parliament of the People's Republic of Croatia passed the Law on Pedagogical Academies on July 7, 1960, a legal basis was created for the establishment of the Pedagogical Academy in Slavonski Brod, which was to be created by the integration of the Teacher's School and the Center for Outstanding Study in Slavonski Brod [14]. That is why the People's Committee of the District of Slavonski Brod decided to establish the Pedagogical Academy Slavonski Brod on March 20, 1961. Then, in the “Narodne novine” gazette, a competition was launched for the director and teachers on April 26 of the same year, after which teachers Ivan Alinjak were employed[5], Marija Buzatović[6], Mijo Cicvarić[7], Miroslav Degoricija[8], Erika Kohn[9], Miroslav Čižmek[10] and Jure Oguić[11]. Marija Buzatović was elected director of the Academy[12], and Ivan Alinjak as deputy director. In early November, English teacher Martin Kaminski was also admitted. On 3 July 1961, the Commission for the Establishment, the representatives of the Faculty of Humanities and Social Sciences from Zagreb, the NRH Council for Education and the Department of Education, determined that all the conditions for the opening of the Pedagogical Academy in Slavonski Brod, which began its work on 1 September 1961, had been met. [13,14,15,18,19].

The Council of the Pedagogical Academy consisted of 11 members, of which were two representatives of the People's Committee of The District (NOK) Slavonski Brod, a representative of the District Committee of the Socialist Union of Working Peoples (SSRN), two representatives of the teaching council, a representative of the Association of Educators in Slavonski Brod, a representative of the District Committee of the People's Youth, a representative of the People's Committee of the Municipality (NOO) Slavonski Brod, two representatives of the students, the director of the Pedagogical Academy. Their term of office was two years [13]. The Council took all important decisions implemented by the Executive Board consisting of three members elected by the Working Community and two members appointed by the Union of Students. It should also be noted the Assembly of the

[5] Ivan Alinjak was a professor at the "Zlatko Šnajder" gymnasium and was elected to the position of professor at the higher school for physics. [15]

[6] Marija Buzatović was a professor-adviser at the Institute for Education and was elected to the position of professor at the higher school for pedagogy. [15]

[7] Mijo Cicvarić was a professor-adviser at the Institute of Education and was elected to the position of professor of the higher school for history. [15]

[8] Miroslav Degoricija was a teacher at the "Zlatko Šnajder" gymnasium and was elected to the position of professor of the higher school for mathematics. [15]

[9] Erika Kohn was the teacher-director of the Teacher's School and was elected to the position of professor of the Russian language school. [15]

[10] Miroslav Čižmek was a tenured professor at the "Radničkom fakultetu" and was elected to the position of lecturer of the Croatian language higher school. [15]

[11] Jure Oguić was a teacher at the "Učiteljska škola" and was elected to the position of professor at the higher school for pedagogy. [15]

[12] Marija Buzatović was the director until November 1962, then Milan Cvitković was elected to the position of director, who held the position until 1969. The last director was professor Mijo Cicvarić (until it was terminated on August 31, 1971).

Academy, which consisted of all students, teachers and associates of the Academy and which was held at least once a year and discussed the work and other issues of interest for the development of the Academy [20].

According to the Statute, the Pedagogical Academy in Slavonski Brod was "a higher education self-governing institution of special social interest within which a study for the acquisition of more fitness is organized and performed" [20]. The chairs that have been active at the Academy since 1961 were: chair of joint study, chair of class teaching, chair of social sciences, chair of foreign languages, department of mathematics and physics and chair of biology and chemistry. The head of the department was elected for two years from among the teachers of the college and once a year he submitted a report on the work of the department. Since 1966, the following chairs have operated: for joint study; "Croatian Serbian" language; history; mathematics; physics; chemistry; biology; classroom teaching; English and Russian language [13].

The Academy also had its own library, which contained books, magazines and other editions. The library was managed by a library board consisting of three members appointed by the Council of the Academy for two years [20].

From 1961 to 1964, the Academy operated in a building on Omladinska 6 (former boy boarding school), then a new building was built (1964/1964) that was connected to the building of the former Teacher's School in Gundulić Street and classes began there in June 1964. [13]

During its 11 years of existence, the Academy has organized several events, most notably the celebration of the fifth anniversary of the Stable Academy, which took place on December 3, 1966 in the cinema "Jadran". At that time, a formal session of the Assembly of the Academy was held, and among the guests were the Director of the Pedagogical Academy from Zagreb and the representative of the Association of Pedagogical Academies of Croatia Prof. Josip Busija and the Director of the Institute for the Improvement of Education of The District Osijek Lazo Petnjarić. Their arrival proved the connection of the Pedagogical Academy from Slavonski Brod with other districts and pedagogical academies that operated on the territory of Croatia and its affirmation by other academies, which Prof. Busija emphasized in his speech [21].

4.2. Organization Study

Students were able to attend the Academy as a full-time and part-time student, and the study lasted two years (four semesters). The winter semester lasted from October 1 to January 15, and the summer semester from February 16 to May 31. [20]. Classes and exams were public and were performed in Croatian literary language. The study was divided into joint study, i.e. the study programme subjects that all students listened to together, and a special study in which students were divided into groups The joint study consisted of the following subjects: philosophy, sociology, general pedagogy with the history of pedagogy, didactics, psychology of children with adolescence, pedagogical psychology, defense and protection, and physical education. All study groups could be entered by candidates who had completed high school, teacher training school, or high school with a special education program [20]. One group consisted of students who studied classroom teaching, and in other study groups students studied for the teachers concerned. Since 1961, there have been the following study groups: mathematics and physics, "Croatian Serbian language" and history, Russian language, English language and music education, and since 1963 class teaching, Croatian or Serbian language and history, English language, and Russian language, mathematics and physics, biology and chemistry. Two years later, in 1965/1966, classroom teaching could be studied in combination with the "Croatian Serbian" language and mathematics, and from 1968/1969 the group music education and physical education were reintroduced. Candidates who

graduated from a four-year technical high school could enroll in a group: mathematics and physics. Candidates who graduated from the four-year secondary medical, agricultural, forestry and chemical school could enroll in the group: biology and chemistry. Languages could be studied by candidates who graduated from high school and studied the language for four years [13,20,22].

A mandatory part of the study was also didactic-methodical exercises in didactic practice, hospitations, practical school work led by methodical teachers at the Academy or teachers in the training room, and fifteen days of practice in elementary schools with which Pedagogy had an agreement signed [20]. Within the Academy there was also a School Pedagogical Centar consisting of the Pedagogical Academy, the Pedagogical Gymnasium and the Exercise Room in Slavonski Brod and which was intended to ensure better education and professional development of primary school teachers. The training room was the "Vladimir Nazor" Elementary School in Slavonski Brod [23], and from 1963, the "Nada Božić" Elementary School (today's "Antun Mihanović" Elementary School) and the "Ivo Lola Ribar" Elementary School (today's "Bogoslav Šulek" Elementary School) [24].

Table 1 shows the number of students per school year.

Table 1. Number of students

School year	Number of regular students
1961./1962.	83
1962./1963.	118
1963./1964.	212
1964/1965.	167
1965./1966.	338
1966./1967.	227
1967./1968.	171
1968./1969.	252
1969./1970.	116
1970./1971.	76

4.2.1. Centers for part-time Study

From 1965/1966, the Academy opened several centres for part-time study in Croatia, Bosnia and Herzegovina and Serbia. Classes were held in the centers once a week during the school year, and the curriculum was shortened to 200-250 teaching hours. After the classes were held, exams were held in the centers. Since classes were not held in the same centres every year, occasional consultations were held in places where there were no classes [23,24]. In 1966/1967, contracts were concluded with elementary schools and municipal education communities in: Slavonska Požega, Nova Gradiška, Županja, Đakovo, Novska, Pakrac, Glina, Podravska Slatina, Virovitica, Derventa, Bosanski Brod, Novi Selo, Koraće and Velika Brusnica.

In order to facilitate the students' education, centres for outstanding study were opened part-time Slavonski Brod, first in Slavonska Požega, and then in Nova Gradiska and Županja. Soon, the request of the workers' universities from Fr BiH and based on the conclusions of the Council of Teachers of the Pedagogical Academy from 18.9.1968. And 5.11.1969. open centres for part-time study in Lukavac, Zenica, Zavidovići and Bosanski Šamac, and later in Mali Zvornik, Smederevo, Kruševac, Belgrade, Ruma with Inđija, Mladenovac and Vrnjačka Banja. Teslić, Maglaj, Srebrenica, Bijeljina, Prnjavor, Pančevo, Paračin, Sremski Karlovci, Kraljevo, Kragujevac and Valjevo were also requested to open the centres, but they were rejected.

Table 2 shows the number of students per place of residence and school year.

Table 2. Centers for part-time study [22,24,25,26]

Place	School year	Number of
Nova Gradiška	1965./1966.	91
	1966./1967.	61
Slavonska Požega	1966./1967.	112
	1967/1968.	
Županja	1966./1967.	52
	1967./1968.	
Bosanski Šamac	1966./1967.	77
Vinkovci	1967./1968.	

	1968./1969.	
Smederevo	1967./1968.	
	1968./1969.	
Kruševac	1967./1968.	
	1968./1969.	
Lukavac	1969./1970.	
	1970./1971.	
Zenica	1969./1970.	
	1970./1971.	
Zavidovići	1969./1970.	
	1970./1971.	

4.3. Federation of Students of the Pedagogical Academy

Students at the Academy enjoyed certain rights and were represented in management structures. The student board had 15 members who dealt with student issues. As noted earlier, the two student representatives were members of the Council of the Academy and represented student interests there. Some students also used student loans, for example, in 1965, 100 students used the loan, in 1966 80 of them, and in 1967 as many as 225. In 1969, 120 students used the loan [13,24,25].

Student activities took place in several sections. The literary section played an active role in the organization of public holiday programs. The choir performed at student ceremonies and other occasions. There was also a biological section within which the student also learned how to make preparations and carried out various tests of plants and maintained plants in the hallway of the building. The photo section did not exist until 1969, then it was the most numerous section in which there were 49 students. The students who were in the section were in charge of recording significant events at the Academy and the photographs served as documentation. The cinema section organized the screening of films, and in 1969 they screened several documentaries, including "Jedan radni dan na PA" and the color film "Tjentište" which was made during the excursion. In addition to them, there was a sports society that included the football, handball, table tennis, chess and shooting sections. Students participated in other sports student games of students of Slavonia in Slavonski Brod in 1966, then in Osijek in 1967 and competed with students from Rijeka and Gospić. In addition to sports competitions, students had organized visits to other places and schools, such as excursions to Sarajevo and Tjentište in BiH, Dubrovnik, Split, Zadar, Zagreb, Rovinj. [24,25].

Some students were also members of the Red Cross and voluntarily donated blood, and in the winter period students organized cultural and entertainment evenings. It should be noted that in the 1968/1969 school year the Student Service was also established [23,26].

From 1961 to 1967, 939 full-time students studied at the Academy. [13].

4.4. Abolition of the Pedagogical Academy

The abolitions of pedagogical academies in the territory of the Socialist Republic of Croatia were discussed in 1966 because there were 14 academies at the time. At the session of the Cultural and Educational Council of the SRH Parliament, which took place on 11 December 2001, the Croatian Parliament was held in 2007. On July 1, 1966, it was decided to reduce the number of academies to eight, and then the following academies remained: Zagreb, Rijeka, Split, Osijek, Slavonski Brod, Zadar, Pula and Petrinja [13].

At the beginning of 1971, the meeting of the Association of Pedagogical Academies in Zagreb discussed the issue of a network of pedagogical academies and it was concluded that more and more people who graduate from the academy did not find a job, so it was necessary to reform the system. It was proposed that education for teachers lasts four years and reorganization into four academies that were regionally represented. At that time, it was decided that the Pedagogical Academy in Slavonski Brod would close, and the teaching staff were offered other jobs: the younger ones to move to the Pedagogical Academy in Osijek, and the older ones to work until retirement. At

that time, the issue of opening a higher school in Slavonski Brod was raised. The Pedagogical Academy was approved to enroll in classroom classes, mathematics and physics, and negotiations were also being made over the enrolment of Croatian and Russian languages. A commission consisting of Mr. Mijo Cicvarić, Prof. Jure Oguić and Prof. Miroslav Čižmek, who negotiated with the Pedagogical Academy in Osijek over the integration of Slavonski Brod's and Osijek Pedagogical Academy, was also appointed, which negotiated with the Pedagogical Academy in Osijek over the integration of the Slavonski Brod and Osijek Pedagogical Academy [23].

Until 1971, the Pedagogical Academy in Slavonski Brod educated a large number of teachers and gradually decreased the interest of students in education at this higher school. Therefore, in Slavonski Brod, the transformation of the Pedagogical Academy into another higher school began to be considered, and the Assembly of the Municipality of Slavonski Brod at its sessions from July 26, 1971 and July 13, 1972, adopted a Decision to establish a Higher Commercial School instead of the Pedagogical Academy in Slavonski Brod.

The Pedagogical Academy enrolled the last generation of students in 1971/1972, but the institution, in order for enrolled students to complete their started education, operated until August 31, 1974, when the Decision of the Council of the Pedagogical Academy definitely ceased its work. The employees of the Pedagogical Academy with this day ceased all rights, and students who had not graduated until that day, were able to pick up their documents and continue their studies at other pedagogical academies in the SRH [27,28].

Most of the pedagogical academy's assets were handed over to the newly established Higher Commercial School. In addition to the building, cabinets and most of the teaching, the Higher Commercial School has taken over most of the teaching and administrative staff. Part of the books of the Library of the Pedagogical Academy was handed over to the City Library in Slavonski Brod, and a smaller part to the Elementary School "Vladimir Nazor" to which part of the cabinet equipment was transferred.

During the existence of the Academy, a total of 3133 students graduated.

5. CONCLUSIONS

The history of higher education of teachers in Slavonski Brod can be traced through two periods of time:

1. Organized education related to the education of one's own clergy, with the needs of elementary teaching of the population as well as with the needs of teaching in religious education organized through the Provincial Study of Philosophy - Franciscan College in Brod and through the Provincial Study of Theology in Brod covers the period of time from 1710 to 1843 with a shorter break from 1711 to 1720 and the second from 1783 to 1806. The very beginnings of Slavonski Brod's education were recorded through franciscan work on the organization and implementation of primary and secondary education from 1709 until 1777. In addition to a significant role in the upbringing of school staff and the organization of education, the work of the Franciscan College and the Provincial Study of Theology is of great importance for the general development of literacy and culture of the city in the 18th and 19th centuries. This is most represented by a rich, national and supranationally valuable written cultural heritage, which still abounds many monastic libraries from Croatia and neighbouring Bosnia and Herzegovina, through Serbia to Hungary, Austria and Romania.
2. The establishment and work of the Slavonski Brod Pedagogical Academy began in 1959 when the extraordinary study of the College of Pedagogy from Zagreb was launched in Slavonski Brod due to the lack of teaching staff that was needed due to the new Education Act. Two years later, in

1961, the Pedagogical Academy in Slavonski Brod was established, which became the center of teacher training and offered several study programs, according to the needs of the market. During his 13 years of work, the Academy was attended by thousands of students who studied at the Pedagogical Academy and dislocated studies in Croatia, Bosnia and Herzegovina and Serbia. Later, the Academy ceased operations because the teacher market was saturated and there was no need to study.

This work in question covers the formal and non-formal education of teachers in Slavonski Brod from the beginning of the 18th century until the founding of the University of Slavonski Brod. The paper of the Faculty of Teacher Education in Osijek, dislocated study in Slavonski Brod later the Faculty of Educational Sciences (1999-2020) was excluded from the presentation. The Department of Training of Teachers and Educators of the Department of Social Sciences of the University of Slavonski Brod is the subject of some future research. The paper covers an extremely rich history of the emergence and development of teacher education in the place as well as from it a valuable educational and cultural heritage.

6. SOURCES AND LITERATURE

[1] F. E. Hoško, Slavonska franjevačka ishodišta. Kršćanska sadašnjost, Zagreb, (2011).

[2] D. Mandić, Franjevačka Bosna: Razvoj i uprava Bosanske vikarije i provincije 1340.-1735. Hrvatski povijesni institut, Rim, (1968).

[3] R. Horvat, Slavonski Brod. [s.n.], Zagreb, (1941).

[4] F. E. Hoško, Franjevačke visoke škole u kontinentalnoj Hrvatskoj. Kršćanska sadašnjost, Zagreb, (2002).

[5] F. E. Hoško, Slavonska franjevačka učilišta. Kršćanska sadašnjost, Zagreb, (2011).

[6] P. Cvekan, Franjevci u Brodu: Povijesno-kulturni prikaz prisutnosti i djelovanja Franjevaca u Slavonskom Brodu, prigodom 360 godina prvog zapisanog svjedočanstva o boravku Franjevaca u Brodu (1623-1983). vlast. nakl., Slavonski Brod, (1984).

[7] D. Šimunović, Franjevačko školstvo u Brodu u prvoj polovici XVIII. stoljeća. U: Franjevci u Slavonskom Brodu, zbornik radova znanstvenog skupa održanog 27. listopada 2007. u Slavonskom Brodu. Hrvatski institut za povijest, Podružnica za povijest Slavonije, Srijema i Baranje : Franjevački samostan, Slavonski Brod (2012), pp. 169-179

[8] M. Hrman, Predavanje iz filozofije u Brodu u jesen 1735. godine. U: Franjevci u Slavonskom Brodu, zbornik radova znanstvenog skupa održanog 27. listopada 2007. u Slavonskom Brodu. Hrvatski institut za povijest, Podružnica za povijest Slavonije, Srijema i Baranje : Franjevački samostan, Slavonski Brod (2012), pp. 181-189

[9] I. Stipić; M. Grubanović; D. Mataić Agičić, Leksikon brodskih pisaca. Društvo hrvatskih književnika : Gradska knjižnica, Slavonski Brod, (2016).

[10] Hrvatski franjevački biografski leksikon (ur. F. E. Hoško; P. Ćošković; V. Kapitanović). Leksikografski zavod "Miroslav Krleža" : Vijeće Franjevačkih zajednica u Hrvatskoj i Bosni i Hercegovini, Zagreb, (2010).

[11] I. A. Brlić, Uspomene na stari Brod. H. Schulman, Slavonski Brod, (1885).

[12] Rješenje Više pedagoške škole u Zagrebu. 302/3-1959. Prijepis 7.6.1961. Hrvatska. Državni arhiv u Slavonskom Brodu. 279. Pedagoška akademija Slavonski Brod. Važniji spisi; Normativni akti (1959.;

1961.-1972. Inv. br. 59. (HR-DASB-279. PASB. Važniji spisi. 59).

[13] *Izvještaj 1961-1966*. 3.12.1966. HR-DASB-279. PASB. Važniji spisi. 59

[14] *Prijedlog za otvaranje Pedagoške akademije u Slavonskom Brodu*. HR-DASB-279. PASB. Važniji spisi. 59

[15] *Zapisnik sjednice Savjeta za prosvjetu NOK-a Slavonski Brod*. 9.7.1961. HR-DASB-279. PASB. Važniji spisi. 59

[16] *Preuzimanje nastavnog centra za izvanredni studij Više pedagoške škole*. 5.10.1961. HR-DASB-279. PASB. Važniji spisi. 59

[17] *Zapisnik o preuzimanju Centra za izvanredni studij Više pedagoške škole Zagreb*. 6.12.1961. HR-DASB-279. PASB. Važniji spisi. 59

[18] *Zapisnik Savjeta Pedagoške akademije*. 4.11.1961. HR-DASB-279. PASB. Važniji spisi. 59

[19] *Izvještaj*. 28.2.1963. HR-DASB-279. PASB. Važniji spisi. 59

[20] *Statut pedagoške akademije Slavonski Brod*. 5.7.1972. HR-DASB-279. PASB. Važniji spisi. 59

[21] *Zapisnik sa redovne godišnje skupštine Pedagoške akademije Slav. Brod i proslave 5. godišnjice njenog postojanja*. 3.12.1966. HR-DASB-279. PASB. Važniji spisi. 59

[22] *Izvještaj o radu Pedagoške akademije Slavonski Brod*. 4.2.1969. HR-DASB-279. PASB. Važniji spisi. 59

[23] *Zapisnik sa sjednice Vijeća nastavnika i Radne zajednice.* 12.4.1971. HR-DASB-279. PASB. Zapisnici sa sjednica Radne zajednice od 1965. do 1973.; Zapisnici sa sjednica Upravnog odbora od 1967. do 1972. inv. br. 61. (HR-DASB-279. PASB. Zapisnici. 61)

[24] *Izvještaj o radu Pedagoške akademije Slavonski Brod*. 20.12.1967. HR-DASB-279. PASB. Važniji spisi. 59

[25] *Izvještaj o radu Pedagoške akademije Slavonski Brod*. 3.2.1968. HR-DASB-279. PASB. Važniji spisi. 59

[26] *Izvještaj o radu u školskoj godini 1968/69.* 18.12.1969. HR-DASB-279. PASB. Važniji spisi. 59

[27] *Odluka o osnivanju Više komercijalne škole* 13.7.1972. HR-DASB-279. PASB. Važniji spisi. 59

[28] *Odluka o prestanku rada Pedagoške akademije u Slavonskom Brodu.* 31.8.1974. HR-DASB-279. PASB. Važniji spisi. 59

Quality and eating habits of student population

A. Katolik Kovačević [a], T. Mišić [b], J. Vujčić [c]

[a] University of Slavonski Brod, Trg Ivane Brlić Mažuranić 2, 35000 Slavonski Brod, Croatia, E-mail akkovacevic@unisb.hr

[b] Student at University of Slavonski Brod, Trg Ivane Brlić Mažuranić 2, 35000 Slavonski Brod, Croatia, E-mail misic.tom@gmail.com

[c] University of Slavonski Brod, Trg Ivane Brlić Mažuranić 2, 35000 Slavonski Brod, Croatia, E-mail jasna.vujcic@gmail.com

Abstract

Healthy and balanced nutrition is the basis of health and adequate quality of life. Increasing proportions of industrially processed foods rich in unhealthy fats and high in sugar cause obesity, and thus risks to overall human health, especially in terms of the risk of developing diabetes and cardiovascular disease. Due to the importance of quality and proper nutrition in the life of every person, the subject of research was the students nutrition and nutritive habits. The aim of the study was to determine whether there is a statistically significant relationship between dietary quality and eating habits and the BMI index of respondents. Authors conducted a survey on a sample of N = 163 respondents to determine the quality of nutrition and eating habits of students. The results of the study showed that the number of meals and consumption of "fast food", which is mainly prepared by deep-frying, has a statistically significant effect on the BMI index in terms of increasing the risk of obesity. Regarding the number of meals, respondents who consumed a larger number of smaller meals per day had a lower propensity for obesity.

Keywords: quality, nutrition eating habits, student population

1. INTRODUCTION

Quality is a term defined as the degree or level of conformity with requirements that differ from each other depending on the type of product or service. [1]. When it comes to food, the requirements that define quality are numerous. The basic requirements related to food quality refer to the classification, categorization and correct nomenclature of food. From a health, hygiene and nutritional point of view, it is very important to determine the physical, chemical, physio-chemical and sensory characteristics of food, as well as its composition with regard to the proportion of macronutrients and micronutrients it contains [1]. Food production is a very delicate activity closely related to key goals in the public health system. For this reason, one of the key requirements related to food quality is the determination of the type, physio-chemical and sensory properties of certain ingredients in the process of production and processing of food products used in the process of product production and placed on the market as the final products [1].

Certain procedures applied in the production and processing of food have to carry out in accordance with health, hygiene and safety standards in food production. In this sense, an important role is played by compliance with legal and by-laws, with special emphasis on the Food Act (NN 81/13, 14/14, 30/15, 115/18) and

HACCP norm by whose application ensures a preventive approach to food safety through all phases of the supply chain "from field to table" [2].

The European Union invests significant resources in order to take care of food safety and protect citizens. In order to achieve following the EU founded the European Food Agency, whose main goal is to promote awareness of the importance of food quality. Its primary role is advisory. As part of the European Food Agency, one should recognise key risks for the various levels of food chain and therefore one needs to monitor and communicate in order to eliminate or suppress risks in a timely manner [3].

2. WORLD HEALTH ORGANIZATION GUIDELINES FOR A HEALTHY DIET

A balanced, high-quality and healthy diet is a basic prerequisite for a successful and high-quality life, and it can also be a significant factor in the fight against numerous diseases. Equally, an unbalanced diet is certainly a factor that contributes to the emergence of numerous diseases. The role of nutrition is particularly important in the fight against obesity, diabetes, cardiovascular diseases, some types of tumors and certain diseases of the bone system.

The fundamental principles on which the Guidelines for a healthy diet of the World Health Organization base are moderation, balance and diversity. At the same time, the Guidelines point out that healthy and balanced eating habit should one adopt from a very early period of life, and therefore guidelines promote breastfeeding with the aim of balanced growth and development of the child. Breastfeeding has significant long-term benefits for the child as it acts as a factor in reducing the risk of developing overweight, diabetes and cardiovascular diseases in later stages of life [4].

A proper, balanced, moderate and healthy diet becomes a base for a balanced relationship between caloric intake and consumption. Age, gender and lifestyle (calorie consumption) are therefore the primary factors based on which it is necessary to plan the daily caloric intake. In addition to quantitative energy intake, it is very important to choose correct energy sources with regard to the composition of individual foods. The restrictions listed in the World Health Organization Guidelines relate particularly to fat intake. Guidelines recommend that the energy intake from fat does not exceed 30%, of which a maximum of 10% of energy may come from saturated fatty acids. At the same time, guidelines recommend that industrially produced Trans fatty acids one could replace by unsaturated fatty acids [4].

Sugar intake should also be limited to a maximum of 10% of the total daily energy intake as part of the Healthy Eating Guidelines. In order to achieve additional health benefits, guidelines recommend further reduce the daily intake of sugar to 5% of the total energy intake. Salt intake should also be limited to up to 5 grams per day, which is equivalent to an intake of 2 grams of sodium. Limiting salt intake in the body has a positive effect on the prevention of hypertension and on reducing the risk of cardiovascular diseases and stroke [4].

2.2. Parameters for determining nutritional status

In a large number of cases, the nutritional status is determined based on body weight, however, the body weight indicator itself is not sufficiently precise in determining the nutritional status. Therefore, an increasingly common indicator of nutritional status is the BMI index (Body Mass Index) or body mass index [5]. One may calculate Body mass index as the ratio between body mass in the numerator, and body height (squared 2) in the denominator [5]. BMI index (Body Mass Index) is age - and sex - independent for adults and have been found to be associated with health outcomes, including mortality [6].

3. METHODS AND MATERIALS USED FOR RESEARCH

The aim of the work is to determine the eating style and habits of the students. It is determined whether there are statistically significant differences in the eating habits of students with regard to the body mass index.

The target population are students. The research was conducted during April 2022 through an online questionnaire, and the research results were collected for N=163 respondents.

The authors used a structured survey questionnaire authors as an instrument for data collection. The questionnaire consists of two parts. In the first part, there are questions related to the socio-demographic profile of the respondents, namely gender, age, place of residence and body weight and body mass index. In the second part of the questionnaire, the questions ask about eating habits: the number and regularity of meals, the type of food consumed and the frequency of consumption of a certain type of food.

Categorical data present the means of absolute, relative (%) frequencies, and the means of the arithmetic mean or average rating of individual dietary habits of respondents. The method of inferential statistics, which examines whether there is a statistically significant difference between the body mass index and their eating habits, is $\chi 2$ test.

4. RESULTS

63% of female respondents and 37% of male respondents participated in the research. The share of respondents aged 18 to 20 is 14%, 34% of respondents are aged 21-23, and 27% are aged 23-25. 25% of respondents remained in the group. A total of 38% of respondents live in Slavonski Brod. Respondents from Zagreb and Županja were present in the survey with shares of 4% each, and respondents from Vinkovci, Osijek, Nova Gradiška, Hrvatska Kostajnica and Novska with a share of 3% each. Pleternica, Đakovo, Kutjevo and Požega are the places of residence for 2% of the total share of respondents. A total of 29% of respondents came from other places of residence (Istrian County, Vukovar, Sisak, Oriovac, Brodski Zdenci, etc.).

Body weight is one of the first indicators of the quality, variety and balance of nutrition. 4% of respondents have a body weight of less than 50 kg. A share of 20% of respondents has a body mass of 50-60 kg, and 28% of them were in the range of 61-70 kg. Respondents weighing between 71-80 kg amounted to 22%, and 11% of respondents weighed between 81-90 kg. 10% of respondents weigh 90-100 kg, and 4% weigh more than 100 kg. A share of 2% of the respondents declared that they did not know what their body weight was (or did not declare).

The largest share of respondents (56%) has normal nutrition and a BMI index level ranging from 18.5-24.99. As many as 19% of respondents are excessively nourished and have a BMI index of 25-29.99. 7% of respondents are obese, and 3% are undernourished. Even 15% of respondents are not familiar with the value of their own body mass index.

In order to respond to the research objective, the $\chi 2$ test was used to determine whether there is a difference between the number of meals, the habit of skipping breakfast and the frequency of consumption of "junk food" and the body mass index or BMI index of the respondents.

In table 1., the authors showed the distribution of respondents with regard to the number of meals and body mass index in order to determine whether there is a statistically significant difference between the number of meals and the BMI index. Respondents who do not know their BMI index the authors excluded from the total distribution, as well as those who answered the rest for the number of meals, because it cannot be determined whether the rest means less than three or more than five meals. Therefore, the test was performed on a total of N=139 subjects.

Table 1. χ2 test - relationship between the number of meals and body mass index (N=139)

BMI index/ Number of meals	Three	Four	Five	IN TOTAL
<18,5	3	1	1	5
18,5-24,99	36	39	17	92
25-29,9	24	3	4	31
More than 29,9	5	4	2	11
In total	68	47	24	139
The result	X^2 (6, N = 139) = 15.19, p = .018			

By performing the χ2 test, it was determined that there is statistically significant difference between the number of meals and body mass index. The result was 15.19, and the p-value is less than .05 and is p=.018.

Authors can see that among subjects with normal nutrition, the proportion of those who consume more than three meals is higher than in other groups.

In table 2., the authors showed the distribution of respondents with regard to the frequency of consumption of "junk food" and the body mass index in order to determine whether there is a statistically significant difference between the frequency of consumption of "fast food" and the BMI index. The test was performed on a sample of N=139.

Table 2. χ2 test - relationship between the habit of skipping breakfast and body mass index (N=139)

BMI/ habit of skipping breakfast	never (1)	rarely (2)	sometimes (3)	often (4)	frequently (5)	IN TOTAL
<18,5	1	1	1	1	1	5
18,5-24,99	9	20	26	20	17	92
25-29,9	5	6	9	6	5	31
More than 29,9	1	3	3	2	2	11
In total	16	30	39	29	25	139
The result	X2 (9, N = 139) = 1.74, p = .99					

By performing the χ2 test, it was determined that there is no statistically significant difference between the habit of skipping breakfast and body mass index. The result was 1.74 and the p-value is greater than .05 and is p=.99.

In table 3., the authors showed the distribution of respondents with regard to the frequency of consumption of "junk food" and the body mass index in order to determine whether there is a statistically significant difference between the frequency of consumption of "fast food" and the BMI index. The test was performed on a sample of N=139.

Table 3. χ2 test - relationship between "junk food" consumption habit and body mass index (N=139)

BMI/ habit of skipping breakfast	never (1)	rarely (2)	sometimes (3)	often (4)	frequently (5)	IN TOTAL
<18,5	1	1	1	1	1	5
18,5-24,99	1	24	34	13	20	92
25-29,9	1	6	12	5	7	31
Više od 29,9	3	1	2	2	3	11
In total	6	32	49	21	31	139
The result	X2 (12, N = 139) = 21.88, p = .038					

By performing the $\chi 2$ test, it was determined that there is a statistically significant difference between the consumption of "junk food" and the body mass index. The result was 21.88, and the p-value is less than .05 and is p=.038.

5. CONCLUSIONS

Correct and high-quality nutrition in terms of composition, quantity and quality or compliance with hygiene and public health requirements is a long-term basis and foundation for preserving health and an adequate quality of life.

In terms of eating habits, the authors investigated the habits related to the number of meals per day, the habit of skipping breakfast, and the composition of food and the method of its preparation (thermal processing). The largest number of respondents (almost half) consume three meals a day. Slightly less than half of the total number of respondents consumes three or four meals a day, and a smaller proportion of respondents have different habits because they consume either less than three or more than 5 meals. The development of awareness of the principles of healthy nutrition indicated the fact that respondents consumed mostly cooked food, and "fast food" or ready-made food to the smallest extent. On the other hand, the proportion of food consumed in raw form is also low. Through the $\chi 2$ test, it was determined whether there is a difference between the number of meals, the habit of skipping breakfast and the frequency of consumption of "junk food" and the body mass index or BMI index of the subjects. The results show that there is a statistically significant difference between the number of meals and body mass index and the frequency of fast food consumption and BMI index. The authors confirmed there was no statistically significant difference between the habit of skipping breakfast and BMI index.

The research also had one limitation. Although the response to the survey was higher than the expe-cted number, about 14% of the respondents did not know what their BMI index was, which reduced the number of respondents with valid answers that could be included in the implementation of the $\chi 2$ test.

6. REFERENCES

[1] Ministarstvo poljoprivrede, Kvaliteta hrane. https://poljoprivreda.gov.hr/istaknute-teme/hrana-111/kvaliteta-hrane/219, last access 07/04/2022

[2] M. Pešić, Uvođenje i primjena međunarodnog standarda HACCP na primjeru subjekata u poslovanju s hranom. Economic research - Ekonomska istraživanja, 22(2), (2009), pp. 132-147

[3] M. Dutour Sikirić, B. Homen, J. Pintar, Laboratoriji za kontrolu kakvoće hrane za životinje u europskim integracijama. Časopis o hranidbi životinja, proizvodnji i tehnologiji krme, 48(5), (2006), pp. 285-294

[4] World Health Organization, WHNO Nutrition Guidelines, https://www.who.int/health-topics/nutrition 30/04/2022

[5] CDC, Body Mass Indeks (BMI), https://www.cdc.gov/healthyweight/assessing/bmi/adult_bmi/index.html, last access 11/05/2022

[6] World Health Organization. European regional obesity report 2022, https://apps.who.int/iris/bitstream/handle/10665/353747/9789289057738-eng.pdf, last access 23/06/2022

[7] D. Karolyi, Iz literature i prakse: Dijetalne masti i meso. MESO: Prvi hrvatski časopis o mesu, 6(2), (2004), pp. 14-17

[8] D. Karolyi, Polinezasićene masne kiseline u prehrani i zdravlju ljudi. Meso: prvi hrvatski časopis o mesu, 9(3), (2007) pp. 151-158

New approaches in Physical Education- an example of good practice

Mirna Mikić, mag.cin
OŠ Dragutin Tadijanović,Nas. A.Hebranga 12/1,35000 Slavonski Brod, Croatia,
mirna.mikic@gmail.com

Abstract

The aim of the paper was to show the difference between modern and traditional teaching and ways of modernizing the PE teaching in elementary school and at the university. PE teachers and coaches are important promoters of daily exercise in all age groups, from primary school to student age.The application of modern work methods in teaching brings physical activity closer to children and young people and makes it more interesting and attractive than traditionally used methods because it enables students to choose physical activity in accordance with their own interests. It teaches them how to be active in class and in their free time, and how to apply proper nutritional recommendations for gaining and maintaining health. Introducing activities such as brisk walking, hiking, swimming, orienteering, cycling, pilates, yoga, bodyweight training, etc. are just some of the activities that help students develop good habits that will continue as adults. A positive example of the implementation of modern teaching in work with young people was shown in Elementary School „Dragutin Tadijanović“ and the University of Slavonski Brod. The application of different forms of exercise with the possibility of individual access and selection of activities contributes to a better interest and involvement of young people in work.

Key words: modern teaching, exercise, youth, primary school, university

1. INTRODUCTION

The introduction of modern teaching brought a lot of positive and constructive changes at all levels of education: primary, secondary and university. Young people accept new forms of work with joy and approval, which can be confirmed by examples of good practice in the teaching of Physical Education at Elementary School „Dragutin Tadijanović“, Slavonski Brod and the University of Slavonski Brod.

Changing traditional and introducing modern forms of work into the educational system contributed to a better understanding and acceptance of exercise as an important component of human everyday life. It is based on interdisciplinarity, which represents a good basis for greater application of new learning models. The subject of Physical Education and health enables young people to learn the importance of lifelong exercise and to understand how much it contributes to improving the quality of health and quality of life. By adopting educational values and a positive attitude towards sports activities, young people acquire proper habits for life.

According to the activity in nature and the natural environment and in general life in motion develops and raises environmental awareness and is a strong motivation for daily use for personal well-being [1].

Students do not practice enough. If they do not have organized sports activities at the university, the students themselves rarely engage in sport in their free time.
According to the Youth Survey in Croatia 2018/2019. conducted on a sample of 1,500 young people aged 14-29, 24% of them stated that they never engage in sports activities, and 46% rarely or sometimes, which are extremely devastating results [2]. Study time is a key period and opportunity for the promotion of physical activity in young adults [3].

The University of Slavonski Brod enables and supports the involvement of students in sports activities outside of curriculum and provides the opportunity to participate in the University's sports competitions, which, in addition to health benefits, also contribute to the psychosocial

development of young people. The University is becoming more and more recognizable for its sports activities. Students learn and improve their knowledge with new and modern work methods. The classes are interesting and stimulating, and the knowledge that these future academic citizens acquire will ultimately be able to consume in the long term. An educated and healthy population contributes to building a productive and working capable society.

2. TRADITIONAL AND CONTEMPORARY TEACHING

With the advent of modern forms of work, educational institutions create an annual curriculum where emphasis is placed on the specifics of the institution and the environment in which it operates. In doing so, the needs and interests of students and the local community are taken as the starting point for work on the contents of the school curriculum. In planning activities, the principles of individualism, impartiality and transdisciplinarity are taken into account. By achieving a transdisciplinary approach, the university will be able to achieve the idea of science as a form of life, which in turn proves to be a moral form of science and academic education [4].

Essential prerequisites for the achievement of the goals set in the curriculum are: the existence of professional competence of the teacher, high-quality cooperation between the student and the school, the support and help of the local community.

The goals that are developed through classes are mastering learning techniques, building permanent knowledge, connecting learning with real life situations, applying knowledge in new tasks and situations. Teachers encourage and support students - they respect the personalities and differences of each student and develop a culture of work, learning and responsibility. Teaching is the joint work of teachers and students and that more diverse student activities are expected. All-round participation of students in the teaching work (preparation, implementation, evaluation of colleagues and self-evaluation) is possible for success and progress in education [5].

The modern definition of teaching is defined as teaching that is planned and designed by the teacher, an organized educational process in which some educational tasks are realized [6].

Modern teaching places the student at the center of the teaching process, respecting his affinities and preferences. Through sport classes, students develop awareness of the need for lifelong physical exercise in modern living conditions, increase their interest and motivation to participate in sports and recreational activities, enable them to discover their own personality and develop a sense of community and responsibility.

In modern teaching, collective education is replaced by individual education, where the student is affirmed as an active researcher who gains knowledge through basic research and personal intellectual efforts [7].

Traditional teaching most often implies a frontal form of work where the teacher teaches and the students are passive participants who apply one type of activity at the same time. This type of teaching was carried out in the past, but in today's conditions it is unimaginable at all levels of education. According to the traditional form of work, the teaching hours are equal, while modern teaching tries to introduce as many elements of natural learning as possible, and to create such a teaching situation in which students will gain knowledge as much as possible through personal experience. Encouraging students to work independently, research and find interesting tasks and content contributes to the acquisition of new knowledge.

In traditional teaching, independent work and research is neglected, and the focus is on the assimilation of the teaching material as much as possible. To a greater extent, such knowledge is retained only at the current level of reproduction and is not applicable in everyday life in the long term.

3. AN EXAMPLE OF GOOD PRACTICE

With the introduction of the "Škola za život" as a modern form of work in educational institutions, many teachers accepted the upcoming changes in a timely manner and with joy. One of the positive examples is Elementary School „Dragutin Tadijanović“, Slavonski Brod and the University of Slavonski Brod. The

teachers showed their willingness to abandon the traditional form of teaching and to approach new, modern teaching methods.
Teaching sport began to differ greatly from the previous approach and method of implementation and took on a new dimension.

In accordance with the agreement of the teachers, classes took place on certain days of the week outside the school, in nature. Emphasis was placed on daily physical activity, so as part of the sport classes, they walked to a nearby nature area where, in addition to hiking and games, orienteering would be organized (moving by running or walking on unknown terrain with the help of a map and compass, with the aim of finding the place as quickly as possible in advance certain control points, which are drawn on the map). A sport in which the knowledge of geography and physical activity in nature is ideally applied and connected. Application of what has been learned in the natural environment. In addition to orienteering, the students participated in many other sports activities: fast walking, relay games, ball games, bodyweight training etc.

Classes, which on other days took place in the sports hall, also experienced some kind of changes. Students are offered a wide range of workplaces where there are different sports (table tennis, basketball, badminton, futsal, obstacle course, bodyweight training...). They are enabled to autonomously choose their workplace and the length of their stay at each. The permanent foundation that kinesiologists want to achieve with young people is self-initiated sports in their free time. They transfer their knowledge to them using different methods and forms of work, all for the purpose of learning and acquiring the habit of continuous exercise with the unique goal of preserving health and quality of life.

Vrtim zdravi film, Vježbaonica, Univerzalna sportska škola are just some of the projects that are being implemented in the Elementary School „Dragutin Tadijanović“, Slavonski Brod. Their main task is to educate as many students as possible about the importance of engaging in physical activity, the basic principles of proper nutrition and its application, and the acquisition of proper lifestyle habits.

The use of different forms of work, street workout, bowling, fast walking, dance structures and swimming are just some of the activities that students get to know and practice while studying at the University of Slavonski Brod. Those who are the most active also participate in University sport competitions, and in this way, in addition to the sports aspect, they also develop a socially desirable component of socialization and ethnic rapprochement. At the university level of education, it is necessary to strive to introduce as many hours of physical activity as possible. It is necessary to create prerequisites for holding sports activities that contribute to the psycho-social component in addition to recreational activities. All students should be involved in sports activities, not only those with good predispositions and sports orientation.

Motivation is extremely important because it is an activity that will make students interested in work and activate their curiosity for further learning. Motivation represents a group of invisible forces that keep a person, his attention, concentration and ability to focus on a certain goal until the result is achieved [8]. Apart from the motivation factor, what significantly affects the cause of behavior and changes in the intensity of behavior are the types of motivation, so we distinguish between intrinsic and extrinsic motivation [9]. Extrinsic motivation is constantly influenced by incentives and pressures from outside, and leads to a superficial approach to learning with the aim of getting a grade. Intrinsic motivation reflects a personal goal and interest in a particular subject or area and it leads to an in-depth approach to learning. Using it, young people actively participate in some activity, they see it as an opportunity for research and learning, as well as quality maturation and actualization [5].

It is important that the teacher knows how to create such a teaching situation that arouses interest and creativity even among those students who are not interested in the material, and achieves this through different activities, activities, that is, active teaching forms and work methods.

One of the ways of change is excellence in the work of teachers and coaches because they are the key to creating and maintaining suitable programs for students and young athletes [10].

4. CONCLUSION

Quite inactive way of life is increasingly affecting the younger population, and it is only possible to act on it with a quality approach and transfer of knowledge. Modern teaching contributes to a successful approach to young people, more interesting performance and diversity in work. New understandings of the teaching process are imbued with special student-teacher relationships focused on student independence. With the help of new teaching methods, young people are transformed from inactive observers into active and interested participants who take part in the preparation, implementation and evaluation of teaching situations. In modern teaching, a collaborative relationship develops, and the student builds personal experience and knowledge. The application of new methods contributes to better teaching in which there is more active student participation, greater interest in the subject, better communication and a working atmosphere. In the center is the student who learns and not the teacher who teaches.

Modern teaching methods are useful in teaching young people about the importance of daily sports and acquiring healthy lifestyle habits. They accept the positive postulates of sport in an effective and appropriate way, so it is more likely that their daily application will be long-term. The author believes that traditional teaching should not be completely abandoned, but its quality parts should be implemented in modern forms of work.

Promoting positive attitudes and values towards sport, tolerance and respect for others, and taking care of one's body and health are just some of the elements that help a young person grow into a health-conscious and culturally aware citizen. Exercise and proper nutrition should be their permanent pleasure and lifestyle choice.

5. REFERENCES:

[1] Narodne novine (2019). *Kurikulum nastavnog predmeta Tjelesna i zdravstvena kultura za osnovne škole i gimnazije*. Preuzeto 21.lipnja 2022, s https://skolazazivot.hr/wp-content/uploads/2020/06/TZK_kurikulum.pdf

[2] Gvozdanović i sur.(2019). *Istraživanje mladih u Hrvatskoj 2018./2019.* available at: https://library.fes.de/pdf-files/bueros/kroatien/15291.pdf

[3] Horvat, M., Pukljak Iričanin, Z. i Jakuš, L. (2013). *Redovitost tjelesne aktivnosti u populaciji studenata fizioterapije*. Medix. available at: https://www.medix.hr/redovitost-tjelesne-aktivnosti-u-populaciji-studenata-fizioterapije

[4] Cerovac, K. (2013). *Transdisciplinarni pristup u razmatranju odnosa znanost — teologija*. available at: https://hrcak.srce.hr/file/323826

[5] Matijević, M., Radovanović, D. (2011). *Nastava usmjerena na učenika*. Zagreb: Školske novine.

[6] Skok, P. (2002). Izvanučionička nastava. Zagreb: Pedagoški servis.

[7] Stevanović, M. (1998). *Metoda recepcije u nastavi*. Tuzla: R & S.

[8] Kecman, B. (2012). *Motivacija i neke od sadržajnih teorija motivacije u suvremenom društvu*. available at: http://motivacija iteorije.blogspot.com/

[9] Krstinić, M. i Pauković, M. (2020). *Ekstrinzična i intrinzična motivacija za učenje stranog jezika u poslovnom okruženju*. Obrazovanje za poduzetništvo - E4E, 10 (1), 76-83. https://doi.org/10.38190/ope.10.1.1

[10] Žnidarić Čučković, A. (2018). *Priručnik dobre prakse za kretanje putem sportske aktivnosti*. available at: https://mint.gov.hr/UserDocsImages/AAA_2020_MINTIS/sport_arhiva/EPAS_prirucnik_VE2018.pdf

Teacher education as a predictor of their professional growth

A. Mirosavljević
University of Slavonski Brod, Gundulićeva 20, 35000 Slavonski Brod, Croatia,
amirosavljevic@unisb.hr

Abstract

All over the world, the role of teachers is inevitably and hurriedly changing in line with current trends in education. The rapid development of technology has changed the way people work and communicate in many segments of society. Therefore, the professional development of teachers, which begins with initial education and continues with various forms of formal, non-formal and informal education, must be accompanied by the imperatives of the educational process that are imposed. The paper shows that teacher education is a prerequisite for student-centered teaching, but also for the development of teacher identity as well as the improvement of their professional development necessary for quality work. All teachers need knowledge, skills, competencies and abilities that enable them to work effectively with students, parents, colleagues, work in and with society, in which they are helped by professional development. The paper explains the importance of initial teacher education and highlights the differences between their formal, non-formal and informal education. A review of various studies highlighted indicators of the importance of the role of teacher education for the educational process and lifelong learning of teachers with the aim of building their teaching skills.

Keywords: Education; Formal / Informal / Non-Formal; Professional Development; Teacher

1. INTRODUCTION

The teacher is an expert who organizes the educational process and with his general education, knowledge of its pedagogical, didactic and psychological basis, in joint work with students, achieves the goal and tasks of education [1]. An effective teacher possesses knowledge about individual students, accepts critical thinking, has an open view of the wider social context by considering ethical and moral issues of the purpose of education [2]. The Eurydice Report [3] finds that completed initial teacher education affects their willingness to do their jobs, especially when it comes to learning theory and practice. The act of teaching depends on the teacher's personal perception and moderation, which is manifested in knowing what to say and do in unpredictable situations as well as established routine and practice [4].

Professional development, which can be formal (conferences, trainings etc.), informal (working with other teachers, mentoring, collaborative activity planning etc.) and informal form leads to professional learning [5]. Malykhin and Aristova [6] describe formal education as one that takes place in an organized and structured environment, and upon completion of the program, participants receive public certification. Non-formal education is encouraged by the initiative of students or adult education institutions. It is organized and determined by learning objectives. Unlike formal and non-formal education, informal education is unintentional, does not lead to the issuance of public certificates and is not organized or structured, and is often defined as experiential learning related to everyday life. Rogers [7] lists four ways in which formal, non-formal and informal education are linked: informal can be used to strengthen formal / non-formal learning; formal and non-formal learning can be used to correct some of the perceived antisocial effects of informal learning; formal / non-formal learning can help students recognize and validate their unconscious informal learning; in any educational encounter, formal / non-formal learning can enter into intercultural dialogue with informal learning.

2. METHODOLOGY

The paper provides literature review about teacher education as a predictor of their professional growth. The goal was to study the different forms of lifelong learning as integral

parts of teachers' professional development and analyzed the role of teachers' professional development in their professional growth.

We searched the following scientific databases: EBSCOhost, ERIC, Google Scholar, J-Store, SAGE and ScienceDirect. Initial key words were identified from the researchers' knowledge of the field. These included formal / informal / non-formal education, initial education. The free Zotero application [8] was used to store the chosen list of references.

3. INITIAL TEACHER EDUCATION

All national education policies are aware of the importance of teacher education and professional development at all levels of formal education for each country, because the quality of teaching staff is one of the main aspects influencing the level of educational and student achievement. Therefore, special attention is paid to the design and implementation of quality initial teacher education, but also their professional development, i.e. continuous professional development, which together makes lifelong learning necessary to encourage lifelong learning of their students [9, p.108]. Lifelong learning is the result of the integration of formal, non-formal and informal learning. They create opportunities for continuous lifelong development of quality of life, at all times, in all places. In order to cope with the challenges of modern living, both in professional and private life, people must constantly improve their skills. This can be achieved through learning or education [10]. According to the Incheon Declaration quality education is one that encourages creativity and knowledge and ensures the acquisition of basic literacy and numeracy skills, as well as analytical problem solving and other cognitive, interpersonal and higher level social skills. It also develops skills, values and attitudes that enable citizens to live healthy and fulfilled lives, to be informed before making decisions and to respond to local and global challenges through education for sustainable development and global civic education.

Initial education should ensure a balanced and consistent approach to theoretical knowledge of a given subject, skillful teaching of that subject and direct teaching experience. Persons who have completed initial teacher education should be able to put theory into practice and constantly inquire their own teaching [3, p.31]. Initial education represents the base for professional thinking and behavior of future teachers, requiring them to be both students and teachers at the same time. In other words, to be taught how to teach and to teach students how to learn. It is important that they learn in a wide range of practical situations, i.e. analyze, question and consider ideas in the context of practice. Initial teacher education encompasses their personal characteristics, including attitudes, beliefs, and emotions to the same extent as their knowledge and competencies. In addition to knowledge, it must enable future teachers to reflect on their own practice or to engage in reflective discussions with experienced teachers. An indispensable part is informing about innovative approaches to information and communication technologies and encouraging the application of digital technologies in teaching [12]. Initial education is only the first phase in the teachers professional learning and ensuring the quality of their work. It should certainly continue with various forms of quality professional development [13].

Significant changes in the field of initial teacher education in the Republic of Croatia, but also in other European countries have occurred with the introduction of the Bologna Process in higher education. The Bologna process includes a two-cycle system of study programmes at some faculties (3 + 2/4 + 1 years of study), as well as integrated study programmes (5-year study programme at the Faculty of Teacher Education), then a uniform student workload expressed in ECTS points and addition of diploma supplement as a prerequisite for qualitative analysis of the student's achievements and professional orientation. With the introduction of the Bologna Process, the study for primary school teachers lasts 5 years in an integrated form, which achieves a total of 300 ECTS points. Teacher training takes place at the former Teachers 'Academies, i.e. teacher training colleges that are today called Faculty of Teacher Education and are an integral part of the University. The training of upper primary school teachers (5th to 8th grade) and secondary school teachers is held at different components of individual universities

(depending on the subject to be taught, most often the Faculty of Social Sciences and Humanities). Their training, as well as training of primary school teachers is also attended by schools that have a contract with the Ministry of Science and Education, in which students conduct practical classes under the supervision of experienced teachers. The study for subject teachers lasts 5 years, but has a two-level structure. The undergraduate level of study lasts 3 years and the student earns 180 ECTS points and acquires the condition for enrollment in the graduate level, and the graduate level lasts 2 years and earns a total of 120 ECTS points. The timetable at the faculties is determined according to the following categories: professional subjects represented by 70-80%, educational sciences represented by 3-5%, subject methodologies represented by 7-12% and other 10-12%. The timetable varies greatly among the faculties. Upon completion of the undergraduate study, students acquire the title of bachelor's degree (lat. Baccalaureus), and after completing the graduate study, they acquire the title of master of education in a particular subject [14]. Kostović-Vranješ [9] warns of the problem of insufficient representation of school practice (practical work) of future teachers of subject teaching, which is crucial for their training during initial education and later work in teaching.

The focus of the study program has shifted from the content of disciplines to competency profiles and learning outcomes. This has led to the introduction of new topics and approaches such as: education for diversity, classroom / school management and teacher leadership, civic education, methods of experiential and collaborative learning and increased self-regulation in learning [15]. In most European countries, initial education providers enjoy considerable autonomy in setting program objectives, content, and outcomes, in line with national guidelines and education policy priorities [12]. The tendency of European policy is that the initial teacher education, guided by clear competence standards, with the inevitable knowledge of subjects and subject methodology, is focused on the development of self-reflection skills and research of future teachers' own practice. The aim is to apply competency standards in initial education motivation and commitment of future teachers to their own professional development throughout their careers, with emphasis on the development of research competencies, reflective practices, capacity building for innovation etc. [16]. Through practical training during initial education, future teachers are expected to develop a variety of competencies: planning, implementing and evaluating the teaching process, learning about school work, communicating with students, parents and colleagues, classroom management and investing in their own professional development [17]. Research results [18] show that novice teachers associate the challenges they face in working with their initial education programs. But they feel that the programs have failed to provide them with the practical skills needed to effectively manage class and develop professional relationships. Equally, research results show that the effects of quality initial education programs on beginning teachers decrease as their experiences increase. It is possible that the reason for this is the overemphasis on professional knowledge in relation to methodological and general pedagogical and psychological knowledge during the initial education of future primary school teachers [19].

4. FORMAL TEACHER EDUCATION

Formal education is an integral part of initial education. It is a systematically organized educational model structured and managed according to set goals and contents. It implies a continuous educational process that necessarily involves the teacher, students and the institution [20]. Steenekamp and Singh [21] state that formal education is not enough to meet the expectations and needs of individuals in the global society in which they live but there is a growing demand for knowledge, skills and competencies acquired in non-formal and informal learning environments to better training for work. The role of informal education is growing in modern societies, mostly due to investment in research, innovation and education in science and technology as integral parts of everyday life. Lifelong learning requires new practical forms, and formal education can be learned from informal, open learning environments such as science centres [22]. Formal teacher

professional development activities can bring teachers together and encourage further collaboration that would continue through informal learning. On the other hand, informal collaboration can provide the necessary ongoing and timely support to projects that have emerged in formal teacher professional development activities [23].

The knowledge acquired during the studies is the basis for establishing a working relationship, but only in communication with students begins the teacher's constructive action, and also his professional development. Professional development in the Republic of Croatia is organized and implemented by the Ministry of Science and Education, faculties, institutes and professional associations in the form of professional, pedagogical-psychological and methodological training. Some of them are: seminars, conferences, lectures, courses, workshops, round tables, conferences, study trips etc., which are organized at school, city, county, inter-county, state and international level [24]. Workshops and seminars bring together teachers from the same school or different schools in a region or country for shared experiences and learning. They represent structured forms of professional development that enable teachers to learn from leaders and other teachers, focusing on specific topics and experiential or practical activities in which they participate in the design of new ideas and the development of teaching materials. They include a variety of learning activities: sharing knowledge and experiences, discussing in small groups, writing professional papers, problem solving, and creating new teaching ideas [25]. Participation in courses, workshops or seminars formally organized by the competent institutions, which take place outside the school and county professional councils, teachers consider a very important factor in their own learning [26].

One of the important aspects of teachers' professional development is their formal education. Continuous professional development, within which it is carried out, Sučević et al. [27] link to three types of activities that take place after initial education: internship; in-service training, formal or non-formal; postgraduate and doctoral studies. The aim of the mentioned forms is to raise the teacher's professional-pedagogical and general competence, but also to improve the overall quality of the educational system. Opportunities for self-education of teachers, i.e. individual professional development are realized in several ways: self-expression, keeping diaries, studying professional literature [28].

Professional development of teachers in the Republic of Croatia is regulated by the Education and Teacher Training Agency. In the document Strategy of professional development for professional development of educators (2014-2020), the Education and Teacher Training Agency highlights the planned training activities aimed at developing personal and professional competencies of teachers, improving the quality of teaching, but also the educational outcomes of all teachers [29]. In order to ensure the quality of professional development of participants in the educational process, the Education and Teacher Training Agency [30] proposes a model with entry, process and exit phases.

In the entry phase (before professional development) the following elements are important:

- determining the need for professional development (at the state, school and individual level)
- defining goals in accordance with identified needs
- following the guidelines defined by the Strategy
- selection of lecturers and trainers to meet the needs and expectations of different participants in the system.

The quality assurance process phase envisages the following steps:

- examining participants' opinions on implemented programs through a questionnaire
- data collection (e-forms are proposed to facilitate processing)
- data processing
- preparing reports for each program
- planning and implementing improvements.

In the exit phase, the basic question is how participants will apply what they have

learned and how the program(s) will change their teaching practice [30, pp. 29-30].

In addition to face-to-face, formal teacher education can be carried out in different ways of online learning, which proved particularly important during the COVID-19 pandemic when there was a comprehensive virtualization of education. Fisher et al. [31] question whether the impact of online and face-to-face workshops on teacher learning and teacher application of professional development learning differs. The results show that there are no significant differences between the two groups in the learning outcomes of teachers, despite the greater satisfaction expressed by teachers who participated in face-to-face workshops. Fishman et al. [32], examining the application of the new science curriculum, investigate the differences between online learning and face-to-face training. In both groups, teachers show an increase in self-confidence in using new teaching materials. There are no particular differences in the learning of students taught by teachers from the two groups mentioned. Based on the conducted research, the authors learn that online professional development has the same impact on the beliefs and teaching practice of teachers and student learning as professional training that is held face-to-face. However, when applying professional development at a distance, it is important to give priority to continuous interaction between its participants so that all together can focus on improving the quality of teaching. This includes, among other things, effective guidance, which is especially evident in reflective activities in the online community of practitioners, as well as various online tools (examples of teaching videos and digital and multimedia content) that contribute to learning activities [33]. Lynch et al. [34] find that online learning programs have a smaller effect on student learning outcomes compared to face-to-face programs.

Mizell [35] finds the most important limitations for online learning:

• professional development may not address the specific learning challenges faced by individual teachers in working with students

• the teacher learns in isolation, not as a member of a team in which the expertise and experience of other colleagues can be useful

• collective progress of teachers at the school level has a greater impact on student learning than individual learning.

5. NON-FORMAL TEACHER EDUCATION

Non-formal education refers to organized learning outside the established curriculum of the formal education system (school and higher education). It aims to train adults to work in order to meet the needs of the labor market or participate in social activities and improve their personal development [21]. It is not conducted by an educational institution and generally does not result in a certificate. However, it is structured in terms of learning objectives, learning time, or learning support. Thus, the similarity between formal and non-formal education is that both learning programs are planned. The differences are visible in the fact that formal education is standardized and decontextualized. In non-formal education, participants can be more directly involved and influence the content and manner of teaching. Non-formal learning programs are more flexible in that each different group of learners can influence time, scope and location. In addition, through teacher-student interaction, content can be changed to meet the intentions and aspirations of different learners [7]. Kálmán [36] finds that the popularity of non-formal forms of education is still quite low because a diploma, i.e. a formal certificate, is crucial for the job. For the same reasons, formal education is generally more popular. On the other hand, Rogers [7] observes that the balance between formal and non-formal learning is changing and that non-nformal is becoming increasingly important. Although they have different values, the author considers them closely related.

The International Standard Classification of Education [37] explains in detail the concept of non-formal education. According to this document, it is an alternative or supplement to formal education in the process of individual lifelong learning in order to ensure the right of education for all. It is mainly conducted in the form of short courses, workshops or seminars and may include on-the-job training to improve existing qualifications and skills, training of the unemployed, alternative educational pathways to formal education and training, and personal

development learning activities. Non-formal programs are often focused on acquiring practical knowledge, skills or competencies in a specific context and are therefore less often focused on theoretical learning. They can be organized by different institutions: educational institutions, private companies, NGOs and public institutions. Sometimes institutions that provide formal education can also provide non-formal education and training. Examples of non-formal learning are training programs provided by institutions such as libraries, music schools, foreign language schools, community centers or other centers that organize courses to develop sports and artistic skills [38].

Non-formal education is linked to the goals and content of activities structured and organized in an institutionalized context. They are elective in nature and diverse and provide an opportunity for participants to make a choice according to their interests and needs. They are coordinated by experts such as teachers, instructors who have the function of moderators [39]. Because non-formal education is voluntary, the role of the teacher may be less important, and participants are not strictly associated with the teacher in non-formal settings and their attendance is not mandatory [40]. Schwier and Seaton [41] consider independence to be an important factor in different approaches to the non-formal learning environment. In doing so, they extend the term of independence to independence from the structural contexts of education, because each student needs to show aspects of self-direction in their own learning. In non-formal education, the curriculum loses its central role in the interests of non-passive learners. Thus, it is not so much focused on education as on individual and collective learning [42].

Given that formal learning environments generally require learners to engage in certain, externally defined ways, and the informal environment imposes less control on learners, one of the main challenges of educational technology is understanding how learners participate in non-formal learning networks to build their own learning spaces [41]. According to research results [40], the level of problem-solving skills in technology-rich environments is higher among individuals involved in formal or non-nformal learning activities, compared to those who are not. Skupnjak and Tot [26], examining the frequency of non-formal and informal learning of primary school teachers, find how the most common forms of such learning are assessed by teachers: cooperation with other teachers in school, informal conversation with fellow colleagues, participation in courses, workshops or seminars outside school, county expert councils and media monitoring (newspapers, television, internet, social media).

6. INFORMAL TEACHER EDUCATION

Informal learning is not limited to a specific environment, it often happens spontaneously, unconsciously and unintentionally. It is carried out autonomously, individually or collectively, but also without a guide. Learning is the result of engaging in everyday work activities where learning is not the primary goal and learning outcomes are unpredictable [43]. Newspapers, magazines, the Internet, television, libraries, leisure organizations, peers and family can be sources of informal education. Likewise, self-education is part of informal education [22]. Kennedy [44] defines collaborative learning as formal, informal, planned and random learning and states that effective collaborative learning takes place through informal learning elements, i.e. social interaction and learning that results from that interaction or cooperation with others. Research results [45] show that although teachers participate in various forms of formal and informal professional learning, their informal experiences are more significant for their work. Although informal vocational learning is not a substitute for traditional formal vocational learning, it can provide ways to improve formal vocational learning. Informal professional experiences enabled teachers to learn by reading, interacting with colleagues seeking advice, daily reflections on their own teaching, participating in professional learning communities and collaborating with others (exchanging ideas and discussing common problems).

Research [46] shows that informal teacher communities not only support the professional development of teachers in student-centered curricula, but also strengthen teacher identity. Such communities provide opportunities to encourage informal intercollegiate learning,

share experiences and difficulties in work, and promote teacher identity. Jones and Dexter [23] define informal teacher communities as groups of practitioners who gather to share information and solve problems in teaching practice. They are mostly formed between teachers who are in a close relationship, either virtually or physically. They provide the same benefits as formal teacher communities, such as improved communication among teachers, but provide an even higher level of timely support to teachers. Such support is not limited to pre-set time or organizational tasks such as professional development activities in the form of workshops.

Informal education as a form of continuous professional development is subject of many obstacles: time required to attend, location, costs and the existence of a replacement in the workplace. Regardless, teachers enjoy flexible, accessible and free professional development because they choose the content and colleagues with whom they attend classes. In doing so, it is not so much the confirmation they acquire, but more lasting values such as creating their own informal learning opportunities, networking and specific knowledge that they acquire and that lead to improved student learning [47]. Informal education always derives directly from real situations and is woven into certain life tasks. It is both social and individual, and relies on prior learning [7]. Nygren et al. [40] in their research find that informal, personalized and self-directed activities can be very useful for lifelong learning in the digital age.

When it comes to informal teacher learning, research [48] points to the need for differentiated support for teacher learning in their workplace. From a lifelong learning perspective, teachers should be encouraged to improve their informal learning ways by using more learning tools, such as feedback from colleagues, reflections, new ideas from the environment and trying out new materials in collaboration with colleagues. Research results [49] show that informal learning has a more significant role in encouraging proactive teacher motivation than formal learning. They also discover that formal and informal learning complement each other in the development of motivation, that is, that theoretical learning and practical teaching can interact and complement each other. The main features of informal learning in this study were a change in the beliefs and behavior of teachers. Research results [50] suggest that specially designed informal approaches to science can support novice teachers in developing positive orientations toward science, building understanding of the work of scientists, and developing contemporary ideas about teaching and learning science. Informal science environments offer a number of benefits for teacher preparation. They have a motivating effect on teachers, are rich in resources and enable learning according to the choice of content.

Although the presence of informal learning environments does not diminish the use of formal ones, there are situations where the formal learning environment presents constraints (e.g., time) that make learning difficult [51]. Czerkawski [52] emphasizes the importance of developing a learning environment with regard to different goals, needs and situations in learning and understanding the learning opportunities provided by formal and informal educational networks. He states that informal educational networks provide opportunities for self-regulated and autonomous learning opportunities, while offering up-to-date, authentic and diverse knowledge and skills. It is important that teachers apply different approaches to informal education to create an environment in which, for example, social activities become an integral part of practice in schools, youth work etc. Informal education activities include visits to museums or scientific and other fairs and exhibitions; listening to or watching educational shows; reading educational and scientific literature; participation in scientific competitions; participation in lectures and conferences etc. [20].

7. CONCLUSION

In modern society, the balance between formal, non-formal and informal education is increasingly changing. Although they are becoming more and more interconnected, we can find that they are becoming more and more important and applied informally. This is mostly because they take place outside the formal learning environment and become an inevitable part of students' daily lives. In

addition, they result from the student's conscious decision to master certain activities, skills or knowledge without having to follow a formal curriculum and to be better trained to work and cope with challenges and uncertainties, which are also guided by 21st century competencies. 21st century education requires a transition from a traditional to a new paradigm that goes beyond basic knowledge acquisition and focuses on developing new skills and attitudes such as thinking skills, problem solving, organizational, communication and technological skills and positive attitudes, self-esteem, confidence, innovation, creativity, flexibility, self-motivation etc.

The synthesis of formal, non-formal and informal education inside and outside the classroom enables holistic education that is realized through complementary activities. This can certainly help in developing students' independent and critical thinking, their creativity and effective communication. The tendency is that educational policies are constantly rethinking the synthesis and synergy of formal, non-formal and informal education so that they become a more important aspect in teachers professional development. Informal learning needs to be given special importance because it results in experiential learning needed to master students' life skills. This should be realized through a certain policy of continuing professional development programs launched at the national level or as initiatives at the local level. But also through the personal investment of each teacher in their own professional development. Furthermore, it is desirable that higher education institutions develop challenging strategies that will support their pursuit of excellence and respond to future challenges and needs of students, the labor market, society and the economy.

8. ACKNOWLEDGEMENTS

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9. REFERENCES

[1] V. Rosić, Obrazovanje učitelja i odgojitelja. Metodički obzori: časopis za odgojno-obrazovnu teoriju i praksu, 4(7-8), (2009), pp.19-32.

[2] P. Singh; L. Rowan; J. Allen, Reflection, research and teacher education. Asia-Pacific Journal of Teacher Education, 47(5), (2019), pp.455-459. https://doi.org/10.1080/1359866X.2019.1665300

[3] European Comission, Nastavnička struka u Europi: Praksa, percepcija i politike. Luksemburg: Ured za publikacije Europske Unije, (2015). https://doi.org/10.2797/323773

[4] M. Van Manen, The tact of teaching: The meaning of pedagogical thoughtfulness. Routledge, (2016).

[5] J. Kenny; L. Hobbs; R. Whannell, Designing professional development for teachers teaching out-of-field. Professional Development in Education, (2019). https://doi.org/10.1080/19415257.2019.1613257

[6] O. Malykhin; N. Aristova, Improving Computer Engineering and Information Technologies Undergraduate Students' Training Through Combination of Formal, Non-Formal and Informal Learning. Environment. Technology. Resources. Proceedings of the 12th International Scientific and Practical Conference, 2, (2019), pp. 208-213. http://dx.doi.org/10.17770/etr2019vol2.4113

[7] A. Rogers, The Base of the Iceberg Informal Learning and Its Impact on Formal and Non-formal Learning. Opladen: Barbara Budrich Publishers, (2014). https://doi.org/10.3224/84740632

[8] Zotero, Personal research assistant, last access 20.8.2020. https://www.zotero.org/

[9] V. Kostović-Vranješ, Inicijalno obrazovanje i profesionalno usavršavanje učitelja usmjereno prema osposobljavanju za promicanje obrazovanja za održivi razvoj. Zbornik radova Filozofskog fakulteta u Splitu, 6-7, (2016), pp.105-118.

[10] M. Laal, Lifelong learning: what does it mean? Journal of Procedia - Social and Behavioral Sciences, 28, (2011), pp.470-474.

[11] United Nations Educational, Scientific and Cultural Organization (UNESCO), Incheon declaration education 2030: Towards inclusive and equitable quality education and lifelong learning for all, (2015), last access 26.5.2022. http://unesdoc.unesco.org/images/0023/002331/233137E.pdf

[12] F. Caena, Initial teacher education in Europe: An overview of policy issues. European Commission, (2014).

[13] B. Bognar, Ususret promjenama odgojno-obrazovnog sustava. Radovi Zavoda za znanstvenoistraživački i umjetnički rad u Bjelovaru, 10(11), (2017), pp.143-166.

[14] M. Sablić; A. Škugor; M. Lesandrić, Teacher education in Croatia: Reforms and challenges. In: M. Kowalczuk-Walędziak, R. A. Valeeva, M. Sablić, & I. Menter (Eds.), The Palgrave Handbook of Teacher Education in Central and Eastern Europe Palgrave Macmillan, (2022), pp. 183-201.

[15] V. Vizek Vidović; V. Domović, Učitelji u Europi – glavni trendovi, pitanja i izazovi. Croatian Journal of Education, 15(3), (2013), pp.219-250.

[16] Strategy of education, science and technology – New colours of knowledge (Strategija obrazovanja, znanosti i tehnologije – Nove boje znanja). Ministarstvo znanosti obrazovanja i sporta, (2014).

[17] T. Vršnik Perše; M. Ivanuš Grmek; T. Bratina; K. Košir, Students' Satisfaction with Teaching Practice during Pre-service Teacher Education. Croatian Journal of Education: Hrvatski časopis za odgoj i obrazovanje, 17(2), (2015), pp.159-174.

[18] A. E. Du Plessis; M. Cullinan; G. Gramotnev; D. K. Gramotnev; N. T. H. Hoang; L. Mertens; K. Roy; A. Schmidt, The multilayered effects of initial teacher education programs on the beginning teacher workforce and workplace: Perceptions of beginning teachers and their school leaders. International Journal of Educational Research, 99, (2020). https://doi.org/10.1016/j.ijer.2019.09.010

[19] B. Bognar, Kako do suštinskih promjena u obrazovnom sustavu? In: R. Jukić, K. Bogatić, S. Gazibara, S. Pejaković, S. Simel, A. Varga, & V. Campbell-Bar (Eds.), Zbornik znanstvenih radova s Međunarodne znanstvene konferencije Globalne i lokalne perspektive pedagogije. Filozofski Fakultet Osijek, Sveučilište Josipa Jurja Strossmayera u Osijeku, (2016), pp. 324-334.

[20] R. Mahajan, Importance of Informal Learning over Formal Learning in 21st Century. International Journal of Advance Research and Innovation, 5(2), (2017), pp.152-154.

[21] S. Steenekamp; M. Singh, Recognition and validation of non-formal and informal learning, and NQFs: Critical levers for lifelong learning and sustainable skills development. Comparative analysis of six African countries, (2012), last access 20.3.2022. https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.462.6492&rep=rep1&type=pdf

[22] H. Salmi, Evidence of bridging the gap between formal education and informal learning through teacher education. Reflecting Education, 8(2), (2012), pp.45-61.

[23] W. M. Jones; S. Dexter, How Teachers Learn: The Roles of Formal, Informal, and Independent Learning. Educational Technology Research and Development, 62(3), (2014), pp.367-384.

[24] A. Horvat; G. Lapat, Cjeloživotno obrazovanje učitelja. Andragoški glasnik, 16(2), (2014), pp.131-142.

[25] S. Loucks-Horsley; K. E. Stiles; S. E. Mundry; N. B. Love; P. W. Hewson, Designing Professional Development for Teachers of Science and Mathematics: Third Edition. Corwin Press, SAGE, (2010). http://dx.doi.org/10.4135/9781452219103

[26] D. Skupnjak; D. Tot, Zastupljenost neformalnog i informalnog učenja u profesionalnom razvoju učitelja. Nova prisutnost, 17(2), (2019), pp.309-322. https://doi.org/10.31192/np.17.2.5

[27] V. Sučević; S. Cvjetićanin; M. Sakač, Obrazovanje nastavnika i učitelja u europskom konceptu kvalitete obrazovanja zasnovanom na kompetencijama. Život i škola, 25(57), (2011), pp.11– 23.

[28] D. Skupnjak, Kurikulum i profesionalni razvoj učitelja u Hrvatskoj. Napredak, 152(2), (2011), pp.305–324.

[29] D. Anđić, Profesionalni razvoj i kompetencije učitelja u odgoju i obrazovanju za održivi razvoj. In: R. Čepić & J. Kalin (Eds.), Profesionalni razvoj

učitelja: status, ličnost i transverzalne kompetencije. Poglavlje 5. Sveučilište u Rijeci, Učiteljski fakultet, (2017), pp.87–118.

[30] Education and Teacher Training Agency (Agencija za odgoj i obrazovanje), Strategija stručnog usavršavanja za profesionalni razvoj odgojno-obrazovnih radnika (2014-2020), (2014), last access 20.8.2020. https://www.nszssh.hr/pdf/Strategija%20strucnog%20usavrsavanja.pdf

[31] J. B. Fisher; J. B. Schumaker; J. Culbertson; D. D. Deshler, Effects of a computerized professional development program on teacher and student outcomes. Journal of Teacher Education, 61, (2010), pp.301–312.

[32] B. Fishman; S. Konstantopoulos; B. W. Kubitskey; R. Vath; G. Park; H. Johnson; C. Edelson, Comparing the impact of online and face-to-face professional development in the context of curriculum implementation. Journal of Teacher Education, 64(5), (2013), pp.426–438. https://doi.org/10.1177/0022487113494413

[33] B. Bognar; M. Filipov, Online stručno usavršavanje: važan uvjet uspješne nastave na daljinu. In: V. Strugar, A. Kolak, & I. Markić (Eds.), Školovanje od kuće i nastava na daljinu u vrijeme HR-COVID-19. Element, (2020), pp. 203-239.

[34] K. Lynch; H. C. Hill; K. E. Gonzalez; C. Pollard, Strengthening the research base that informs STEM instructional improvement efforts: A meta-analysis. Educational Evaluation and Policy Analysis, 41(3), (2019), pp.260–293. https://doi.org/10.3102/0162373719849044

[35] H. Mizell, Why professional development matters. Learning Forward, (2010).

[36] A. Kálmán, Formal -nonformal Learning Acknowledgement to the New Employment Competencies. 40th SEFI Annual Conference. Thessaloníki, Greece, (2012).

[37] United Nations Educational, Scientific and Cultural Organization (UNESCO). International Standard Classification of Education ISCED 2011. Montreal, UNESCO Institute for Statistics, (2012), last access 26.5.2022. http://uis.unesco.org/sites/default/files/documents/international-standard-classification-of- education-isced-2011-en.pdf

[38] S. L. Tudor, Formal – Non-formal – Informal in Education. Procedia - Social and Behavioral Sciences, 76, (2013), pp.821–826. doi:10.1016/j.sbspro.2013.04.213

[39] O. Moldovan; V. Bocoş-Binţinţan, The Necessity of Reconsidering the Concept of Non-formal Education. Procedia - Social and Behavioral Sciences, 209, (2015), pp.337–343. https://doi.org/10.1016/j.sbspro.2015.11.245

[40] H. Nygren; K. Nissinen; R. Hämäläinen; B. Wever, Lifelong learning: Formal, non-formal and informal learning in the context of the use of problem-solving skills in technology rich environments. British Journal of Educational Technology, 50(4), (2019), pp.1759-1770. https://doi.org/10.1111/bjet.12807

[41] R. A. Schwier; J. X. Seaton, A Comparison of Participation Patterns in Selected Formal, Non-Formal, and Informal Online Learning Environments. Canadian Journal of Learning and Technology, 39(1), (2013).

[42] S. Bohlinger, Comparing Recognition of Prior Learning (RPL) across Countries. In: M. Mulder (Ed.), Competence-Based Vocational and Professional Education, Technical and Vocational Education and Training: Issues, Concerns and Prospects 23. Springer International Publishing, (2017), pp.589-606. https://doi.org/10.1007/978-3-319-41713-4_27

[43] E. Kyndt; N. Govaerts; E. Verbeek; F. Dochy, Development and validation of a questionnaire on informal workplace learning outcomes: A study among socioeducational care workers. British Journal of Social Work, 44, (2014), pp. 2391–2410. https://doi.org/10.1093/bjsw/bct056

[44] A. Kennedy, Collaborative continuing professional development (CPD) for teachers in Scotland: Aspirations, opportunities and barriers. European Journal of Teacher Education, 34(1), (2011), pp.25–41.

[45] E. S. Thacker, ”PD is where teachers are learning!” high school social studies teachers' formal and informal professional learning. The Journal of Social Studies Research, 41(1), (2015). http://dx.doi.org/10.1016/j.jssr.2015.10.001i

[46] T. Van Lankveld; J. Schoonenboom; R. Kusurkar; J. Beishuizen; G. Croiset; M. Volman, Informal teacher communities enhancing the professional development of medical teachers: a qualitative study. BMC Medical Education, 16(1), (2016). https://doi.org/10.1186/s12909- 016-0632-2

[47] A. Casey, Practitioner research: A means of coping with the systemic demands for continual professional development? European Physical Education Review, 19(1), (2012), pp.76-90. https://doi.org/10.1177/1356336X12465510

[48] A. Hoekstra; F. Korthagen; M. Brekelmans; D. Beijaard; J. Imants, Experienced teachers' informal workplace learning and perceptions of workplace conditions. Journal of Workplace Learning, 21(4), (2009), pp.276-298. https://doi.org/10.1108/13665620910954193

[49] X. Huang; C. Lai, Connecting formal and informal workplace learning with teacher proactivity: a proactive motivation perspective. Journal of Workplace Learning, 32(6), (2020), pp.437- 456. https://doi.org/10.1108/JWL-01-2020-0005

[50] L. Avraamidou, Reconceptualizing Elementary Teacher Preparation: A case for informal science education. International Journal of Science Education, 37(1), (2015), pp.108–135. doi:10.1080/09500693.2014.969358

[51] B. L. Dorie; C. A. Dankenbring; D. L., Denick; D. Ferguson; J. Huff; C. Phillips; C. Schimpf; M. E. Cardella, FILE: A taxonomy of formal and informal learning environments, in ASEE 2012 IL/IN Sectional Conference. American Society for Engineering Education: Valparaiso, Indiana, (2012).

[52] B. Czerkawski, Blending Formal and Informal Learning Networks for Online Learning. The International Review of Research in Open and Distributed Learning, 17(3), (2016), pp.138-156. https://doi.org/10.19173/irrodl.v17i3.2344

Enhancing Learning Outcomes in STEM E-Assessments in Higher Education by Didactic Adjustments

O. Mülken[a], F. Pude[a], L. Friedhoff[a], and J. Rausenberger[a]

[a] School of Life Sciences, University of Applied Sciences and Arts Northwestern Switzerland, Hofackerstrasse 30, 4132 Muttenz, Switzerland, corresponding author: oliver.muelken@fhnw.ch

Abstract

We report on a pilot project aiming at establishing didactically adjusted questions for e-assessments in first year courses in Mathematics for students in Life Sciences. In contrast to classical pen-and-paper exams, online tests require different types of questions. By setting boundary conditions for these questions, we built sets of questions for the topics of one course. These sets have been tested and evaluated by the students of that course. We conclude from the students' feedback as well as from the results in regular intermediate e-assessments that the questions have enhanced the learning outcomes for that course.

Keywords: STEM, e-assessments, higher education, didactic learning outcomes, didactics

1. INTRODUCTION

Teaching basic STEM courses at the university level becomes an ever more complex challenge. The COVID19 pandemic has clearly shown that the way we teach such courses needs continuous development [1][2]. This includes adjusting to distant or hybrid settings for lectures but also (partly) changing the assessment methods. Assessing the learning outcomes is still done via analogue pen-and-paper-exams. However, digital means to assess the topics within a learning management system (LMS) such as MOODLE or ILIAS are increasingly made use of.

While it is easy to use the existing questions for analogue exams for digital ones, one should bear in mind the consequences a switch from analogue to digital exams has for the students, see e.g. [3]. In analogue STEM exams, we are used to not only assess and grade the correct final answer but also the calculations shown on the exam sheets. The latter part is mainly lost when asking the same questions in a digital exam. In a pilot project at the School of Life Sciences (HLS), University of Applied Sciences and Arts Northwestern Switzerland (FHNW), we addressed this issue by developing new sets of questions which have been didactically adjusted to assess the learning outcomes of STEM students in digital exams on tertiary level.

2. DIDACTIC ADJUSTEMENTS OF STEM E-ASSESSMENTS

Funding of the FHNW allowed us to establish a collaboration between four different schools within the FHNW [4] to investigate the possibilities of using new sets of questions for digital exams. These questions have been tested during the course "Analysis 2" taught to approximately 100 students in the second semester at the HLS.

2.1. Learning management system and framework for questions

The FHNW provides the LMS MOODLE. All courses taught at the FHNW are listed there

and are managed by the course's responsible teacher(s). MOODLE also provides tools to generate digital exams with different types of questions, ranging for simple multiple-choice (MC) questions to more complex types especially aimed at STEM assessments like STACK which uses the underlying computer algebra systems MAXIMA [5][6].

When we started to develop alternative questions for digital exams, we set boundary conditions for these questions: a) Assessing the learning outcomes, b) increase understanding of topic, c) complement the examples discussed during the lecture, d) prevent easy solution by using websites such as www.wolframalpha.com, and e) prevent cheating by randomizations.

The last point can be achieved by using for every student the MOODLE build-in features (i) randomization of possible answers and (ii) randomly picking a question from a defined set of questions. Additionally, the STACK-questions allows for controlled randomization of parameters, such that every student gets a different version of the same question.

3. RESULTS

The course "Analysis 2" covers the following different topics: 1) complex numbers, 2) advanced differential and integral calculus in one dimension, 3) Fourier series, 4) differential calculus in many dimensions and 5) integral calculus in many dimensions. For each topic we generated a set of new alternative questions satisfying the mentioned boundary conditions. STACK allowed us to use random numbers for parameters such that all students will obtain the same question but with different numbers.

For each topic, all generated question were uploaded to the MOODLE-course for this lecture. We distinguished between two phases: (a) exercise, where the students had access to all newly generated questions and (b) assessment where we generated intermediate online exams with randomized selections of these questions, see below. In addition to the intermediate online exams, the lecture will be concluded by a final analogue pen-and-paper exam.

3.1. Examples of questions

An example of such an appropriate question is shown in Fig. 1 for the topic of complex numbers. Here, all real numbers entering the expression for the complex number z are randomly drawn from adjustable sets of integers. The students must solve for the parameter b such that z becomes a real number.

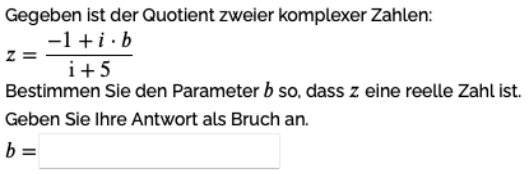

Fig. 1: Exemplary question for complex numbers

Another option, where students cannot simply search for the answer on the internet is shown in Fig. 2, where the graphical component has been implemented by using JSXGraph [7]. The students are asked to move (i) the red point to a specific randomly chosen position on the x-axis, x_0, and (ii) the circle (slider) to a randomly chosen value corresponding to the order of the Taylor expansion.

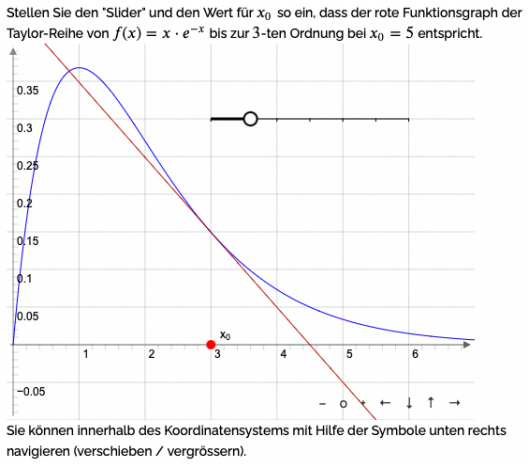

Fig. 2: Exemplary question for Taylor series

Clearly, these types of questions cannot be generated for an analogue pen-and-paper exam. Using the possibilities of graphical interaction allows not only for a new type of question but also for an enhanced understanding of the topic due to its direct graphical visualization.

As a third example, Fig. 3 shows an exemplary question where the underlying CAS MAXIMA is used to verify the student answer.

Here, the students must give the upper limit of the integral over x (shown in red) as a valid expression. As support, we give indications of the syntax for entering these expressions into the answer field.

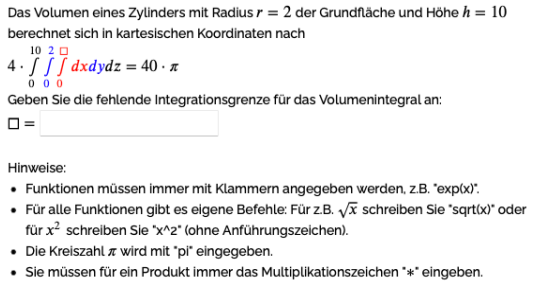

Fig. 3: Exemplary question for integral

Again, an internet-search will not immediately show the correct answer and the students must understand what to do to solve this task.

3.2. Assessment procedure and feedback

During the first exercise phase, the students were allowed to answer these questions independently as many times as they liked. We asked for feedback concerning the content of the generated questions.

Figure 4 shows the feedback of the students to four different aspects and for each topic with sample sizes of e_1=47, e_2=10, e_3=14, e_4=27, and e_5=35, respectively. Most students considered the exercise phase good feedback on their current knowledge and a good means to increase their understanding of that topic. While more than 50% of the students regarded the level of the questions reasonable, a considerable amount (around 20%) evaluated the level to be high or very high. In total, the students felt well prepared for the subsequent intermediate e-assessments, see Fig. 4(d).

Out of the newly created questions, we generated five different intermediate e-assessments each consisting of in total six different questions for every topic. Here, we used the feature of MOODLE to shuffle the questions, such that each student will see a different sequence of questions. The assessment was carried out at the end of each thematic unit of the lecture. Each e-assessment was scheduled for 20 minutes with subsequent feedback from the students regarding fairness and time limit.

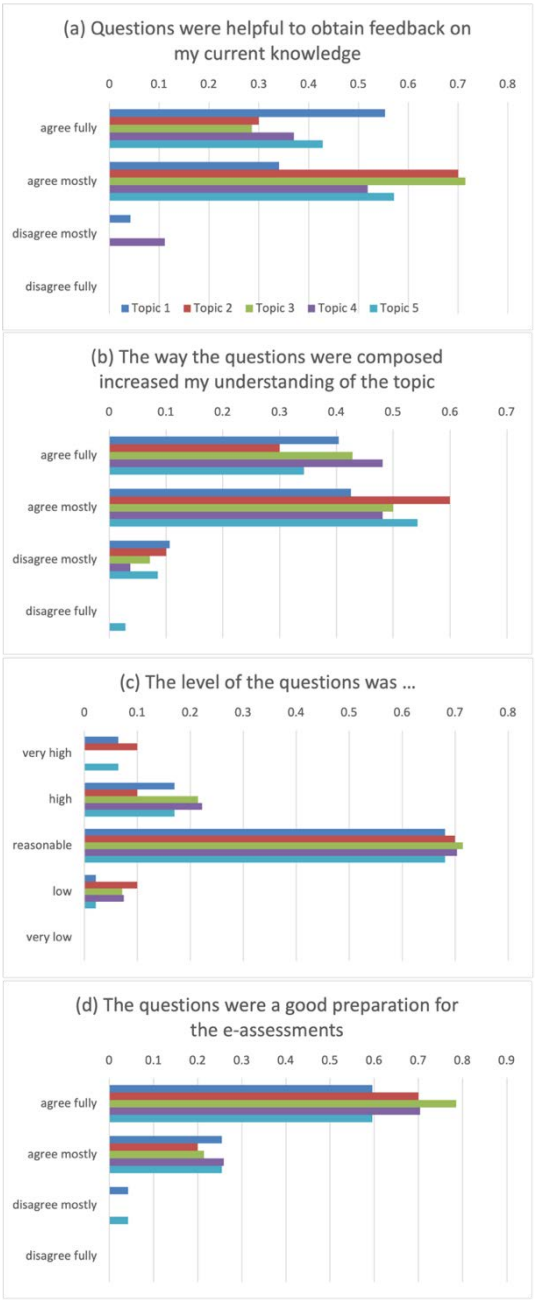

Fig. 4: Feedback on the content of the questions

Figure 5 summarizes the feedback for each of the five e-assessments with sample sizes of a_1=73, a_2=38, a_3=51, a_4=29, and a_5=41, respectively, for each topic. Nearly all students agreed that the questions were fair. The feedback regarding time was a bit more diverse. However, also here most students said they had enough time to complete the exam.

The feedback regarding the e-assessments correlates with the actual grades of the exams. Table 1 shows the average marks for each topic, on the Swiss scale for 1 (lowest mark) to 6 (highest mark).

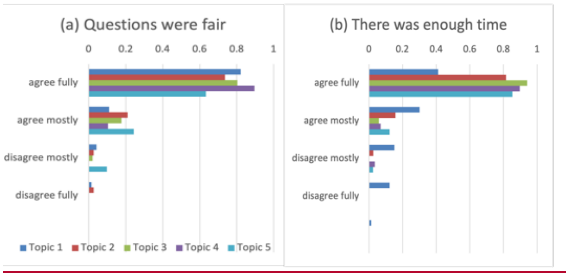

Fig. 5: Feedback on regular e-assessments

In general, the procedure of having regular short e-assessments at the end of each topic was welcomed by most students. A continuous examination with the content of the lecture has increased the understanding and such enhanced the learning outcomes for most students.

Table 1: Average marks for each e-assessment

Topic	**1**	**2**	**3**	**4**	**5**
Avg. mark	5.1	5.3	5.7	5.6	5.2

It remains to be seen if the good marks in the e-assessments will also translate to good marks in the final analogue pen-and-paper exam.

4. CONCLUSIONS

We have studied the possibilities to enhance the learning outcomes of STEM students in higher education by using didactically adjusted e-assessments. We generated questions for different topics of the course “Analysis 2” taught at the HLS of the FHNW. For this we used STACK and implemented randomized questions in MOODLE. For each topic of the course, the students had the possibility to exercise with these new questions. Subsequently, we tested the acquired knowledge with selections of the new questions. The feedback showed that the questions helped to extend and to consolidate the students’ knowledge. Using the same type of questions for practising as well as for the e-assessments was appreciated by the students. Due to the positive experiences and the broad acceptance of the questions and the intermediate online examinations, we will conduct the e-assessment already in the first semester in future. The aim is to promote continuous learning and a conceptual understanding of the mathematical topics.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

[1] T. Bailey, G. Kinnear, C. Sangwin, und S. O’Hagan, „Modifying closed-book exams for use as open-book exams“, OSF Preprints, Mai 2020.

[2] P. Iannone, „Assessing Mathematics at University: Covid-19 and Beyond“, *NLMS*, Sep. 2020.

[3] M. Greenhow, „Effective computer-aided assessment of mathematics; principles, practice and results“, *Teaching Mathematics Applications*, Bd. 34, Nr. 3, S. 117–137, Sep. 2015.

[4] School for Life Sciences (HLS), School of Architecture, Civil Engineering and Geomatics (HABG), School of Engineering (HT), School of Education (PH)

[5] C. Sangwin, „Computer Aided Assessment of Mathematics Using STACK“, in *Selected Regular Lectures from the 12th International Congress on Mathematical Education*, S. J. Cho, Hrsg. Cham: Springer International Publishing, 2015, S. 695–713.

[6] MAXIMA, https://maxima.sourceforge.io

[7] JSXGraph, https://jsxgraph.uni-bayreuth.de

Application of computers and knowledge of ICT in agriculture

P. Nakić [a], I. Lacković [b], T. Ćosić [c], I. Džambo [d]

[a] University of Slavonski Brod, Ivane Brlić Mažuranić 2, Hr 35000 Slavonski Brod, Croatia, pnakic@unisb.hr

[b] University of Slavonski Brod, Ivane Brlić Mažuranić 2, Hr 35000 Slavonski Brod, Croatia, ilackovic@unisb.hr

[c] University of Slavonski Brod, Ivane Brlić Mažuranić 2, Hr 35000 Slavonski Brod, Croatia, idzambo@fina.hr

[d] University of Slavonski Brod, Ivane Brlić Mažuranić 2, Hr 35000 Slavonski Brod, Croatia, idzambo@fina.hr

Abstract

The aim of the work is to determine the level of computer knowledge and knowledge IT technology among farmers. The growing demand for food in terms of quality and quantity has increased the need for industrialization and intensification in the agriculture field. Internet of Things (IoT) is a highly promising technology that is offering many innovative solutions to modernize the agriculture sector. The research was conducted in May 2022 on a sample of 112 farmers in the Brod - Posavina county. The survey was conducted orally, and part online. The research showed that a very small number of farmers have excellent computer skills, and an even smaller number of farmers are familiar with the term IT technology.

Keywords: IT technology, IoT, ICT, agriculture, computers.

1. INTRODUCTION

Research conducted around the world shows that the use of information and communication technology in agriculture enables farmers to be better informed, exchange data and knowledge, place their goods on the market, promote products, provides better access to financial markets, brings savings in transaction costs, and generally contributes to the improvement business of farmers [1].

With the increase in the number of inhabitants on the globe, we also come to an increase in the need to increase food production. According to the Food and Agricultural Organization of the United Nations (FAO), more than 60% of the human population depends on agriculture, and about 12% of the total land area is under agricultural production [2]. Predictions are that by 2050 there will be around 10 billion inhabitants. That alone will have to increase the production of agricultural food.

The widespread of the internet from the last two decades has brought unlimited benefits for organizations and citizens over the globe. The major benefit of this innovation was the capability to producer and consumer services in real time. In the field of agriculture, IoT is used at different levels in the agriculture industrial production chain [3]. The main applications of IoT in agriculture are Precision Farming, Livestock, and Greenhouses, which are grouped into different monitoring domains. All these applications are monitored with the help of different IoT-based sensors/devices by using

wireless sensor networks (WSNs) that helps the farmers collect relevant data through sensing devices.

Information literacy (or ICT literacy) implies computer knowledge configurations and the basis of using operating systems computer systems (programs) and different application [4], communicating by e-mail and knowing internet browsers and search engines.

2. METHODS AND MATERIALS USED FOR RESEARCH

The research was conducted during May 2022 on a sample of 116 registered farmers in Brod-Posavina County. It should be emphasized that the respondents were owners or registered members of a family farm.

The survey consisted of 17 questions, which were divided into three groups. The first one related to the sociodemographic characteristics of the respondents. The second one related to owning and knowing how to work on a computer, while the third group refers to knowing the term IoT.

2.1. Methods of data processing

The methods used for data processing included calculating descriptive statistical parameters for all variables: arithmetic mean (AS), standard deviation (SD). The data were processed in MS Excel.

3. RESULTS AND ACHIEVEMENTS

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3.1. Basic characteristics of the respondents

More men participated in the survey (74.14 %) compared to the female population (table 1). Most of the respondents belong to the age group from 31 to 60 years old, of which there are 72, and 27 belong to the age group from 18 to 30 years old.

Table 1. Characteristics of the respondents.

Variables		f	%
Sex	Female	30	74,14
	Male	86	25,86
Age	18 - 30	27	23,28
	31 – 60	72	62,07
	>60	17	14,65

3.2. Possession and knowledge of using computers and mobile devices

It is known that IT technologies such as mobile phones, computers, the Internet increasingly play a large role in everyday life. Research shows that the age of farmers is not such a key obstacle to the introduction of ICT and that the application of new technologies can be successful regardless of the age group. [5].

The research showed that all respondents have mobile devices, with 89.96% of respondents having smartphones. Most of them use a mobile device to make and receive calls and send messages. More than 60% of them use mobile devices both to search the Internet and to use communication applications such as Viber or Whatsapp.

Also, most respondents have a desktop computer or laptop in their home. The majority of respondents rated their computer skills as poor. They use computers mostly to get information about the machinery they need to work or to get information about the prices of goods.

Table 2. Possession and knowledge of using computers and mobile devices.

Variables		f	%
Mobile phone	Classic	12	10,04
	Smartphone	104	89,96
Computer/laptop	Yes	82	70,69
	No	34	29,31
Frequency of computer use	0-1 hours a day	40	34,49
	2 or more hours a day	76	65,51
Computer skills	Very bad	8	6,90
	Bad	56	48,28
	Good	29	25,00
	Very good	15	12,93
	Excellent	8	6,89

The results show that the majority of agriculturists believe that they have poor IT literacy. The best average score was given to the skills of using communication applications such as Viber and Whatsapp. On average, respondents rated their work on the Internet, and the use of mobile banking and knowledge of the MS Office package the worst (table 3).

Table 3. Assessment of knowledge and skills in the application of basic computer programs and the Internet.

Variables	1+2 (%)	3 (%)	4+5 (%)	AM	SD
Use e-mail	38,2	14,8	47,0	3,11	1,60
Use MS Office	43,5	15,7	40,8	2,92	1,56
Use internet	50,4	12,2	37,4	2,73	1,61
Use application for communication	38,3	9,6	52,1	3,13	1,65

1 – very bad, 2 – bad, 3 – good, 4 – very good, 5 – excellent, AM – arithmetic mean, SD – standard deviation

3.3. Attitudes about the application of informatics technologies in agriculture

ICT has many advantages, such as sharing information and expanding knowledge, but research shows that farmers are not sufficiently informed about the benefits of using new technologies in their work.

The results of the research showed that the majority of farmers have not encountered terms such as IoT, "smart agriculture", ICT.

Respondents who encountered these terms do not apply new technologies in their business.

The respondents indicated that they had not encountered the term ICT, only 7.76% of them had encountered the term (table 4). Also, the majority of respondents did not come across the term "smart agriculture", about 90%. The third term that was surveyed is the term Internet of Things, which is also used by a very small number of respondents in their business. For the improvement that is needed in the future, awareness should be increased among farmers and the benefits they would have from new technologies.

What are the problems and reasons why respondents do not use and are not familiar with new technologies and possibilities is the main question. There has been a lot of talk lately about new possibilities that can make our lives easier, but these are devastating results of people's knowledge that could improve their work. When we look at the results of the research, it is obvious that a big problem is that the respondents are not familiar with the possibilities available to them nowadays.

Table 4. Attitudes about the application of informatics technologies in agriculture

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Variables		f	%
Do you know how to define the term ICT?	Yes	9	7,76
	No	107	82,24
Do you know how to define the term “smart agriculture”?	Yes	12	10,34
	No	104	89,66
Do you use IoT (Internet of Things) in your work?	Yes	3	2,59
	No	113	97,41

4. CONCLUSIONS

The Internet is revolutionizing our world. Communication via connective devices has become the countenance of survival. Agriculture is growing from precision farming to micro farming. IoT has addes more potential to communication by enabling the communication between humans and objects along with the environmental aspects.

The research showed that our farmers have a low level of IT literacy. For the better use of new information technologies in the work of the farmer, it is important to understand the new technologies. The majority of farmers assessed that their level of knowledge of new concepts that would help them in their work was very poor.

However, most farmers have positive attitudes towards the introduction of new technologies in order to improve their business.

5. REFERENCES

[1] FAO, The World Bank, (2017).

[2] G. Zavatta, Agriculture Remains Central to the World Economy. 60% of the Population Depends on Agriculture for Survival, (2014).

[3] Medela, A.; Cendón, B.; González, L.; Crespo, R.; Nevares, IoT multiplatform networking to monitor and control wineries and vineyards. In Proceedings of the 2013 (2013).

[4] S. Špiranec, Z. Banek, Information literacy: theoretical framework and starting points, 2008. (in Croatian)

[5] J. Allspaw, J. Robbins, Web Operations, (2010).

[6] A. Barauh, The farmers’ view towards the use of Information and Communication Technology in agriculture: a study among farmers in the ner (north- eastern region) of India, (2018).

[7] F. A. Abdullah, B. A. Samah, Fatorc Impanging Famers Use of Agriculture Technology, (2013)

[8] H. De Silva, D Ratnadiwakara, Using ICT to reduce transaction costc in agriculture through better communication, (2008.)

[9] V. Singh, P Sankhwar, D. Pandev, The role of Information Communication Technology (ICT) in Agriculture, (2015.)

[10] E. O. Buyukbay, O. Gundunz, An investigation on computer and internet use for agricultural development in rural areas, (2013.)

[11] A. A. Barakabitze, E. J. kitindi, C. Sanga, A. Shabani, J. Philipo, G. Kibirige, New technologies for disseminating and communicating agriculture knowledge and information (AKI), (2015.)

Image reconstruction by the weighted median

V. Novoselac [a]

[a] Mechanical Engineering Faculty in Slavonski Brod, Trg I. B. Mažuranić 2, HR-35000, Croatia, vnovoselac@unisb.hr

Abstract

This paper considers an image denoising by the weighted medina, where the impulse noise, or "salt and pepper" noise is taken into the consideration. Reconstruction of a noisy image is conducted by the weighted median where the central weight of the weighted window is taken into the consideration. The MAE (Mean Absolute Error) and MSE (Mean Squared Error) measurements are considered for determination of the central weight, where the experimental results are conducted for various noise ratio.

Keywords: weighted medina, image denoising, optimization.

1. INTRODUCTION

In this research the weighted median of data is considered in order to reconstruct noisy image. For that purpose a certain component of the weighted vector is taken into the consideration [1], which corresponds to the corresponding central weight of the weighted window.

In the image processing area denoising of an image present a process in which a noisy image is reconstructed via different measurements, where commonly used measurements are MAE and MSE. For that purpose a different types of methods, i.e. filters, are constantly used and developed [2], where filters based on the weighted median is commonly used [3].

For that purpose the experimental results are conducted on the central weight in order to optimize reconstruction of an image via MAE and MSE, where the well known impulse noise, or so called "salt and pepper" noise is observed.

2. THE WEIGHTED MEDIAN

The weighted median of data has great application in different branches of statistics, applied mathematics, and image processing [1], [3], [4]. So, in the next theorem is directly presented the determination of the weighted median $\text{med}(\omega, z)$ for the given input vector $z = (z_1, \dots, z_n) \in \mathbb{R}^n$, and its corresponding vector of weights $\omega = (\omega_1, \dots, \omega_n) \in \mathbb{R}_+^n$.

Theorem (The Weighted Median). *Let denote the input vector as* $z = (z_1, \dots, z_n) \in \mathbb{R}^n$, *and its corresponding weighted vector* $\omega = (\omega_1, \dots, \omega_n) \in \mathbb{R}_+^n$, *and let denote set*

$$T = \left\{ t : 2\sum_{i=1}^{t-1} \omega_{(i)} \le \sum_{i=1}^{n} \omega_{(i)} \right\}, \quad t \in \{1, \dots, n\}, \qquad (1)$$

where

$$z_{(1)} \le \cdots \le z_{(n)}, \qquad (2)$$

presents sorted elements of input vector. Then it holds:

i.) $2\sum_{i=1}^{m-1} \omega_{(i)} < \sum_{i=1}^{n} \omega_{(i)} \Rightarrow \text{med}(\omega, z) = z_{(m)};$

ii.) $2\sum_{i=1}^{m-1} \omega_{(i)} = \sum_{i=1}^{n} \omega_{(i)} \Rightarrow \text{med}(\omega, z) = (1-\alpha) z_{(m-1)} + \alpha z_{(m)};$

where $m = \max T$, *and* $\alpha \in [0,1]$.

3. IMAGE DENOISING

In this section the image denoising is presented, where filter is used to reconstruct noisy image which is based on the weighted median.

3.1. Image presentation

In image processing area image of $N \times M$ dimensions can be presented in matrix form as

$$Y = \begin{bmatrix} y_{1,1} & \cdots & y_{1,M} \\ \vdots & \ddots & \vdots \\ y_{N,1} & \cdots & y_{N,M} \end{bmatrix}, \tag{3}$$

where each matrix element $y_{i,j}$ presents image pixel which denotes colour intensity of image. Colour intensity can be presented in different colours types and scales. For that purpose the grayscale level of image colour is observed, which present an image in monochromatic shades of grey in integer scale, i.e. $y_{i,j} \in [0,255]$. Next figure present the image of an astronaut in grayscale level of a dimensions 100×100. In figure the part of the image is extracted were pixel values are denoted to an each pixel in range of 0 to 255 (0 denotes black, while 255 denotes white colour).

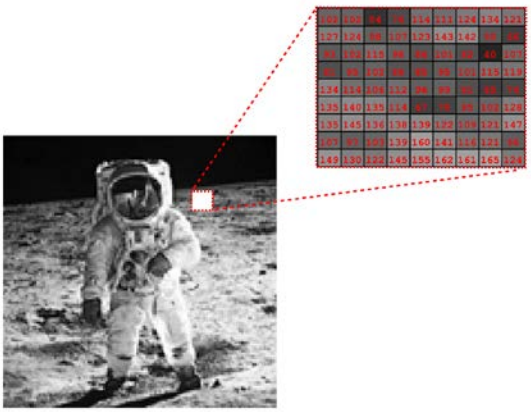


Fig. 1. Image presentation

3.2. Noise model

In image processing a noises are generated by different mathematical models. One of the most known "salt-and-pepper" noise is modeled as

$$x_{i,j} = \begin{cases} \xi_{i,j}, & \text{with probability } \rho; \\ y_{i,j}, & \text{with probability } 1-\rho; \end{cases} \tag{4}$$

where $\rho \in [0,1]$ present noise ratio, and $\xi_{i,j}$ presents random variable with probability density function which is define as

$$P(t) = \begin{cases} P_p, & t = p; \\ P_s, & t = s; \\ 0, & \text{otherwise}; \end{cases} \tag{5}$$

where $P_p, P_s \geq 0$, $P_p + P_s = 1$ (we observe when $P_p, P_s = 0.5$), presents occurrence probabilities of value p, and s. For an impulse noise, i.e. "salt-and-pepper" noise, it is usual to observe a values which reach maximum and minimum value of observed scale, i.e. $p = 0$ and $s = 255$. In that way a noisy image is generated which is denoted by

$$X = \begin{bmatrix} x_{1,1} & \cdots & x_{1,M} \\ \vdots & \ddots & \vdots \\ x_{N,1} & \cdots & x_{N,M} \end{bmatrix}. \tag{6}$$

3.3. Filtering scheme

Reconstruction of a noisy image X is constructed to process each pixel $x_{i,j}$, and thus reconstructed image is created which is denoted by

$$X^* = \begin{bmatrix} x^*_{1,1} & \cdots & x^*_{1,M} \\ \vdots & \ddots & \vdots \\ x^*_{N,1} & \cdots & x^*_{N,M} \end{bmatrix}. \tag{7}$$

Filter process each pixel $x_{i,j}$ in such a way that it considered all neighbourhood of $x_{i,j}$ into the process. An observed neighbourhood of $x_{i,j}$ is centered around the observed pixel, which is called the filtering window and is denoted as

$$X_{i,j}=\begin{bmatrix} x_{i-C,j-C} & \cdots & x_{i-C,j} & \cdots & x_{i-C,j+C} \\ \vdots & \ddots & \vdots & \iddots & \vdots \\ x_{i,j-C} & \cdots & x_{i,j} & \cdots & x_{i,j+C} \\ \vdots & \iddots & \vdots & \ddots & \vdots \\ x_{i+C,j-C} & \cdots & x_{i+C,j} & \cdots & x_{i+C,j+C} \end{bmatrix}. \quad (8)$$

A dimension of the filtering window is $D\times D$, $D=2C+1$, $C\in\mathbb{N}$, and it slides trough all image in order to reconstruct noisy image. In the image processing area filters are often modelled in order to use the weighted median into a process of reconstruction of a noisy image. For that purpose the weighted window W of a dimensions $D\times D$ is also constructed, i.e.

$$W=\begin{bmatrix} w_{1,1} & \cdots & w_{1,C+1} & \cdots & w_{1,D} \\ \vdots & \ddots & \vdots & \iddots & \vdots \\ w_{C+1,1} & \cdots & w_{C+1,C+1} & \cdots & w_{C+1,D} \\ \vdots & \iddots & \vdots & \ddots & \vdots \\ w_{D,1} & \cdots & w_{D,C+1} & \cdots & w_{D,D} \end{bmatrix}, \quad (9)$$

which correspond to the filtering window $X_{i,j}$. Each element of the weighted window W corresponds to an element in the filtering window $X_{i,j}$, which is settled on the same position. In order to apply the weighted median to the filtering window $X_{i,j}$ with corresponding weighted window W, the mapping which transforms matrix form into a vector is constructed. So, let us define the mapping

$$u(k)=\sum_{l=1}^{n}\left(\left\lfloor\frac{l-1}{D}\right\rfloor-C\right)\cdot\chi_{\{l\}}(k), \quad (10)$$

$$v(k)=\sum_{l=1}^{n}\left(l-1-C-D\left\lfloor\frac{l-1}{D}\right\rfloor\right)\cdot\chi_{\{l\}}(k), \quad (11)$$

where in this situation follows that $n=D^2$, and

$$\chi_A(x)=\begin{cases}1, & x\in A;\\ 0, & x\notin A;\end{cases} \quad (12)$$

denotes the indicator function, where $A\subseteq\mathbb{R}$. In that way, to an each element z_k, $k\in\{1,\ldots,n\}$, of input vector $z=(z_1,\ldots,z_n)\in\mathbb{R}^n$, and to an each element ω_k, $k\in\{1,\ldots,n\}$, of the weighted vector $\omega=(\omega_1,\ldots,\omega_n)\in\mathbb{R}_+^n$, a corresponding element of the filtering window $X_{i,j}$, and the weighted window W, are mapped, i.e.

$$z_k=x_{i+u(k),j+v(k)},\quad \omega_k=w_{C+1+u(k),C+1+v(k)}. \quad (13)$$

In this situation, a reconstructed pixel $x_{i,j}^*$ is obtained as an output of the weighted median which process the filtering window $X_{i,j}$ with the corresponding weighted window W, what can be written as

$$x_{i,j}^*=\operatorname{med}(\omega,z). \quad (14)$$

3.4. Reconstruction measurement

Quality of reconstructed image are most commonly measured by MAE (Mean Absolute Error) and MSE (Mean Squared Error), which are defined as

$$\mathrm{MAE}=\frac{\sum_{i=1}^{N}\sum_{j=1}^{M}\left|y_{ij}-x_{ij}^*\right|}{N\cdot M}, \quad (15)$$

$$\mathrm{MSE}=\frac{\sum_{i=1}^{N}\sum_{j=1}^{M}\left(y_{ij}-x_{ij}^*\right)^2}{N\cdot M}. \quad (16)$$

MAE measurement are commonly used for insight of detail and edges reconstruction. This property are inherited from robustness on outliers. Otherwise, MSE measurement are used as an information for an impulse noise removal. This is because MSE possesses sensibility to an outliers [4].

4. EXPERIMENTAL RESULTS

In this section an experimental research is conducted in order to optimize reconstruction measurements, i.e. MAE, and MSE. This task yield to a reconstruction of a noisy image which is affected by an impulse noise that is generated by model (4). The optimization problem is set in such a way that a central weight $\omega_{(n+1)/2}=w_{C+1,C+1}$ is observed as a unknown

parameter, while other weights are set to one, i.e. $\omega_k = 1$, $k \neq (n+1)/2$. In this way, a regulation to a filtering process is managed, and thus invariability to an unnecessary filtering process of an observed pixel can be provided. This process yields to a preservation of a fine details and edges of an image, and a prevention to an image blurring. In the Fig. 2 and Fig. 3 the experimental results are presented which are conducted on the central weight $\omega_{(n+1)/2}$ respect to the different noise ratios ρ. The research is conducted on discrete set for the central weight, i.e. $\omega_{(n+1)/2} \in \{1,\ldots,n\}$, where in [1] it is shown that on this discrete set MAE, and MSE reaches its global optimum.

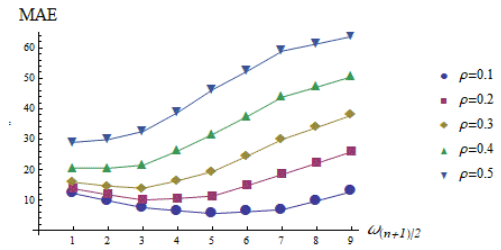


Fig. 2. MAE

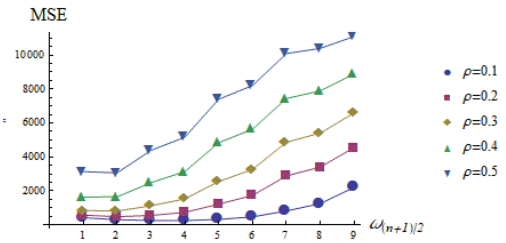
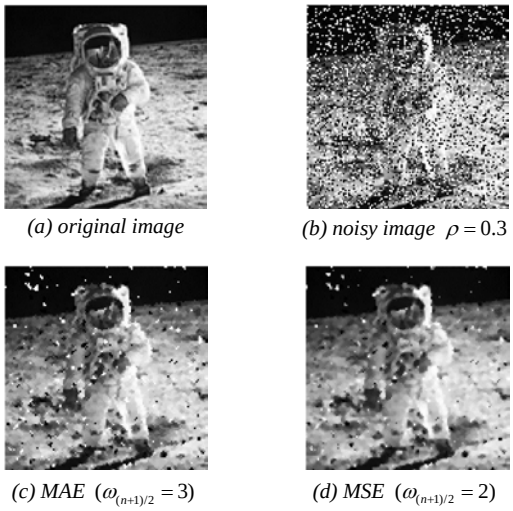


Fig. 3. MSE

In Fig. 4(a) experimental image is presented, while in Fig. 4(b) the noisy image with the presence of the "salt-and-pepper" noise with the noise ratio $\rho = 0.3$ is shown. In Fig. 4(c) and Fig. 4(d) results of filtering with the proposed method is presented, where optimal center weight is implemented. The results which are presented in Fig. 2, shows that for noise ratio $\rho = 0.3$ the optimal center weight, with the respect to MAE, is reached at $\omega_{(n+1)/2} = 3$, while the results which are presented in Fig 3. shows that the optimal center weight with the respect to MSE, is reached at $\omega_{(n+1)/2} = 2$.



(a) original image *(b) noisy image* $\rho = 0.3$

(c) MAE $(\omega_{(n+1)/2} = 3)$ *(d) MSE* $(\omega_{(n+1)/2} = 2)$

Fig. 4. Filtering results

5. CONCLUSION

In this research a reconstruction of a noisy image is conducted by the filter which is based on the weighted median. The problem is set as the optimization problem which considers MAE and MSE, in order to determined central weight of the weighted window.

6. ACKNOWLEDGEMENTS

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7. REFERENCES

[1] V. Novoselac, The Component Weighted Median Absolute Deviations Problem, European Journal of Pure and Applied Mathematics 4(2020), pp. 964-976

[2] V. Novoselac, B. Zovko-Cihlar, Image Noise Removal by Vector Median Filter, Proceedings ELMAR-2012, (M. Grgić), Croatian Society Electroncis in Marine-ELMAR, (2012), 57-62

[3] I. Pitas, Digital Image Processing Algorithms and Applications, Whiley and Sons, (2000)

[4] P. J. Rousseeuw, A. M. Leroy, Robust Regression and Outlier Detection, Whiley, New York, (2003)

Moss as a bioindicator of radioactive contamination in Croatian nature parks

B. Petrinec[a], M. Popijač[b], D. Rašeta[c], D. Babić[d], K. Marjanović[e], I. Puharić[f], T. Bogdanović[g], A. Vukoja[h]

[a] Institute for Medical Research and Occupational Health, Ksaverska cesta 2, HR-10001 Zagreb, Croatia, petrinec@imi.hr

[b] Javna ustanova "Park prirode Medvednica", Bliznec 70, HR-10000 Zagreb, Croatia, marina.popijac@pp-medvednica.hr

[c] Institute for Medical Research and Occupational Health, Ksaverska cesta 2, HR-10001 Zagreb, Croatia, draseta@imi.hr

[d] Institute for Medical Research and Occupational Health, Ksaverska cesta 2, HR-10001 Zagreb, Croatia, dbabic@imi.hr

[e] Josip Juraj Strossmayer University of Osijek, Department of Physics, Trg Svetog Trojstva 3, HR-31000 Osijek, Croatia, kmarjanovic@unios.hr

[f] Josip Juraj Strossmayer University of Osijek, Department of Physics, Trg Svetog Trojstva 3, HR-31000 Osijek, Croatia, ipuharic@unios.hr

[g] Javna ustanova "Park prirode Kopački rit", Mali Sakadaš 1, HR-31327 Kopačevo, Bilje, Croatia, tomobogdanov@gmail.hr

[h] Klinički bolnički centar "Osijek", Ul. Josipa Huttlera 4, HR-31000, Osijek, andrea.vukoja@kbco.hr

Abstract

Bioindicators are used for detection of heavy metal pollution since late 1960s on land and since 1970s in sea. Among different bioindicators, molluscs, especially mussels, are popular bioindicators of heavy metal pollution of waters. Mosses are among more often used bioindicators of heavy metal pollution of air and soil. Mosses are well suited to be used as indicators of radioactive contamination. They receive water and nutrients predominantly through atmospheric deposition. Mosses have been proven to accumulate radionuclides from fallouts after nuclear tests and after the Chernobyl accident. We sampled moss at 26 locations in and around Papuk Nature Park and at 40 locations in and around Kopački Rit Nature Park. Using gamma-ray spectrometry, we measured radionuclides. Of special concern were two radionuclides: ^{137}Cs, predominantly a result of the Chernobyl accident, and ^{210}Pb, ^{222}Rn progeny and the only radionuclide in uranium or thorium decay chains with half-life of more than days expected to be present in larger quantities in atmospheric deposition. The results show that the activity concentrations of ^{137}Cs measured in Papuk Nature Park and especially in Kopački Rit Nature Park are low compared to the activity concentrations of ^{137}Cs measured at other locations in Europe, including Plitvice Lakes National Park. As for ^{210}Pb, the measured activity concentrations are largely in line with other measurements in Europe. We can conclude that especially Kopački Rit Nature Park, and to a lesser extent also Papuk Nature Park, can be considered places with very low ^{137}Cs background, and as such a suitable detection site for atmospheric deposition of radionuclides even in cases of smaller of far-away accidents.

Keywords: bioindicators, radioactivity, .gamma-ray spectrometry, 137Cs, contamination

1. INTRODUCTION

Ecological concerns are nowadays among central topics related to the sustainable development of our civilisation. This especially holds true for densely populated areas, where even a modest pollution may pose a public health issue. The source of such a pollution does not have to be close to the polluted area, since many pollutants can travel long distances as part of air masses. In particular, this is not uncommon in case of a leakage of radioactive substances into the environment, as evident from the Chernobyl and Fukushima disasters in 1986 and 2011, respectively [1]. While accidents involving radioactive matter are relatively rare, less dramatic (but still alarming) leakages from nuclear facilities occur from time to time; they may even remain undeclared but sometimes cannot avoid detection due to a global network of monitoring stations [2]. To maintain and even expand this network is a future challenge, and the goal of this paper is to contribute to the related efforts by investigating two nature parks close to the most important agricultural areas in Croatia - Kopački Rit Nature Park (KRNP) and Papuk Nature Park (PNP).

Kopački Rit Nature Park (KRNP) is in the middle of Danube River basin (MDBR), a densely populated area that covers significant part of Middle Europe. We focus on a possibility of using the KRNP as a detection site for airborne radioactive pollutants in the MDBR, based on the fact that the KRNP is abundant in suitable bioindicator organisms and, as shown recently [3], radiologically unpolluted. These properties make the KRNP sensitive to the presence of anthropogenic radionuclides as well as to elevated concentrations of naturally occurring radionuclides, which may appear in consequence of human activities. As shown in Fig. 1, the KRNP is located on the Croatian side of the tripoint of Croatia, Hungary, and Serbia. It comprises 177 km^2 of mainly intact marshy lowland that contains abundant wildlife and is subject to flooding. It is close to an urban centre (Osijek, ~100,000 inhabitants), downstream from a nuclear power plant (Packs, Hungary), in the vicinity of regions of intense agriculture, and bordered by two large rivers (the Danube in the east and the Drava in the south). These are all potential sources of anthropogenic pollution at a local level. Moreover, since the KRNP is about 1200 km from the source of the Danube and 1400 km from the its mouth, i.e., virtually in the centre of the MDBR, airborne radionuclides that would appear over a larger area in the MDBR from a nonlocal source should also be clearly detectable in KRNP.

Papuk is the highest mountain of eastern Croatia. In 1999, an area of Papuk was designated a nature park. In the eastern part of the PNP, there is the Radlovac Quarry complex consisting of four quarries close together: Hercegovac, Oršulica, Brenzberg-Točak, and Žervanjska. Hercegovac and Oršulica are sources of dolomite (sediment rock), while Brenzberg-Točak and Žervanjska provide diabase (volcanic rock) (Fig. 1.). While the quarries are not attractive to PNP visitors, they are very close to Lake Orahovac, a very popular tourist destination on the edge of the PNP. In addition, popular hiking trails lead through the forest right up to and around the quarries. Papuk is interesting as one of few protected areas in the world with an active quarry, possible source of radioactivity.

For any detection of airborne radionuclides, the use of bioindicators is a reasonable choice. The bioindicators in our study were mosses, known for their ability to accumulate toxic or mutagenic substances without suffering substantial damage themselves [4], [5]. Mosses absorb matter by the entire surface of the body, through phyllodes, and not only via rhizoids that perform the function of roots, which makes them ideal for studies on airborne pollutants including radionuclides [6]. We collected samples of mosses in the KRNP and its vicinity in order to investigate their current radionuclide content, assess the related overall situation, identify possible hotspots and, if these being absent, prepare data for comparison in case of a future

radioactive contamination. Our analytical method was a high-resolution gamma-ray spectrometry, which allowed us to quantify activity concentrations (A) of the most significant gamma emitting radionuclides in the environment. Due to its simplicity, sensitivity, and accuracy, this method is the most widely used in studies on environmental radioactivity.

In the PNP, we collected moss around two of four quarry fields and the path between them, as well as around Lake Orahovac, a popular spot just putside of PNP.

Of anthropogenic radionuclides, we concentrated on ^{137}Cs (with a half-live $T_{1/2}$ = 30.1 years) - which was actually the only manmade gamma emitter that we could have detected - and the measured activity concentrations set the background values for the monitoring of airborne ^{137}Cs in the future. Human activities can result in numerous radionuclides, some of which are gamma emitters and some are not, but radiocaesium is very frequently in the focus of ecological concerns. ^{137}Cs is a strong gamma emitter - therefore easily detectable - that can become airborne if being released into the atmosphere by a nuclear explosion or an accident in a nuclear power plant. Another widely studied isotope of caesium is ^{134}Cs ($T_{1/2}$ = 2.06 years), which was not detected in our study. It is also a strong gamma emitter but can appear in the environment only by a leakage from a nuclear reactor and not due to a nuclear explosion. Elaborated studies of causes and consequences of an anthropogenic radioactive pollution requires detailed analyses of other radionuclides as well, but ^{137}Cs and ^{134}Cs provide a bulk of relevant information if the fission of uranium is behind a radionuclide release. The abundance of nuclear facilities in Europe clearly calls for a constant awareness based on continual measurements in selected areas, and the research presented in this paper identifies the KRNP as a suitable one for this purpose.

Not every radioecological threat is related to a nuclear facility; some are caused by industrial process which enhance environmental concentrations of naturally occurring radionuclides. In our assessment of this aspect of radioactive pollution, we focused on ^{210}Pb ($T_{1/2}$ = 22.4 years), since it is a product of the decay of airborne ^{222}Rn and is therefore abundant in the air. The obtained reference values are also of importance, but in this case more locally. ^{210}Pb is deposited onto the surface of plants due to the deposition of airborne progenies of gaseous ^{222}Rn [7], which makes its concentration in mosses high enough to be measured. Elevated concentrations of ^{210}Pb in the air may be related to different human activities, such as the use of soil amendments rich in ^{226}Ra (the mother nucleus of ^{222}Rn) [8], burning of coal in power plants and other uses of fossil fuels [9], etc. Hence, the A of ^{210}Pb in mosses is also a valuable indicator of human impact on the environment.

2. METHODS AND MATERIALS USED FOR RESEARCH

In and around the KRNP, altogether 40 samples of mosses were collected at the locations that are in Fig. 1. shown by encircled numbers. In order to obtain more complete information, mosses were sampled inside the KRNP (henceforth, denoted as I; shaded, L = 1-21), in the vicinity but outside the KRNP (II; L = 22-26), along the Danube (III; L = 27-34) and the Drava (IV; L = 35-40). In order to cover the diversity of the KRNP, sampling locations therein were selected by considering different parameters like types of microhabitats and substrates (stone, earth, wood) and the level of anthropogenic influence.

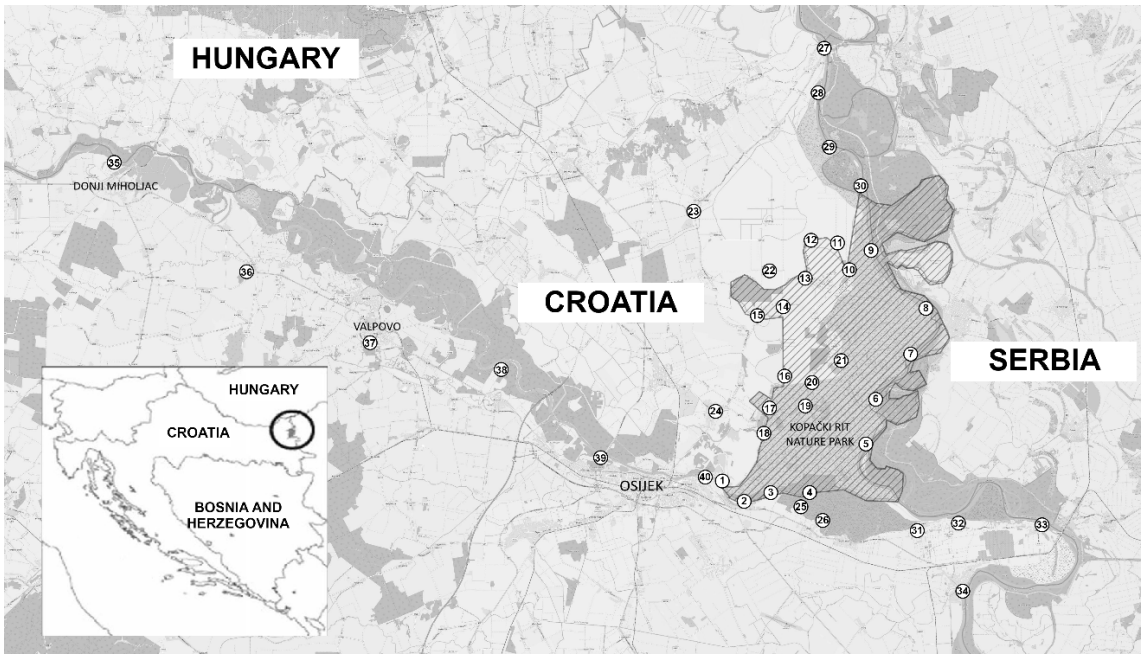

Fig. 1. Sampling locations L = 1-40 (encircled numbers) and the position of the studied area on the map (inset). Sampling was carried out inside the KRNP (shaded, L = 1-21), in the vicinity but outside the KRNP (L = 22-26), along the Danube (L = 27-34) and the Drava (IV, L = 35-40).

Fig. 2. Locations of measurements near Žervanjska quarry (1, 2, 9), near Brenzberg-Točak quarry (7, 8, 19-22, 25-26), near the road between those quarries (3-6, 10-18) and near Lake Orahovac (23-24); the picture was taken from Google Maps (https://www.google.com/maps)

In and around the PNP, 24 locations were selected along the Brenzberg-Točak (c; 7, 8, 19-22, 25-26) and Žervanjska (a; 1, 2, 9) quarries and the road between them (b; 3-6, 10-18), and two additional locations (d; 23, 24) by Lake Orahovac, a couple of kilometres away (Fig. 2.). The locations were selected based on the availability of moss. All the locations except the two by Lake Orahovac were on forest trails.

The sampling was carried out on several occasions from April through May 2018 in the PNP and from May through August 2018 in KRNP. Samples were thoroughly cleaned, dried to constant mass, tightly sealed into Marinelli beakers (volume 1 litre), and left to rest for about 30 days in order to ensure the establishment of secular equilibria within the ^{232}Th and ^{238}U decay chains. Therefore, our results for A refer to dry mass.

A was determined by means of high-resolution γ-ray spectrometry, using a high-purity Ge coaxial detector (Ortec GMX; relative efficiency of 74.3% and energy resolution of 2.23 keV, all at ^{60}Co 1.33 MeV). The measurement time was about 80,000 s. The energy and efficiency calibration of the system (40-2000 keV) was carried out using a certified calibration source obtained from the Czech Metrology

Institute. All quality assurance procedures in γ-ray spectrometry [10] were applied, and the method has been accredited according to the ISO 17025 standard. Our focus was, as outlined above, on ^{137}Cs and ^{210}Pb, and their activities were quantified from the peaks at 661.7 keV and 46.5 keV, respectively. For completeness, we also addressed other representative naturally occurring radionuclides, that is, ^{40}K (peak at 1460.8 keV), ^{238}U (in equilibrium with ^{234}Th, peak at 63.3 keV and doublet at 92.4-92.8 keV), ^{226}Ra (in equilibrium with ^{214}Pb, peaks at 295.2 keV and 351.9 keV), and ^{232}Th (in equilibrium with ^{228}Ac, peaks at 338.3 keV and 911.2 keV), and ^{7}Be (peak at 477.6 keV). Since a measurement would be carried out within a month after the corresponding sampling, time correction for radioactive decay was calculated only for ^{7}Be (T1/2 = 53.4 days), as it was negligible for other studied radionuclides due to their long $T_{1/2}$.

3. RESULTS AND DISCUSSION

Our analysis of the recorded gamma-ray spectra revealed which gamma emitters were present in the samples. We detected ^{40}K, ^{7}Be, radionuclides from the ^{232}Th and ^{238}U decay chains, and ^{137}Cs as the only anthropogenic radionuclide. Regarding ^{40}K, this primordial radionuclide - found in all living organism due to the biogenic nature of potassium - in our samples from KRNP had A between 170 and 450 Bq kg^{-1}, the average being 290 Bq kg^{-1}, and in our samples from PNP had A between 150 and 440 Bq kg^{-1}, the average being 240 Bq kg^{-1}. The A of cosmogenic ^{7}Be ($T_{1/2}$ = 50.4 days) was, at the time of the sampling, in the range 80 – 1050 Bq kg^{-1}, averaging at 480 Bq kg^{-1}, in KRNP samples, and in the range 60 – 630 Bq kg^{-1}, averaging at 290 Bq kg^{-1}, in PNP samples. Since ^{7}Be descends towards Earth from the upper atmosphere, its concentration in mosses depends on atmospheric conditions significantly. ^{232}Th, ^{238}U, and ^{226}Ra, as significant representatives of the decay chains before the appearance of radon, were detected in some of our samples but not in all of them, and their maximum values of A were 31, 44, and 28 Bq kg^{-1}, respectively, in KRNP, and 29, 39, and 37 Bq kg^{-1}, respectively, in PNP. The absence of these radionuclides in some samples and their comparatively low activity concentrations in the mosses were related primarily to the fact that their concentrations in the air are generally low.

3.1. ^{137}Cs and ^{210}Pb in KRNP

Table 1. Activity concentrations of ^{137}Cs in mosses sampled at locations L = 1-40 that are shown in Fig. 1. Results are presented in Bq per kg of dry mass, with uncertainties expressed using the coverage factor two. Ranges of measured values, AM, and SD are listed for sampling areas I-IV. If all samples are treated as a single dataset, the range of values is 0.7 – 13.1 Bq kg^{-1}, whereas AM = 5.3 Bq kg^{-1} and SD = 3.7 Bq kg^{-1}.

L	A (Bq kg^{-1})	L	A (Bq kg^{-1})
I. Range 1.3 – 12.4; AM = 5.4; SD = 3.4 (Bq kg^{-1})			
1	2.6 ± 0.2	2	3.6 ± 0.2
3	11.0 ± 0.3	4	12.4 ± 0.3
5	9.6 ± 0.3	6	9.4 ± 0.4
7	4.1 ± 0.3	8	6.5 ± 0.3
9	3.6 ± 0.2	10	7.1 ± 0.2
11	1.3 ± 0.2	12	1.8 ± 0.2
13	6.1 ± 0.3	14	3.3 ± 0.2
15	2.9 ± 0.3	16	2.6 ± 0.3
17	2.3 ± 0.2	18	10.1 ± 0.3
19	7.3 ± 0.3	20	2.5 ± 0.2
21	3.3 ± 0.3		
II. Range 0.7 – 10.0 ; AM = 4.4; SD = 3.8 (Bq kg^{-1})			
22	3.8 ± 0.2	23	0.7 ± 0.1
24	10.0 ± 0.3	25	6.2 ± 0.2
26	1.3 ± 0.1		
III. Range 0.9 – 13.1; AM = 7.8; SD = 4.5 (Bq kg^{-1})			
27	13.1 ± 0.5	28	6.7 ± 0.3
29	11.7 ± 0.3	30	12.7 ± 0.3
31	4.3 ± 0.3	32	0.9 ± 0.1
33	8.3 ± 0.4	34	4.5 ± 0.2
IV. Range 1.0 – 3.9; AM = 2.5; SD = 1.1 (Bq kg^{-1})			
35	1.0 ± 0.1	36	1.9 ± 0.2
37	2.0 ± 0.2	38	3.3 ± 0.2
39	3.1 ± 0.2	40	3.9 ± 0.2

Table 2. Activity concentrations of ^{210}Pb in mosses sampled at locations L = 1-40 that are shown in Fig. 1. Results are presented in Bq per kg of dry mass, with uncertainties expressed using the coverage factor two. Ranges of measured values, AM, and SD are listed for sampling areas I-IV. If all samples are treated as a single dataset, the range of values is 183 - 690 Bq kg^{-1}, whereas AM = 360 Bq kg^{-1} and SD = 125 Bq kg^{-1}.

L	A (Bq kg^{-1})	L	A (Bq kg^{-1})
I. Range 220 - 600; AM = 370; SD = 110 (Bq kg^{-1})			
1	520 ± 10	2	330 ± 10
3	310 ± 10	4	335 ± 9
5	220 ± 10	6	260 ± 10
7	330 ± 10	8	320 ± 10
9	430 ± 10	10	390 ± 10
11	600 ± 10	12	520 ± 10
13	400 ± 10	14	440 ± 10
15	440 ± 10	16	220 ± 10
17	520 ± 10	18	220 ± 10
19	380 ± 10	20	350 ± 10
21	220 ± 10		
II. Range 183 - 390; AM = 280; SD = 80 (Bq kg^{-1})			
22	390 ± 10	23	183 ± 8
24	332 ± 9	25	271 ± 8
26	229 ± 7		
III. Range 220 - 690; AM = 390; SD = 160 (Bq kg^{-1})			
27	220 ± 10	28	300 ± 10
29	310 ± 10	30	370 ± 10
31	270 ± 10	32	690 ± 10
33	550 ± 20	34	380 ± 10
IV. Range 234 - 660; AM = 380; SD = 160 (Bq kg^{-1})			
35	234 ± 9	36	300 ± 10
37	660 ± 10	38	318 ± 9
39	460 ± 10	40	305 ± 8

Activity concentrations of the two radionuclides that are in the focus of this paper, namely ^{137}Cs and ^{210}Pb, are shown in Tables 1 and 2, respectively, together with the ranges of measured values, arithmetic means (AM), and standard deviations (SD) for sampling areas I-IV. These radionuclides were detected in all of the samples, which was not surprising because of their abundance in the air. Overall, for all samples, the A of ^{137}Cs was between 0.7 and 13.1 Bq kg^{-1}, with AM = 5.3 Bq kg^{-1} and SD = 3.7 Bq kg^{-1}. The A of ^{210}Pb was much higher, in the range 183 – 690 Bq kg^{-1}, with AM = 360 Bq kg^{-1} and SD = 125 Bq kg^{-1}. This difference is not surprising, since ^{210}Pb is a progeny of gaseous ^{222}Rn that constantly emanates into the air due to the decay of naturally occurring ^{226}Ra.

3.2. ^{137}Cs and ^{210}Pb in PNP

Table 3. Activity concentrations of ^{137}Cs in mosses sampled at locations L = 1-26 that are shown in Fig. 2. Results are presented in Bq per kg of dry mass, with uncertainties expressed using the coverage factor two. Ranges of measured values, AM, and SD are listed for sampling areas a-d. If all samples are treated as a single dataset, the range of values is 0.5 – 35 Bq kg^{-1}, whereas AM = 16.2 Bq kg^{-1} and SD = 9.9 Bq kg^{-1}.

L	A (Bq kg^{-1})	L	A (Bq kg^{-1})
a. Range 2.5 – 25; AM = 13.2; SD = 9.2 (Bq kg^{-1})			
1	2.5 ± 1.5	2	12.1 ± 0.9
9	25 ± 2		
b. Range 2.5 – 35 ; AM = 17.3; SD = 9.0 (Bq kg^{-1})			
3	35 ± 2	4	2.5 ± 0.7
5	26 ± 1	6	8 ± 1
10	12 ± 1	11	7 ± 1
12	11 ± 1	13	21 ± 2
14	22 ± 2	15	14 ± 1
16	16 ± 2	17	25 ± 2
18	26 ± 2		
c. Range 0.5 – 25; AM = 11.9; SD = 8.5 (Bq kg^{-1})			
7	24 ± 1	8	5.6 ± 0.6
19	25 ± 2	20	13 ± 1
21	15 ± 1	22	8 ± 1
25	4 ± 1	26	0.5 ± 0.5
d. Range 26 – 35; AM = 30.5; SD = 4.5 (Bq kg^{-1})			
23	26 ± 2	24	35 ± 2

Table 4. Activity concentrations of ^{210}Pb in mosses sampled at locations L = 1-26 that are shown in Fig. 2. Results are presented in Bq per kg of dry mass, with uncertainties expressed using the coverage factor two. Ranges of measured values, AM, and SD are listed for sampling areas a-d. If all samples are treated as a single dataset, the range of values is 230 - 1000 Bq kg^{-1}, whereas AM = 570 Bq kg^{-1} and SD = 220 Bq kg^{-1}.

L	A (Bq kg^{-1})	L	A (Bq kg^{-1})
a. Range 240 – 900; AM = 480; SD = 300 (Bq kg^{-1})			
1	240±35	2	300±20
9	900±60		
b. Range 230 – 1000; AM = 610; SD = 230 (Bq kg^{-1})			
3	610±50	4	230±30
5	780±40	6	360±30
10	1000±80	11	800±30
12	900±40	13	290±45
14	600±70	15	780±70
16	500±50	17	410±60
18	620±40		
c. Range 310 – 750; AM = 565; SD = 130 (Bq kg^{-1})			
7	650±30	8	670±30
19	620±60	20	750±40
21	560±40	22	420±60
25	540±70	26	310±30
d. Range 300 – 570; AM = 435; SD = 135 (Bq kg^{-1})			

23	300±50	24	570±50

Activity concentrations of the two radionuclides that are in the focus of this paper, namely ^{137}Cs and ^{210}Pb, are shown in Tables 1 and 2, respectively, together with the ranges of measured values, arithmetic means (AM), and standard deviations (SD) for sampling areas a-d. These radionuclides were detected in all of the samples, which was not surprising because of their abundance in the air. Overall, for all samples, the A of ^{137}Cs was between 0.5 and 35 Bq kg^{-1}, with AM = 16.2 Bq kg^{-1} and SD = 9.9 Bq kg^{-1}. The A of ^{210}Pb was much higher, in the range 230 – 1000 Bq kg^{-1}, with AM = 570 Bq kg^{-1} and SD = 220 Bq kg^{-1}. This difference is not surprising, since ^{210}Pb is a progeny of gaseous ^{222}Rn that constantly emanates into the air due to the decay of naturally occurring ^{226}Ra.

3.3. Discussion

The suitability of mosses as biomonitors can be related to their relatively primitive structure in comparison to vascular plants, which leads to a slower exchange of matter in their tissues and enhances the accumulation of different elements. Most mosses absorb water, inorganic substances, and minerals mainly through phyllodes - directly from the air, precipitation, soil moisture, surface reservoirs, and floodwater - whereas the absorption from the substrate via rhizoids is less important [11], [12]. Due to their strong absorption and retention of airborne substances [13], [14], [15], and in spite of additional pathways of the absorption of matter, mosses have been recognised as reliable biomonitors for atmospheric pollution. This has been used worldwide to monitor environmental stress caused by numerous non-radioactive [16], [17], [18], [19], [20] and radioactive [9], [16], [21], [22], [20], [23], [24], [25], [26], [27] elements. Since mosses appear in different habitats, they have been for a long time used to record the dynamics of pollution within small areas such as industrial zones [28], [29], [30], cities [12], [31] or motorways [32], [33].

Radioecological concerns are usually focused on anthropogenic radionuclides and excessive amounts of naturally occurring radionuclides due to human activities. Of gamma emitting anthropogenic radionuclides, we detected only ^{137}Cs in very small concentrations in KRNP, and slightly larger concentrations in PNP – as can be seen in Table 1 and Table 3. The contemporary appearance of ^{137}Cs in nature is primarily a consequence of three contributions: global radioactive fallout originating from nuclear weapons tests, the Chernobyl accident, and the Fukushima accident. The contribution of the Chernobyl accident to the total budget of ^{137}Cs in KRNP was, at the time shortly after the release, at the level of the background set by the global fallout, i.e., considerably lower than in other areas at the same distance from Chernobyl [34], [35]. This was a consequence of atmospheric factors that are outside the scope of this paper. Although an influx of fission products (^{137}Cs, ^{134}Cs, and ^{131}I) from the Fukushima accident was observed in Croatia [21], [36], its magnitude was comparatively low [37], and this did not increase the concentration of ^{137}Cs in the studied area significantly. Moreover, a recent comprehensive study on the radioactivity of soil in Croatia revealed that the KRNP was situated within a part of the country where the concentrations of ^{137}Cs in soil were the lowest, below 5 Bq kg^{-1} [38].

In PNP, on the other hand, the contribution of the Chernobyl accident to the total budget of ^{137}Cs was larger, because of mountainous terrain. This is reflected both in higher concentrations of ^{137}Cs in soil [38], and higher concentrations of ^{137}Cs in mosses in this study.

The A of ^{137}Cs in the mosses from KRNP studied here was particularly low, which becomes evident when we compare our results with some other published data on ^{137}Cs in mosses from regions that are at similar distances from Chernobyl as the KRNP. In the below listing, the data refer to the situation extrapolated to 2018, calculated by taking into account the radioactive decay, original values, and the elapsed time. The A of ^{137}Cs in mosses from the Plitvice Lakes National Park in Croatia was in the range 25-1460 Bq kg^{-1} (sampled in 2011-2012) [21], in Armenia 3-300 Bq kg^{-1} (2018-2020) [27], in Austria 870-10680 Bq kg^{-1} (2006) [25], in

Greece 0-400 Bq kg^{-1} (2016) [16], in Turkey 30-360 Bq kg^{-1} (2007) [23], and in Serbia 6-65 Bq kg^{-1} (2008) [26]. The A of ^{137}Cs in the mosses from PNP studied here was higher than the A of ^{137}Cs in the mosses from KRNP, but still lower than the A in other studies above.

A number of combined factors have resulted in comparatively low concentrations of ^{137}Cs in mosses from the KRNP. Our main conclusion is that the KRNP, with its mosses and geographical location, is well suited for a sensitive detection of the appearance of new ^{137}Cs in the wider region. This may as well have implications for other radioactive matter that is not naturally occurring. In particular, since no ^{134}Cs was detected in our study, the background for its detection is very low (the detection limit being below 0.5 Bq kg^{-1}), which implies a high sensitivity to its appearance as a warning to a problem in a facility where the fission of uranium is taking place.

While PNP is slightly less suited than PNP, it is also well suited for a sensitive detection of the appearance of new ^{137}Cs in the wider region. Moreover, this study has shown that there is no discernible effect of a quarry on ^{137}Cs concentrations in moss.

Regarding naturally occurring radionuclides, mosses have been used mostly in studies on ^{7}Be [16], [26] and ^{210}Pb [9], [16], [20], [21], [26] due to their abundance in the air. From the radioecological point of view, however, ^{7}Be is of no particular interest, because it is just one of cosmogenic radionuclides - the production of which depends solely on the influx of cosmic rays on Earth [39] and not on any human activity. On the other hand, the impact of ^{210}Pb is important in radioecology. Having the longest $T_{1/2}$ of the progenies of gaseous ^{222}Rn, this radionuclide accumulates on surfaces exposed to the air and remains there for a long time [7]. Excessive amounts of ^{210}Pb in components of the environment that are exposed to the air may signal an abundance of airborne ^{222}Rn and consequent adverse effects for the health of the exposed population. This could be linked to human activities such as the use of materials rich in ^{226}Ra, e.g., some soil amendments used in the contemporary agricultural production. Other sources of excess ^{210}Pb in air are industrial processes involving ores that contain significant amounts of ^{238}U, and the burning of fossil fuels [9]. Measurements of the A of ^{210}Pb may serve as a warning system for undesirable effects of these activities on the environment.

That the predominant origin of ^{210}Pb in our samples was deposition from the air, and not other mechanisms, can be inferred by comparing results for the A of ^{226}Ra and of ^{210}Pb. The A of ^{226}Ra was, first of all, in some samples below detection limit (typically, 1 Bq kg^{-1}), and its maximum value was 37 Bq kg^{-1}. If the origin of ^{210}Pb in the samples had been the decay of ^{226}Ra taken up by mosses via other pathways, the activities of the two radionuclides would have been similar. However, the measured A of ^{210}Pb was much higher, implying that the deposition of ^{222}Rn and its progenies from the air was the main source of ^{210}Pb in our mosses. This leads to a conclusion that mosses in the KRNP can be used as indicators of atmospheric pollution due to the use of materials that contain naturally occurring radioactive matter.

The range of the A of ^{210}Pb in our samples from KRNP (183 – 690 Bq kg^{-1}) was similar to that for mosses from the Plitvice Lakes National Park in Croatia, where it was 68-639 Bq kg^{-1} [21]. This suggests that it was likely that the origin of ^{210}Pb in both areas was the emanation of ^{222}Rn from uncultivated soil rather than any human activity. Hence, any significant increase in the A of ^{210}Pb in mosses from either of the areas would arise suspicion of an anthropogenic pollution. This is especially important for the KRNP, which is surrounded by several potential sources of such a pollution. Ranges of A that are not drastically different from the ones for our samples have been found elsewhere too. For instance, 212-532 Bq kg^{-1} in Germany [20], 147-1920 Bq kg^{-1} in Greece [16], 526-881 Bq kg^{-1} in Serbia [26], 199-660 Bq kg^{-1} in Thailand [26], 220-720 Bq kg^{-1} in Turkey [9], etc.

The range of the A of ^{210}Pb in our samples from PNP (230 – 1000 Bq kg^{-1}) was higher than from KRNP and from Plitvice Lakes National

Park in Croatia, cited above. Compared to other above-cited studies, it is similar, but leaning towards the high end. PNP is forested area, which can result in higher ^{210}Pb concentration in soil [40]. Also, digging stone in quarry can increase the release of ^{222}Rn from the soil into the air, increasing the concentration of ^{210}Pb.

4. CONCLUSIONS

We studied radionuclide activity concentrations in mosses from the Kopački Rit Nature Park in northeastern Croatia, close to the tripoint of Croatia, Hungary, and Serbia, and from the Papuk Nature Park, close to the centre of the continental part of Croatia. Comprising mainly intact nature and being situated virtually in the centre of the middle Danube River basin, Kopački Rit Nature Park is promising for detecting a potential pollution that might originate from a number of sources and affect the entire basin. Mosses, chosen for this study because of their ability to take up airborne radionuclides, were sampled in 2018 and measured for radionuclide content by means of high-resolution gamma-ray spectrometry. We detected radionuclides from the ^{232}Th and ^{238}U decay chains, ^{40}K, ^{7}Be, and ^{137}Cs. From the point of view of radioecology, the most interesting were ^{210}Pb and ^{137}Cs, as their concentrations in the air are sensitive to human activities. The activity concentrations of ^{137}Cs were particularly low in Kopački Rit Nature Park, ranging from 0.7 to 13.1 Bq kg^{-1}, and only somewhat higher in Papuk Nature Park, ranging from 0.5 to 35 Bq kg^{-1}. Thus low values imply a considerable sensitivity to any extra amount of ^{137}Cs that might arise from facilities and events that involve nuclear matter. While an appearance of extra ^{137}Cs could originate from a faraway location, extra ^{210}Pb would more likely signify a local source of pollution. Such a source might be, e.g., a material rich in ^{226}Ra and emanating ^{222}Rn, industrial processing of ores rich in ^{238}U or the burning of coal or other fossil fuels. In our mosses, the activity concentrations of ^{210}Pb in Kopački Rit Nature Park were 183 – 690 Bq kg^{-1}. As in the case of ^{137}Cs, a future measurement of the activity concentration of ^{210}Pb above the mentioned values could signify a possibility of an ecologically undesirable human activity. In Papuk Nature Park, the activity concentrations of ^{210}Pb in our mosses were 230 – 1000 Bq kg^{-1}, indicating that the active quarry may have an influence on ^{222}Rn emanation.

5. REFERENCES

[1] G. Steinhauser; A. Brand; T. E. Johnson, Comparison of the Chernobyl and Fukushima nuclear accidents: a review of the environmental impacts. Science of the Total Environment 470-471 (2014), pp.800–817

[2] O. Masson et al, Airborne concentrations and chemical considerations of radioactive ruthenium from an undeclared major nuclear release in 2017. Proceedings of the National Academy of Sciences of the United States of America 116 (2018), pp.16750-16759.

[3] B. Petrinec et al, Assessing the radiological load on the environment in the middle Danube river basin on the basis of a study of the Kopački Rit Nature Park, Croatia. Radiation and Environmental Biophysics 57 (2018) , pp.285-292

[4] F. Charlot et al, RAD51B plays an essential role during somatic and meiotic recombination in Physcomitrella. Nucleic Acids Research. 42 (2014), pp.11965–11978

[5] C. J. Harrison; A. H. K. Roeder; E. M. Meyerowitz; J. A. Langdale, Local cues and asymmetric cell divisions underpin body plan transitions in the moss Physcomitrella patens. Current Biology. 19 (2009), pp.461–471

[6] D. Cove; M. Bezanilla; P. Harries; R. Quatrano, Mosses as model systems for the study of metabolism and development. Annual Review of Plant Biology 57 (2006), pp.497-520

[7] Ž. Zgorelec et al, Effects of fertilisation on radionuclide uptake by maize from an acidic

soil in northwestern Croatia. Soil and Tillage Research 212 (2021), 105030.

[8] P. M. Rutherford; M. J. Dudas; J. M. Arocena, Radioactivity and elemental composition of phosphogypsum produced from three phosphate rock sources. Waste Management, Research 13 (1995), pp.407-423

[9] M. Belivermiş; Ö. Kılıç; A. Çayır; Ma. Coşkun; Mü. Coşkun, Assessment of 210Po and 210Pb in lichen, moss and soil around Çan coal-fired power plant, Turkey. Journal of Radioanalytical and Nuclear Chemistry 307 (2016), pp.523-531

[10] B. Petrinec; Z. Franić; T. Bituh; D. Babić, Quality assurance in gamma-ray spectrometry of seabed sediments. Arhiv za higijenu rada i toksikologiju 62 (2011), pp.17-23

[11] Y. M. Bahuguna; S. Gairola; D. P. Semwal; P. L. Uniyal;; A. B. Bhatt Bryophytes and ecosystem in Diversity of lower plants (ed. R.K. Gupta; M. Kumar). I.K. International Publishing House Pvt. Ltd. (2013), pp.279-296

[12] Y. Jiang; M. Fan; R. Hu; J. Zhao; Y. Wu, Mosses Are Better than Leaves of Vascular Plants in Monitoring Atmospheric Heavy Metal Pollution in Urban Areas. International Journal of Environmental Research and Public Health 15 (6) (2018), 1105

[13] T. Berg; O. Røyset; E. Steinnes, Moss (Hylocomium splendens) used as biomonitor of atmospheric trace element deposition: Estimation of uptake efficiencies. Atmospheric Environment 29 (1995), pp.353-360

[14] H. Harry, Review of the European moss survey (1990 – 2005): deliverables and use of data. Centre for Ecology and Hydrology, Bangor (2009)

[15] Y. Jiang; M. Fan; R. Hu; J. Zhao; Y. Wu, Mosses are better than leaves of vascular plants in monitoring atmospheric heavy metal pollution in urban areas. International Journal of Environmental Research and Public Health 15 (6) (2018), 1105.

[16] Ch. Betsou et al, Heavy metals and radioactive nuclide concentrations in mosses in Greece. Radiation Effects and Defects in Solids 9-10 (2018), pp.851-856

[17] L. Galsomiés; M. A. Letrouit; C. Deschamps; D. Savanne; M. Avnaim, Atmospheric metal deposition in France: initial results on moss calibration from the 1996 biomonitoring. Science of The Total Environment 232 (1999), pp.39-47

[18] A. C. Mazzoni; R. Lanzer; J. Bordin; A. Schäfer; R. Wasum, Mosses as indicators of atmospheric metal deposition in an industrial area of southern Brazil. Acta Botanica Brasilica 26 (2011), pp.553-558

[19] R. Pesch; W. Schroeder, Mosses as bioindicators for metal accumulation: Statistical aggregation of measurement data to exposure indices. Ecological Indicators 6 (2006), pp.137-152

[20] W. Shotyk; H. Kempter; M. Krachler; C. Zaccone, Stable (^{206}Pb, ^{207}Pb, ^{208}Pb) and radioactive (^{210}Pb) lead isotopes in 1 year of growth of Sphagnum moss from four ombrotrophic bogs in southern Germany: Geochemical significance and environmental implications. Geochimica et Cosmochimica Acta 163 (2015), pp.101-125

[21] D. Babić et al, Baseline radioecological data for the soil and selected bioindicator organisms in the temperate forest of Plitvice Lakes National Park, Croatia. Environmental Science and Pollution Research 27 (2020), pp.21040-21056

[22] A. Boryło; G. Romańczyk; B. Skwarzec, Lichens and mosses as polonium and uranium biomonitors on Sobieszewo Island. Journal of Radioanalytical and Nuclear Chemistry 311 (2017), pp.859–869

[23] U. Cevik; N. Celik, Ecological half-life of ^{137}Cs in mosses and lichens in the Ordu province, Turkey by Cevik and Celik. Journal of Environmental Radioactivity 100 (2009), pp.23-28

[24] S. Grdović et al, Natural and anthropogenic radioactivity of feedstuffs, mosses and soil in the Belgrade environment, Serbia. Archives of Biological Sciences 62 (2010), pp.301-307

[25] A. R. Iurian; W. Hofmann; H. Lettner; R. Türk; C. Cosma, Long term study of Cs-137 concentrations in lichens and mosses. Romanian Journal of Physics 56 (2011), pp.983–992

[26] M. Krmar et al, Airborne radionuclides in mosses collected at different latitudes. Journal of Environmental Radioactivity 117 (2013), pp.45-48

[27] N. Movsisyan; G. Demirtchyan; K. Pyuskyulyan; O. Belyaeva, Identification of radionuclides' altitudinal distribution in soil and mosses in highlands of Armenia. Journal of Environmental Radioactivity 231 (2021), 106550

[28] G. Ellison; J. Newham; M. J. Pinchin; I. Thompson, Heavy metal content of moss in the region of Consett (North East England). Environmental Pollution 11 (1976), pp.167-174

[29] M. Makomaska, Heavy metal contamination of pinewoods in the Niepolomice forest (southern Poland). Bulletin of the Polish Academy of Sciences II 26 (1978), pp.679-685

[30] T. J. Sumerling, The use of mosses as indicators of airborne radionuclides near a major nuclear installation. Science of The Total Environment 35 (1984), pp.251-265

[31] W. Loetscert; R. Wandtner; H. Hiller, Schwermetallanreicherung bei Bodenmoosen in Immission Gebieten. Berichte der Deutschen Botanischen Gesellschaft 88 (1975), pp.419-431

[32] A. Rühling; G. Tyler, An ecological approach to the lead problems. Botaniska Notiser 121 (1968), pp.321-342

[33] M. Y. Hanfi; M. Y. A. Mostafa; M. V. Zhukovsky, Heavy metal contamination in urban surface sediments: sources, distribution, contamination control, and remediation. Environmental Monitoring and Assessment 192 (2019), 32

[34] M. De Cort et al, Atlas of Caesium 137 deposition on Europe after the Chernobyl accident. EUR 1673 EN/RU Eureopean Comission REPORT EUR Luxemburg (1998).

[35] M. De Cort, et. al, Atlas of caesium deposition after the Chernobyl accident. European Commission, Directorate-General for Research and Innovation, Publications Office (2009).

[36] D. Babić; J. Senčar; B. Petrinec; G. Marović; B. Skoko, Fine structure of the absorbed rate monitored in Zagreb, Croatia, in the period 1985-2011. Journal of Environmental Radioactivity 118 (2013), pp.75-79

[37] A. Stohl et. al, Xenon-133 and caesium-137 releases into the atmosphere from the Fukushima Dai-ichi nuclear power plant: determination of the source term, atmospheric dispersion, and deposition. Atmospheric Chemistry and Physics 12 (2012), pp.2313–2343

[38] M. Šoštarić et al, Radioactivity of soil in Croatia II: ^{137}Cs, ^{1}K, and absorbed dose rate. Arhiv za higijenu rada i toksikologiju 72 (2021), pp.15-22

[39] D. Babić; J. Senčar, Periodic behaviour in ground-level environmental radioactivity: fingerprints of solar activity? Proceedings of the Royal Society A 474 (2018), 20180109

[40] M. Šoštarić et al, Radioactivity of soil in Croatia I: naturally occurring decay chains. Arhiv za higijenu rada i toksikologiju 72 (2021), pp.6-14

New ideals of the education in the second half of the 20th century

Luka Pongračić[a], Ana Maria Marinac[b]

[a] *University of Slavonski Brod, Department of Social Sciences and Humanities, Ivana Gundulića 20, 35000 Slavonski Brod, Croatia, lpongracic@unisb.hr*

[b] *University of Slavonski Brod, Department of Social Sciences and Humanities, Ivana Gundulića 20, 35000 Slavonski Brod, Croatia, marinac.anamaria98@gmail.com*

Abstract

In the middle of the 20th century, the awareness of the shortcomings in the society and education of that time began to develop rapidly. Critical pedagogues and creators of alternative pedagogical ideas are appearing, mostly in the USA and Europe. With the development of child psychology, carried by new insights that bring great changes like Melanie Klein, Peter Blos, Jane Kroger and many others. In the second half of the 20th century, the number of alternative schools modeled on Summerhill has been growing since 1973. These schools, ie pedagogical ideas, appear as a countermeasure to traditional pedagogical and didactic standards. New ideals are becoming emancipation, democracy and self-control. By 1990, an average of 0.88 such schools were opened per year, while at the beginning of the 21st century that number rose to an average of 4.56 schools per year, with the interesting fact that more than half of these schools are modeled on Freinet. The aim of this paper is to present a historical overview of the development of critical pedagogy and their importance for the modern education system. By observing the historical development of education and pedagogical ideas in general, we give room for future progress and understanding that many things we consider modern are not so new and that there is room for improvement, it is important to notice and use it.

Keywords: *Alternative schools; Child psychology; Critical pedagogy; Democracy; Summerhill.*

1. INTRODUCTION

In the second half of the 20th century, since 1973, the number of alternative schools based on the example of Summerhill has been increasing. These schools, or pedagogical ideas, appear as a countermeasure to traditional pedagogical and didactic standards. The biggest reasons for this emergence are dissatisfaction with the society and the school system at that time, and the new ideals become emancipation, democracy and self-control. Until 1990, an average of 0.88 such schools were opened per year, while at the beginning of the 21st century, that number rose to an average of 4.56 schools per year, with the interesting fact that more than half of these schools were opened according to the model of Freinet [1]. Ivan Illich is one of the biggest proponents of a freer approach and understanding of school. In the second half of the 20th century, it created a much-needed counterbalance to educational radicals. He is celebrated for his first book, Deschooling Society, published in 1971, in which he presents criticisms of educational policies in America. This is just one of the triggers for thinking about the shortcomings in the education system, and it stands out in particular because this movement of critics is gaining much more momentum in the USA than in Europe. Scialabba [2] elaborates Ilich's thought and sees it as a struggle against inequality and control. The biggest problem are the differences between the poor and the rich and that the educational system is based on wrong values. His fight against control does not only apply to education, but also to everyday life in the family, at work and, more broadly, the excessive authority of the church and the state. Darder [3]

points out the fact that richer schools and environments have greater opportunities to use (modern) technology and better access to the Internet and its possibilities, and that in competition with other (poorer) schools, the prospects are uneven since the opportunities are not equal.

2. DEVELOPMENT OF THE CHILD PSYCHOLOGY

There are numerous theories about the developmental paths of 8-year-olds, 9-year-olds, and 10-year-olds. According to Piaget, children at the age of 8, 9 and 10 are at the level of concrete operations. This level is characterized by the possibility of logical thinking and the possibility of conversation on unknown and concrete contents [4]. At that age, children begin to pay attention to the needs of listeners in their social interactions, and their thought processes are increasingly influenced by logic. Piaget believes that the world of 8, 9 and 10-year-olds is more stable, realistic and organized than the world of a younger child [5, p. 25]. Vygotsky noticed that children of that age develop inner speech, which children use as a means of thinking, while social psychologist Erik Erikson believes that this developmental period is a time of psychological development in which children master important cognitive and social skills. In this period, children learn to work, play with their peers, acquire the skills of their culture, go to school and acquire the skills of reading, writing, mathematics and culture [5]. The latency phase, which lasts from the age of seven to eleven, is characterized by the expansion of the child's interests outward, and the child tries to master many skills and tools of culture. For Piaget, Erikson and Freud, 8, 9 and 10-year-olds are in a phase of development that is directed towards the outside world and is characterized by diligence [5, p. 26]. All the above theories are important for teachers because they serve as a starting point that helps them understand certain child's behaviour and decisions.

It is also important to understand the relationship between children and their parents. Girls have a stronger relationship with their mothers than boys. This relationship can also bring some obstacles. Since during adolescence there is a departure from infantile relationships and an approach to reality, it can be more difficult for girls to take that step towards accepting real life. During adolescence, girls struggle more with object relations, so separation from the mother is the biggest task of the adolescence period. During adolescence, psychological separation should occur, and if it does not occur, it can leave lasting consequences in personality development [6, 7, 8, 9].

2.1. (Early)Adolescence

Peter Blos and Jane Kroger made one of the most significant contributions to the understanding of adolescents. In particular, they worked on the development of psychoanalysis, which in the middle of the 20th century did not have many scientists working in this field.

Blos made a departure from the "popular concepts" of the time, so his advances in science were not widely accepted. He devoted himself mostly to deviations in development, violence that occurs among young people, so his theories were mostly used by psychiatrists [10]

Blos [11, 12, 13, 14] reveals that different defensive and adaptive mechanisms change in adolescents during puberty. In early adolescence, children develop various skills and interests that depend on peer approval. Also, during early adolescence there is a reorganization of emotions followed by different periods of chaos. There is a big departure from the previous object relations. There is conflict with parents, but in those children with enhanced ego development, this phenomenon may also be absent. Often there are very specific interests that the author calls "single-minded interest" [11, p. 59). Kroger [15, 16] deals with the later period of adolescence. It reveals that the self develops and changes in interaction with others throughout life. Adolescence, however, is the period with the most activity in this development, where many balances are lost, but also new ones come. Here, the processes of adolescence are viewed as a mechanism in which the entire personality of a person is transformed and formed, but not permanently.

2.3. Melanie Klein

Melanie Klein appears a little earlier but deals with a deeper approach. She makes a departure from Sigmund Freud (Table 1) and deals with the subconscious. Using toys and role play, he observes the way a child's mind works. He concludes that children project subconscious object relations onto the toys they play with and

the drawings they draw. Also, it explains the phase "Depressive position" where the child learned object relations in a completely different way. He has less need for separation and begins to understand external and internal realities much more accurately [17, 18, 19]. Object relations are important to us so that we can understand how children experience the world around them, but also how their inner world works. Teachers and parents can recognize potential difficulties in a child by observing which toys he chooses and the contents of his free drawings.

Table 1. How did Klein disagree with Freud?

Melanie Klein	Sigmund Freud
Places emphasis on interpersonal relationship	Places emphasis on biologically based drives
Emphasizes the intimacy and nurturing of the mother	Emphasizes the power and control of the father
Behavior is motivated by human contact and relationships	Behavior is motivated by sexual energy (the libido)
Klein stressed the importance of the first 4 or 6 months	Freud emphasized the first 4 or 6 years of life

Source: Etherington [20]

2.3. Erikson's psychosocial approach

Erik Erikson was the first psychoanalyst to extensively research the phenomenon of identity development during adolescence. Eriksen makes a departure from Freud's observations and deals with the study of interactions. He concludes that adolescents develop their ego in interaction with others and that personality development does not end in adolescence but takes place throughout life. Here, identity is viewed interdisciplinary, through a biological, experiential and cultural prism. The combination of these aspects constitutes the true form of identity. For the first time, identity, especially in adolescents, is associated with the culture in which a person lives. Identity is formed to the greatest extent during adolescence, while in earlier childhood it is mostly related to relationships with parents [21, 22, 23]. Erikson views identity as a balance between commitment and confusion about the child's role in his environment and community [16].

2. ALTERNATIVE SCHOOLS

Alternative schools appear as a counterbalance to public schools. Global society is becoming more pluralistically oriented, which is first visible in the political sphere. With the progress of science, especially developmental psychology, there is also pluralism in education. It is mainly brought by the creators of alternative pedagogical ideas, and the basis of their activity is criticism of the existing school system.

In the case of alternative schools, it is important that they were autonomous, and their pedagogical significance was the introduction of innovations [24]. In addition, they tried to encourage the system to return to nature and create an education in which there is no coercion [25]. According to Raywid, there are three types of alternative schools: *(1) alternative schools with a corrective function are primarily intended for at-risk groups of students; (2) alternative schools that have an innovative function, including the introduction of innovative curricula, the implementation of non-standard methods, partnership in education and the creation of a positive psychosocial climate in the classroom, and (3) alternative schools whose purpose is to introduce systemic changes in education in order to, through a series of educational possibilities made possible by variability* [26, p. 258]. This division best describes the main purpose of the creation and establishment of alternative schools. They are still a partial turning point in Europe because they brought the necessary changes, but their impact on the education systems was not as great as expected.

3.1. The need for alternative schools

At the beginning of the 20th century, there are movements among teachers and parents who express dissatisfaction with the education system, and the basis of the new demands are free education and its democratization. There are requests for school institutions that are not under the direct management of the government [27]. The traditional education system ceases to be functional because it does not meet the requirements of that time and the needs of students and society in general. Some of the biggest shortcomings were - insufficient variety of content, lack of free choice, outdated methods and forms of work not adapted to students [28]. Since the society was becoming more and more pluralistic, these changes had to take place in

education as well, which happened only in countries where democratic pluralism was also developing [29].

3.2. Summerhil

Alexander Neil is one of the more prominent alternative pedagogues because of his ideas about education, which were very radical at the time, at the beginning of the 20th century, and could still be called radical today. Neil turned his ideas into action in 1921 when he opened his Summerhill School in Leiston, Scotland. Neil is important because he dealt a lot with psychology, based on Freud's psychoanalysis, and the most important contribution to the development of pedagogical science is his work on the concept of freedom. This approach is based on the freedom of the students, so coming to classes is not mandatory, while the greatest freedom is seen in free expression and frequent discussions in which the students are active participants [30, 31]. Klaus [32, p. 2) says that the Summerhill school is *a Mount Olympus of alternative education.* He was employed at that school and describes many experiences, and from his work we get an important insight into how teaching and accommodation are really organized. Gilbert [33] recognizes progress in the social sciences in the 20th century as a move away from language as the only form of communication. The understanding of communication is expanded in the context that it results from meeting and interacting with others [34, 33].

3.3. Freinet

Celestin Freinet was born in 1986 in France and was a child who grew up in the countryside. He grows up in nature, which he firmly planted in his pedagogical thought. Since he worked as a teacher, he had the opportunity to introduce his innovations directly into his work with students.

Freinet's work gained particular importance after the Second World War, when pluralism started to develop more, stemming from the need to connect with other countries. He encouraged the exchange of student works, and he started the I concept of a network of schools based on the exchange of free student works. In 1951, the Institut Cooperatif de l'Ecole Moderne (ICEM) was founded with the aim of developing an educational system based on its pedagogical concepts [24, 29]. One of the special values it brings to schooling is both the development of democratic education and the establishment of cooperation between participants in the education system [36,37]. Also, it introduces the use of a printing machine in the class, which enables the additional development of student freedom. Here, the possibility of using technology in school [38] begins to be considered as a concept that later enters education as ICT.

3.4. Development of private schools in the Republic of Croatia

Private education began in the Republic of Croatia in 1991 with the establishment of the company Pitagora in Pula, which was the first private company to provide intellectual services. In accordance with the initial positive experiences, in 1993 this company became the first private primary school in the Republic of Croatia under the name Juraj Dobrila. This stimulated the process of establishing other private schools, and three years after that, five private elementary schools are operating in the Republic of Croatia [38]. It is evident from these years that private education in the Republic of Croatia appeared very late compared to the USA and the rest of Europe, and the reason for this can be attributed to the same as in other countries where this development was delayed, namely the lack of political (democratic) pluralism in which there was no room even for school pluralism.

In the Republic of Croatia, alternative schools in the true sense of the concept appeared only at the very end of the 20th century, and Waldorf and Montessori pedagogy are the most represented. The way they came was very difficult, filled with rejection and discontinuity. Nevertheless, they brought the acceptance of new knowledge in the field of child psychology, the participation of teachers in reforms and reflective views on extracurricular pedagogical work [39]. Alternative pedagogical ideas have brought a futurological approach in education, which mostly refers to the research of educational practice, which leads to new educational concepts. Another advantage is the modernization of teaching subjects and content, as well as the preparation of students for the future [40].

4. CONCLUSIONS

The 20th century is a real turning point in the progress of education seen globally. A development is taking place in the psychology of children, which enables the development of pedagogy as a science. It is obvious that some ideas that we consider new and modern today appeared more than a hundred years ago, but they are still very current. With an increased understanding of the functioning of the child's brain and the processes that take place in certain stages of childhood, we can adapt the school system and the teaching itself to the needs of the child. Here, more focus is diverted from the content itself to student motivation, and free activities appear to a greater extent. Psychologists who dealt with the processes of adolescence, especially the development of identity, such as Blos, Kroger, Klein and Erikson are presented here, enabled pedagogues like Freinet and Neil, but also many other reform pedagogues to bring potential advances in pedagogy. The best example and representative of this progress is the emergence of alternative schools. These schools, by their example, offered a new approach to education and encouraged changes, especially in the USA and Europe. Critical pedagogues provided an insight into the problems and shortcomings of the school system, which, albeit partially, brought visible progress.

5. REFERENCES

[1] T. De Coster; F. Simon; M. Depaepe, "Alternative" education in Flanders, 1960–2000: transformation of knowledge in a neo-liberal context. *Paedagogica Historica 45/4* (2009), pp. 645-671. DOI: 10.1080/00309230903100999

[2] G. Scialabba, Against Everything: On Ivan lllich, scourge of the professions. *The Baffler 34* (2017). pp. 174-181. https://www.jstor.org/ stable/44466505

[3] A. Darder, *Reinventing Paulo Freire: A pedagogy of love*. Boulder, CO: Westview, (2002).

[4] R. Vasta; M.M. Haith; S.A. Miller, *Dječja psihologija: moderna znanost*, Jastrebarsko: Naklada Slap, (1998).

[5] K. B. Walsh, *Kurikulum za drugi, treći i četvrti razred osnovne škole: Stvaranje razreda usmjerenog na dijete*, Zagreb: Pučko otvoreno učilište Korak po korak, (2004).

[6] S. Freud, Female Sexuality, *Collected Papers, vol 5*, The Hogarth Press, (1931).

[7] A. Freud, Psychoanalysis and Education, *Psychoanalytic Study of the Child, vol. 9*, International Universities Press Inc., (1954).

[8] H. Deutchs, The Imposter. *Psychoanalytic Quarterly 13*, (1954).

[9] H. Deutsch, *Psychology of Women*. Grune i Stratton, (1944).

[10] R. Muus, Peter Blos' modern psychoanalytic interpretation od adolescence. *Journal of adolescence 3* (1980), pp. 229-252.

[11] P. Blos, *On Adolescence A Psychoanalytic Interpretation*, The Free Press, New York, (1962).

[12] P. Blos, The Second Individuation Process of Adolescence. *The Psychoanalytic Study of the Child 22(1)* (1967), pp. 162-186.

[13] P. Blos, Character Formation in Adolescence. *The Psychoanalytic Study of the Child 23(1)* (1968), pp. 245-263.

[14] P. Blos, *The adolescent passage*, International Universities Press, New York, (1979).

[15] J. Kroger, Ego structuralization in late adolescence as seen through early memories and ego identity status. *Journal of adolescence 13* (1990), pp. 65-77.

[16] J. Kroger, *Identity in Adolescence*, Routledge, (1996).

[17] M. Klein, *The Psychoanalysis of Children, No. 22*, The International Psycho-analytical Library, (1932).

[18] M. Klein, A contribution to the psychogenesis of manic-depressive states. *International Journal of Psycho-Analysis 1*6 (1935), pp. 145-174.

[19] M. Klein, *Narrative of a child analysis: The conduct of the psychoanalysis of*

children as seen in the treatment of a ten year old boy, No. 55, Random House, (1961).

[20] L. Etherington, *Melanie Klein and objects relation theory*, (2020), https://www.simplypsychology.org/Melanie-Klein.html, last access 24/5/2022.

[21] E. H. Erikson, *Identitiy, Youth and Crisis*, W. W. Norton & Co., (1968).

[22] E. H. Erikson, Autobiographic notes on the identity crisis. *Daedalus 99* (1970), pp. 730-759.

[23] E. H. Erikson, *Toys and reasons: Stages on the Ritualization of Experience*, W. W. Norton & Co., (1977).

[24] M. Matijević, *Alternativne škole: Didaktičke i pedagoške koncepcije*, Zagreb: Tipex, (2001).

[25] S. Vrcelj, *Školska pedagogija*, Rijeka: Filozofski fakultet, (2000).

[26] J. Milutinović; S. Zuković, Odgojne i obrazovne tendencije: Privatne i alternativne škole. *Hrvatski časopis za odgoj i obrazovanje 15* (2), (2012), pp. 241-266. http://hrcak.srce.hr/index.php?show=clanak&id_clanak_jezik=157312

[27] D. Maleš, Od nijeme potpore do partnerstva između porodice i škole, *Društvena istraživanja 1(21)* (1995), pp. 75-88.

[28] K. Riddle, Alternativne škole i inovacije u obrazovanju, *Pedagoška stvarnost 49(3-4)* (2003), pp. 337-346.

[29] M. Matijević, *Školski i pedagoški pluralizam u zemljama u tranziciji*. In: N. Potkonjak (Ed.), Buduća škola: Zbornik radova sa naučnog skupa I, Beograd: Srpska akademija obrazovanja, (2009). https://bib.irb.hr/datoteka/379617.Matijevic_alternativa2.pdf

[30] A. S. Neill, *Summerhill: A radical approach to child rearing*, New York: Wallaby, (1977).

[31] A. S. Neill, *Škola Summerhill: Novi pogled na djetinjstvo*, Zagreb: Sara 93, (1999).

[32] P. Klaus, *'an ordinary day' The Palgrave International Handbook of Alternative Education*, (H. Lees; Noddings, Eds.), London: Palgrave Macmilla, (2016).

[33] J. Gilbert, *Common ground: Democracy and collectivity in an age of individualism*, London: Pluto Press, (2014).

[34] B. Massumi; E. Manning, *Series foreword*. In: M. Combes, (Ed.), Gilbert Simondon and the philosophy of the transindividual, Cambridge, MA: MIT Press, (2013).

[35] N. Jagrović, Sličnosti i razlike pedagoških modela Marije Montessori, Rudolfa Steinera i Celestina Freineta. *Školski vjesnik – Časopis za pedagoška i školska pitanja 56(1)* (2007), pp. 65-77. http://hrcak.srce.hr/index.php?show=clanak&id_clanak_jezik=122949

[36] V. Acker, *The French Educator Celestin Freinet: An Inquiry into How His Ideas Shaped Education*, Lanham, MD: Lexington Books, (2007).

[37] M. Carlin; N. Clendenin, Celestin Freinet's printing press: Lessons of a 'bourgeois' educator. *Educational Philosophy and Theory 51(6)* (2019), pp. 628-639, DOI: 10.1080/00131857.2018.1498334

[38] D. Krbec, Privatne škole i obrazovna politika u Hrvatskoj, *Revija za obrazovnu politiku, 6(3-4)* (1999), pp. 269-290.

[39] Š. Batinić.; I. Radeka, Od reformne do alternativne pedagogije Pokušaji drugačije škole u Hrvatskoj u 20. stoljeću, *Acta Iadertina 14/1* (2017), pp. 41-60.

[40] J. Gidley; D. Batemen; C. Smith, *Futures in Education: Principles, practice and potential*, Melbourne, Australia: Australian Foresight Institute, Swinburne University of technology, (2004).

Knowledge management and digital transformation

K. Schuster [a], V. Lemić [b,c], V. Schuster [d]

[a] Plavi tim d.o.o., Ul. grada Vukovara 18, 10000 Zagreb, Hrvatska

kristian.schuster@plavitim.hr

[b] Središnji ured za arhivsku građu, Sveučilište u Zagrebu, Ulica kralja Zvonimira 8, 10000 Zagreb, Hrvatska

[c] ICARUS Hrvatska, Ul. Sv.Roka 14, 10000 Zagreb, Hrvatska

vlatka.lemic@unizg.hr; info.icarushr@gmail.com

[d] Rochester Institute of Technology, Ul. Damira Tomljanovića 15, 10000, Zagreb

vito.schuster@gmail.com

Abstract

Purpose of this review paper is to present knowledge management as it is one of a key disciplines in a successful organization and its future prosperity. To become learning organization is inevitable for keeping continuity in a world that faces digital transformation causing disruptive effects. Having a good understanding of a knowledge management is prerequisite for students and professionals to grapple with continuous change of a level of interactions between IT driven capabilities which are developing at a high pace and human intellection. This interrelation is becoming incubator of advanced learnings which should be effectively managed.

Keywords: *Knowledge management, learning organization, learning concepts, information technology, digital transformation.*

1. INTRODUCTION

Knowledge management is the process of organizing, creating, using, and sharing collective knowledge within an organization. Successful knowledge management includes maintaining information in a place where it is easy to access [1]. Successful organizations have understood the importance of managing knowledge, developing plans to accomplish this objective and devoting time and energy to these efforts [2]. Companies prosper due to their internal knowledge; its application and development and all these factors lead to its outstanding performance [3].

Senge, Ross, Smith, Roberts and Kleiner are saying that learning organization means continuous testing of experience, transformation of that experience into knowledge which is accessible to the whole organization and relevant to its purpose [4]. Additionally, Cyert and March delibarate as late as 1963 that capability related to maintaining performance in organizations is ability of the organization to learn from experience [5]. To do so presumes that organizations can capture enough information from past experience to establish a cause-and-effect relationship between action and result. Donald Schön argued in 1973 that "we must … become adept at learning. We must become able not only transform our institutions, in response to changing situations and requirements: we must invent and develop institutions which are 'learning systems' systems capable of bringing about their own continuing transformation" [6].

Learning organizations must accomplish five main activities: systematic problem solving, experimentation with new approaches, learning from their own experience and past history, learning from the experiences and best practices of others, and transferring knowledge quickly and efficiently throughout the organization [7].

2. KNOWLEDGDE MANAGEMENT AND LEARNING ORGANIZATION

Learning organization that incorporate successful knowledge management processes must adopt a process of organizational learning - a process of increasing and changing organizational knowledge basis, improving the problem solving and action competences. It is as set of processes and structures to help people create new knowledge, share their understanding and continuously improve themselves as the results of the enterprise.

Organizations that invest in a significant amount of knowledge management can perform better as well as their employees get highly motivated due to that. The first finding is that knowledge management is mainly implemented when the organization want to gain competitive advantage with respect to other competitors by applying various strategies. The second finding is that the organizations implement knowledge management rigorously when its main objective is targeting specific customer segments. The third finding is that effective knowledge management helps to increase productivity among the employees [8].

Argyris and Schön made a contribution through developing concepts including single-loop and double-loop learning. Single loop learning involves the detection and correction of error within a given set of governing variables [9]. Goals, values and strategies are here taken for granted and current learning behaviours are seen as appropriate. It is linked to "incremental changes where organization tries a new method and tactics and attempts to get rapid consequences in order to be able to make continuous adjustments and adaptations" [10].

Double loop learning involves also changing the governing variables themselves. It is associated with radical changes, which may evolve a major change in strategic direction, possibly linked to replacement of senior personnel, and wholesale revision of systems. [10].

There is a third concept – deutero learning which can be considered as learning of learning e.g. meta-level of organizational learning. It is associated with the collection and communication of knowledge about past learning processes, both single-loop and double-loop [11].

Learning Process	System Levels	Learning Models	Learning Types
Identification/Creation	Individual	Cognitive	Single-loop
Diffusion	Group	Cultural	Double-loop
Integration	Organization	Action	Deutero
Action	Interorganizational		

Figure 1. Conceptual framework for organizational learning [12]

3. LEARNING ORGANIZATION BLUEPRINT

Pedler, Burgoyne and Boydell created non-sequential list of eleven characteristics of learning company in a form of model building process [13]. Characteristics are further divided into five clusters.

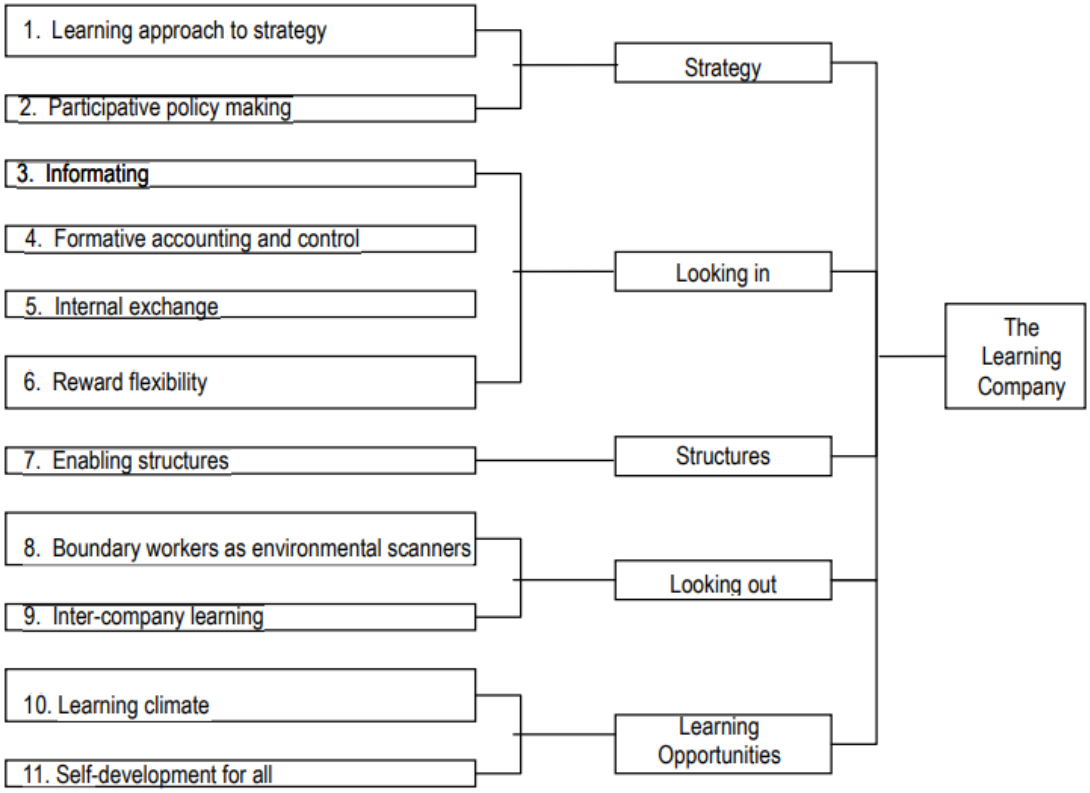

Figure 1. Characteristics of learning company [13]

While "Structure" cluster is central pivot, "looking-in" and "looking-out" are mirrored images and strategy and learning possibilities as external ones. This simplified model can serve as checkpoints in analysing a company as well as foundation for organizational changes because these represents prescriptions and commitments to activities. This framework can also help ones as starting point for a self-development process.

Another blueprint is given by Senge in his famous book The Fifth Discipline published in 1990. These are:

a) Systems thinking: are concept, tools and knowledge which are developed during last fifty years to describe and interpret an underlying structure of interconnected actions and gives help how to effect on them,

b) Personal mastery: special kind of skills which is of continually clarifying and deepening personal vision, of focusing energy, developing patience, and of seeing reality objectively,

c) Mental models: are assumptions, generalization, or even pictures and images that influence hoe we understood the world and how we take action,

d) Building shared vision: is a capacity to hold and share picture of the future we want to create. When there is a appropriate vision, people excel and learn,

e) Team learning: is the process of aligning and developing the capacities of a team to create the results its members truly desire [14].

4. LEARNING ORGANIZATION BUILDING BLOCKS

Organizations striving to develop their learning capabilities should ensure that learning capability occurs by design rather than by chance by implementing unique policies and practices. Goh S.C. (1998) synthesized about managerial practices and policies [15]. He argued that learning organization consists of the following core strategic building blocks:

a) Mission and Vision: Clarity and employee support of the mission, strategy and espoused values of the organization

b) Leadership: Leadership that is perceived as empowering employees, encouraging an experimenting culture and showing strong commitment to the organization.

c) Experimentation: A strong culture of experimentation that is rewarded and supported at all levels in the organization.

d) Transfer of Knowledge - The ability of an organization to transfer knowledge within and from outside the organization and to learn from failures.

e) Teamwork and Co-operation - An emphasis on teamwork and group problem solving as the mode of operation and for developing innovative ideas [15].

5. KNOWLEDGE MANAGEMENT AND DIGITAL TRANSFORMATION

Between number of knowledge management models, SECI model defined by Nonaka and Takeuchi is between the most common. Knowledge is created and then transferred from a person to a group through processes of socialization, combination, externalization and internalization. [16]. However, the manner in which knowledge management should exist is questioned in an age where thousands of devices are connected in the cloud and are able to perform both simple and complex tasks without any or with only limited interaction with their human counterparts [17]. Digital transformation means implementation of different IT technologies which contributes to data collection in extensive and continuous way, implementation of advance analytics and machine learning which contributes to knowledge creation thus being able to perform complex activities without human interaction. This kind of digitized organizations should have knowledge management strategies integrated with this type of systems and embedded within processes.

Schwab (2016) describes the 4th industrial revolution in a way that it is characterized by new technologies fusing the physical, digital and biological worlds, will impact all disciplines, economies and industries in a way not seen before due confluence of emerging technology breakthroughs which are covering wide ranging fields such as artificial intelligence (AI), robotics, the internet of things, autonomous vehicles, 3D printing, nanotechnology, biotechnology, materials science, etc. [18].

According to Natarajan, the key challenge for Fourth Industrial Revolution organizations is to harness the real potential for digital transformation by having an integrated strategy and a holistic approach towards knowledge management, building internal systems and processes to streamline information exchange and data analytics, along with a strong culture of data-driven decision-making [19]. It means that in knowledge management models typical elements are not related exclusively to humans, but also advanced IT systems are becoming relevant entities and its building blocks should be extended by aspects of IT disruptive influence.

6. KNOWLEDGE MANAGEMENT IN CROATIA

Although globally recognized in various sectors, knowledge management is still relatively under-researched theme in Croatia. Milanović Glavan and Ivančić from Faculty of Economy in Zagreb in 2017 had analysed the state of knowledge management in Croatian companies with special emphasis on information technology. They conducted knowledge management measurement on the sample of 200 companies, in the format of survey, by using questionnaire focusing on 3 domains recognised as critical success factors: Knowledge (8 questions), Information technology (6 questions), Organizational culture (9 questions). Data results shows that Croatian companies have the lowest grade for IT aspect of knowledge management, as well as a need to higher their stage of knowledge management. Authors had tvo recommendations: ”

- Actively develop and use all critical success factors of KM. It means that companies have to have KM strategies, KM workers and organizational culture where the motto will be: "Sharing knowledge is power."
- Increase the use of IT for all KM tasks.” [20].

Beside business sector, public administration is also become more and more aware of the importance of knowledge management issues, primarily because of the European regulations and digital transformation of public services, mainly those dealing with national registers and big data. These processes are usually manifested in practice through the various e-services projects and initiatives, e.g. e-Citizens portal of Croatian Government provides information and list of e-services for citizens and organisations in Croatia [21]. Experience of the Central Bureau of Statistics shows that they recognised the need for changes because Eurostat and national statistics of the EU countries are working with advanced technologies and rapidly introduce new standards, applications and integrated information systems. New technologies are primarily based on XML solutions, which is a basis for data standardization and exchange. In the context of their organisational needs, knowledge management was recognised as a solution for dealing with the challenges of new technologies and aligning of their business processes with international standards. In that sense, Jerak argue that setting of a knowledge management strategy and implementation of systematic and organized process of knowledge management are key points for improving of communication and cooperation, change of organizational culture and improving the extent of documenting knowledge, which would ultimately improve the performance of organization and respond to contemporary challenges. The starting point of the analysis of the situation would be the IT sector, because it is understood as a support to all other organisational sectors in providing their services, as well as, provider of information technology for conceptual and practical implementation of knowledge management [22].

7. CONCLUSION

Successful organizations have understood the importance of managing knowledge through process of organizing, creating, using, and sharing collective knowledge within an organization. Organizations must invent and develop institutions which are 'learning systems', systems capable of bringing about their own continuing transformation. Knowledge management as a discipline is mature as broad number of authors contributes to the theoretical foundations. However, digital transformation opens new aspects of interactions between humans and technology which inherit potential for a further development of knowledge management discipline to be able to respond to disruptive future.

8. REFERENCES

[1] Knowledge Management, Guru Technologies, https://www.getguru.com/reference/what-is-knowledge-management, last access 30/6/2022

[2] F.O. Omotayo, Knowledge Management as an important tool in Organizational Management: A Review of Literature. Library Philosophy and Practice (e-journal) 1238 (2015), pp. 2-3 http://digitalcommons.unl.edu/libphilprac/1238

[3] H. Inkinen, Review of empirical research on knowledge management practices and firm performance. Journal of Knowledge Management 20(2) (2016), pp. 230-257

[4] P.M..Senge; A. Kleiner; C. Roberts; R.B. Ross; B.J. Smith, The Fifth Discipline Fieldbook. Strategies and Tools for Building a Learning Organization. Nicholas Brealey Publishing, London, (2002), p. 49

[5] R.M. Cyert; J.G. March, A Behavioral Theory of the Firm. Prentice-Hall, Englewood Cliffs, New York, (1963).

[6] D.A. Schön, Beyond the Stable State. Penguin, Harmondsworth/Norton, N. J., (1973), p. 30

[7] D.A. Garvin, Building a Learning Organization. Harward Business Review: The Magazine, 71(4) (93), pp. 78-91

[8] S. Mahendher; D. Bhattacharya; K. Jyoti Talukdar; V. Shenoy, Impact of Knowledge Managment on IT Sector Performance. PalArch's Journal of Archaeology of Egypt / Egyptology 17(12) 2020, pp. 1102-1110

[9] C. Argyris; D. Schön, Organizational learning: A theory of action perspective, Addison Wesley, Reading, MA, (1978).

[10] M. Easterby-Smith; L. Araujo, Organizational learning: current debates and opportunities. In: M. Easterby-Smith; L. Araujo; J. Burgoyne (Eds.) Organizational Learning and the Learning Organization: Developments in Theory and Practice, pp. 1-22, SAGE Publications Ltd, (1999).

[11] M. Visser, Gregory Bateson on Deutero-Learning and duble Bind: A Brief Conceptual History. Journal of History of the Behavioral Sciences 39(3) (2003), pp. 269–278, https://www.researchgate.net/publication/227615493_Gregory_Bateson_on_deutero-learning_and_double_bind_A_brief_conceptual_history

[12] P. Pawlowsky, Treatment of organizational learning in management science. In: M. Dierkes; A. Berthoin-Antal; J. Child; I. Nonaka (Eds.). Handbook of Organizational Learning and Knowledge, pp. 61-88, Oxford University Press, Oxford (2001).

[13] Pedler, M., Burgoyne, J. & Boydell; The Learning Company: A Strategy for Sustainable Development. Mc Graw-Hill, (1991), p. 25

[14] P. Senge, The Fifth Discipline. Doubleday/Currency, New York, (1990). pp. 6-7

[15] C.S. Goh, Toward a learning organization: The strategic building blocks. SAM Advanced Management Journal 63(2) (1998), pp. 15-22

[16] I. Nonaka; H. Takeuchi, The knowledge creating company: How Japanese companies create the dynamics of innovation. Oxford University Press, New York, (1995), pp. 71-2, 89

[17] D. Botha, Knowledge Management and the Digital Native Enterprise. Deloitte & Touche, South Africa, (2019), p. 3

[18] K. Schwab, The fourth industrial revolution. World Economic Forum, Cologne/Geneva, (2016).

[19] G. Natarajan, Knowledge management and big data. Confederation of Indian Industry, New Delh, (2018), pp.4-5

[20] Lj. Milanovic Glavan; L. Ivančić, Knowledge Management: Case of Croatia, Proc. of 46th International Scientific Conf. on Economic and Social Development "Sustainable Tourist Destinations", Varaždin, Croatia, (2019), pp. 197-204

[21] e-Citizens, Information of services, https://gov.hr/en, last access 17/06/2022

[22] N. Jerak, Knowledge management in CBS Croatia. Entrepreneurial learning 3(1) (2013), pp. 83-91

Differences in the impact of limiting factors on choosing the sports products

H. Sivrić [a], T. Vidranski [b], M. Bičanić [c]

[a] University of Slavonski Brod, Trg Ivane Brlić Mažuranić 2, 35000 Slavonski Brod, Croatia, hsivric@unisb.hr

[b] University of Slavonski Brod, Trg Ivane Brlić Mažuranić 2, 35000 Slavonski Brod, Croatia, tvidranski@unisb.hr

[c] Former student of University of Slavonski Brod, Trg Ivane Brlić Mažuranić 2, 35000 Slavonski Brod, Croatia, mjovanovac1@unisb.hr

Abstract

The goal of the paper is to determine the differences between potential/current sports consumers in the impact of limiting factors on the choice of practicing sports products. The sample consist of 357 examinees, average chronological age 24.5±7.46, of which 66.94% are female consumers and 33.06% male consumers. All examinees filled out an online questionnaire which contain 12 items. Examinees expressed their degree of agreement with each statement on a 5-point Likert scale. Canonical discriminant analysis shows the difference in arithmetic mean between female and male consumers CanR=0,42 with statistical error p=0,00. Male consumers unlike female consumers have in general less negative impact on choosing the sports products, that is they have a higher willing moment and they are more willing to pay more for it. Although a part of the same population - consumers, preferences and opinions of female and male consumers are significant different. This shows that targeting groups in marketing is very important.

Keywords: consumer, sports product, factor

1. INTRODUCTION

The usefulness of sports and the effects of sports activities in everyday life are now well known from the aspect of satisfaction the needs for movement, the impact on the development of abilities, traits and sports knowledge, as well as the preservation and improvement of psychophysical abilities and health. But, the reality and rhythm of life characterised by less and less movement and a least of free activities that are little or not at all related to physical exercise. Taking care of one's own body and awareness that health is the most important part of a person's life, along with engaging in sports activities, should be of social interest due to the negative impact of inactivity on the human body. Scientific knowledge shows that physical inactivity is one of the strongest factors affecting health today [1]. Goals such as quality of life, i.e. managing one's own resources in time and space, are important social factors [2]. In order for sports service providers to be more successful, they should have knowledge organizing and managing to achieve goals with the rational use of limited resources [3]. This can benefit them in the field of marketing. Marketing is a human activity aimed at satisfying needs and desires through the process of exchange [4]. At the center of the business of sports service and product providers is the consumer and the quality and value of a

particular product or service that should please the consumer's wishes, demands and expectations [5]. The consumer market considered an economic space where the most diverse supply and demand of all possible goods, services and ideas meet, i.e., in general, exchange as part of the economic process [6]. Sports programs and services can define as everything that can offered to the market to attract attention, sale, use or consumption, and which could please some desire or need [7]. To establish this exchange, knowing the opinions and perceptions of consumers is important. The problem investigated in this paper is the differences between consumers and/or potential consumers in the influence of limiting factors on the choice of practicing sports products.

The goal of this research was to determine whether there are significant differences between two groups, "female" and "male" potential or current sports consumers, in the impact of limiting factors on the choice of practicing sports products, how much the difference is, and which of the above observed variables best discriminate two groups of consumers and to what extent. The sample consisted of 357 examinees, average chronological age 24.5±7.46, of which 66.94% are female consumers and 33.06% male consumers. For the purposes of determining the difference between female and male consumers on the impact of limiting factors on the choice of practicing sports products, a questionnaire containing a total of 12 items. Therefore, the following hypothesis formed: H_1: There is a significant difference between the group of "female consumers" and the group of "male consumers" in selected indicators of the possible impact of limiting factors on the choice of practicing sports products with an error of 0.05.

2. METHODS

2.1. Examinee sample

The sample composed of 357 examinees, average chronological age 24.5±7.46 years with a range of 16 - 52 years. The structure of the sample consists of 42.57% of respondents from Brod-Posavina County, or 57.43% from other counties of the Republic of Croatia; 66.94% (239) of the female consumer population and 33.06% (118) of the male consumer population; of which 38.09% (136) employed and 61.90% (221) unemployed.

2.2. Variable sample

For the purposes of determining the difference between female and male consumers on the impact of limiting factors on the choice of practicing sports products, a questionnaire containing a total of 55 items was used for the general research. For the purposes of this work only 12 items used. Examinees expressed their degree of agreement with each statement on a 5-point Likert scale (1=not at all/5= exceptionally).

DOB = chronological age of the examinee; SOA = Average weekly participation in organized physical/sports activities for most of the year (not including classes); POS = Assessment of the level of awareness/information about the need to engage in physical/sports activities in general in life; PVS = Assessment of the importance/need of practicing physical/sports activities in general in life; PFO-V = Time (schedule limitation, lack of free time...); PFO-I = Previous experiences; PFO-F = Financial; PFO-A = Lack of attractiveness of sports activities offer (lack); FO-N = Lack of information; PFO-D = Availability of sports facilities; PPA = Assessment of the offer of physical/sports activities (programs/services) offered in the place of current residence; PMI = How much money are you willing to spend per month for participating in physical/sports activities.

2.3. Methods of data processing

The methods used for data processing included calculating descriptive statistical parameters for all variables: arithmetic mean (AS), standard deviation (SD), minimum (Min) and maximum (Max) result. In order to determine if there are significant differences between the two groups the canonical

discriminant analysis conducted on the groups of female and male consumers. Within the canonical discriminant analysis the coefficient of canonical discrimination was determined, as well as groups position on discriminant function and correlation between the variables and the discriminant function. The significance of coefficients of canonical discrimination was tested by Bartlett's test. The data was classified by statistical package STATISTICA 13.0.

2.4. Description of experimental procedure

All examinees voluntarily and anonymously filled out the online survey questionnaire. The questionnaire conducted in the period from March 11-30, 2022. through social networks, in a period in which there are no exams, holidays and vacations, so the examinees were freer to more realistically assess the impact of limiting factors on the choice of practicing sports products.

3. RESULTS AND ACHIEVEMENTS

Table 1. shows descriptive indicators of variables for the total sample of consumers and also for the both groups female and male consumers.

Table 1. Descriptive indicators of measuring variables.

Variables	all consumers (N=357)			female consumers (N=239)			male consumers (N=118)		
	AS±SD	Min	Max	AS±SD	Min	Max	AS±SD	Min	Max
DOB	24,54±7,46	16	52	25,44±7,72	17	52	22,72±6,58	16	50
SOA	1,23±1,23	0	3	0,97±1,16	0	3	1,75±1,21	0	3
POS	3,72±1,01	1	5	3,62±1,01	1	5	3,91±1,00	1	5
PVS	4,22±0,85	1	5	4,22±0,83	1	5	4,22±0,88	1	5
PFO-V	3,57±1,12	1	5	3,67±1,05	1	5	3,35±1,22	1	5
PFO-I	3,02±1,13	1	5	3,11±1,08	1	5	2,84±1,22	1	5
PFO-F	3,22±1,12	1	5	3,41±1,06	1	5	2,85±1,16	1	5
PFO-A	3,21±1,01	1	5	3,29±0,94	1	5	3,05±1,11	1	5
PFO-N	2,97±1,14	1	5	3,13±1,09	1	5	2,64±1,19	1	5
PFO-D	3,44±1,11	1	5	3,51±1,08	1	5	3,28±1,15	1	5
PPA	3,09±1,11	1	5	3,09±1,12	1	5	3,09±1,09	1	5
PMI	232,3±170,1	25	1000	203,3±126,4	50	1000	291,1±224,5	25	1000

AS–arithmetic mean, SD–standard deviation, Min–minimal result, Max–maximum result

Observing the total sample, the highest average values are in two variables *Assessment of the importance/need of practicing physical/sports activities in general in life* (PVS=4.22) and *Assessment of the level of awareness/information about the need to engage in physical/sports activities in general in life* (POS=3.72), what expected. It unexpected that, considering the high average ratings of the variable's importance/need and awareness/information about the need to engage in physical/sports activities, the average value of weekly participation in organized physical/sports activities is low in most of the year, at the level of SOA=1.23. Unfortunately, the results show that, although they are aware of the importance of practicing sports, on average they practice sports only once a week. This

shows an obvious physical inactivity. Furthermore, based on the parameter of standard deviation we can see that the variation of results is the higher in the case of the average practice of sports (SOA=1.23±1.23), while in the other two variables the homogeneity of results is much higher (PVS=4.22±0.85 and POS=3.72±1.01). Most of this variance made up of, which is also worrying information, even 153 (42.85%) consumers who are completely inactive, do not take part in any sports activities. Observing the sample by group separately, it is evident that male consumers have higher average values for playing sports and for *awareness/information about the need to engage in physical/sports activities*, while the average value of the result for the variable *importance/need of practicing physical/sports activities in general in life* is identical. Observing the limiting factors, the factors "time" (PFO-V=3.57) and "availability of sports facilities" (PFO-D=3.44) have the highest average values, while the factor "lack of information" (PFO-N=2.97) has the lowest average value. The variability of the answers is the same for all 6 offered factors. The average rating of all 6 limiting factors is 3.24, while the average standard deviation is 1.11, so we can talk about the uniformity of the variance of the factors. Observing the sample by group separately, we see that both female and male consumers rate both of these two factors as the most important. The "time" factor has the greatest impact in the limitation, at least for the observed sample. The question arises, why time is the biggest limiting factor for the observed consumers, whether they burdened with obligations or they have lack of knowledge about the disposal and organization of time resources. The average rating as well as the standard deviation of all 6 limiting factors for male consumers is lower than for female consumers. The limitation factor on choosing the sports products is higher among female consumers. The difference in average values between female and male consumers is also visible in the variable How much money there are willing to spend per month for participating in physical/sports activities. Female consumers are willing to pay only 69.83% of the monthly amount that male consumers are willing to spend. For the offer of sports products, we can say that it did not receive a high average rating, which may mean that consumers are not too satisfied with this factor. The variable Assessment of the offer of physical/sports activities (programs/services) offered in the place of current place of residence rated with the same rating for both groups.

According to the Table 2. which shows differences of arithmetic means and canonical discriminant analysis between groups female consumers and male consumers, it determined that the differences between the groups are statistically significant.

Table 2. Differences of arithmetic means and canonical discriminant analysis between group female consumers and male consumers.

CANR	λ	h^2	df	p
0,42	0,82	67,83	12	0,000

CanR–canonical correlation coefficient, λ–lambda, h^2–Chi square, df – degrees of freedom, p – level of significance

Table 2. shows that the canonical discrimination coefficient (canonical correlation of the discrimination function) is CR=0.42, which shows that the difference between groups female consumers and male consumers in terms of the mentioned variables is relatively small, but the discrimination function still significantly differentiates groups. Testing the significance of the specified coefficient carried out by Bartlet's Chi-square test, which is statistically significant with an error of p=0.000, which leads us to the conclusion that with more than 95% certainty we can claim that a very small difference in "selected indicators" was not obtained by accident. These results show that the preferences and opinions of the female and male population are significantly different, and such results are definitive should considered when planning a business.

From Table 3. we can see that the group female consumers positioned itself at the positive pole of the discrimination function

(their average is at 0.325 standard deviation of the discrimination function), while the group male consumers positioned at the negative pole (their average is at -0.657 standard deviation deviations of the discriminant function).

Table 3. Arithmetic means of groups of male and female students on the discriminant function

	DF
female consumers	0,325
male consumers	-0,657

DF–correlation coefficients of discriminant function and variables

Accordingly, male students have higher average results than female students in those variables that have a positive correlation with the discrimination function. Accordingly, female consumers have higher average results than the male consumers in those variables that have a positive correlation with the discriminant function. From Table 4. we can see that the students and the student are significantly different in four (4) variables. Those are: *Average weekly participation in organized physical/sports activities; Financial factor of limitation; Lack of information factor; How much money they are willing to spend per month for participating in physical/sports activities.*

Table 4. Differences between groups female and male consumers in individual variables

	λ	**p**
SOA	***0,86***	***0,00****
POS	0,82	0,59
PVS	0,83	0,31
PFO-V	0,82	0,49
PFO-I	0,82	0,80
PFO-F	***0,83***	***0,03****
PFO-A	0,82	0,93
PFO-N	***0,84***	***0,02****
PFO-D	0,82	0,58
RNP	0,83	0,33
PPA	0,83	0,26
PMI	***0,85***	***0,00****

λ–lambda, p– significance level

Also, based on the results from Table 4, we can conclude that male consumers have less negative impact on choosing the sports products, that is, they have a higher willing moment and they are more willing to pay more for it.

Table 5. Differences in arithmetic means and canonical discriminant analysis between group of female and group of male consumers

Variables	**female consumers**	**male consumers**	**DF**
	AS±SD	**AS±SD**	
SOA	25,44±7,72	22,72±6,58	**-0,68**
POS	0,97±1,16	1,75±1,21	-0,29
PVS	3,62±1,01	3,91±1,00	0,00
PFO-V	4,22±0,83	4,22±0,88	0,30
PFO-I	3,67±1,05	3,35±1,22	0,24
PFO-F	3,11±1,08	2,84±1,22	0,52
PFO-A	3,41±1,06	2,85±1,16	0,25
PFO-N	3,29±0,94	3,05±1,11	0,44
PFO-D	3,13±1,09	2,64±1,19	0,22
RNP	3,51±1,08	3,28±1,15	0,12
PPA	3,09±1,12	3,09±1,09	0,00
PMI	203,3±126,4	291,1±224,5	-0,54
Centroid	0,32	-0,66	**CanR** =0,42

AS–arithmetic mean, SD–standard deviation, DF–correlation coefficients of discriminant function and variables, CanR–canonical correlation coefficient

Table 5. also shows the structure of the discrimination function, i.e. the correlation of the manifest variables with the discrimination function. Here again we can see the same variables that contribute most to the difference between the groups. Obviously, the economic aspect is the factor that most determines and creates the difference between female and male consumers on the impact of limiting factors on the choice of practicing sports products. It is interesting that in the variables *assessment of the importance/need of practicing physical/sports activities* and *assessment of the offer of physical/sports activities (programs/services) offered* both groups of consumers think identically.

4. CONCLUSIONS

This research used canonical discriminant analysis to analyze difference

between the group of "female consumers" and the group of "male consumers" in selected indicators of the possible impact of limiting factors on the choice of practicing sports products. The sample composed of 357 examinees, average chronological age 24.5±7.46 years. The structure of the sample consists of 66.94% of the female consumer and 33.06% of the male consumer.

The results show that female and male consumers differ significantly in their answers. Canonical discriminant analysis shows the difference in arithmetic mean between female and male consumers CanR=0,42 with statistical error p=0,00. Therefore, the hypothesis is confirmed. H_1: There is a significant difference between the group of "female consumers" and the group of "male consumers" in selected indicators of the possible impact of limiting factors on the choice of practicing sports products. This research does not include all potential limiting factors that could have affect on choosing the sports products. Male consumers unlike female consumers have in general less negative impact on choosing the sports products, that is they have a higher willing moment and they are more willing to pay more for it. Although a part of the same population - consumers, preferences and opinions of female and male consumers differ significantly; this shows that targeting groups in marketing is very important.

The results of this research can used as guidelines for future entrepreneurship activities that ensure profit to sport and from sport, as well as for marketing activities connected to promotion of sport realized through selling of sport product and other connected services.

5. REFERENCES

[1] I. Vuori., Physical inactivity is a cause and physical activity is a remedy for major public health problems, 36 (2) (2004), pp. 123-153

[2] H. Sivrić, Priručnik za samoinicijativni fitnes trening studenata (2013)

[3] M. Bartoluci, S. Škorić, Menadžment u sportu, Udžbenici Društvenog veleučilišta u Zagrebu, Zagreb, (2009)

[4] P. Kotler, Principles of Marketing, Pearson Education, Harlow (England) (2008)

[5] K. Kos, A. Kralj, Sportski marketing, Čakovec (2016)

[6] M. Bartoluci., Ekonomika i menadžment sporta (2) (2003), pp.242.

[7] I. Novak, Sportski marketing i industrija sporta, Mailing d.o.o., Zagreb, 2006.

The Quality of the Study Program from the Perspective of Students

Z. Šimunović [a], V. Vekić - Kljaić [b]

[a] University of Slavonski Brod, Gundulićeva 20, 35 000 Slavonski Brod, Republic of Croatia, zsimunovic@unisb.hr

[b] University of Slavonski Brod, Gundulićeva 20, 35 000 Slavonski Brod, Republic of Croatia, vvkljaic@unisb.hr

Abstract

Preschool educators work in kindergartens and provide care and education, upbringing, and social and health care of children from the first year of life until they start primary school. In order to perform the duties of a preschool educator, it is necessary to complete an undergraduate and/or graduate university study program Early Childhood and Preschool Education. Preschool educators' training includes scientific and professional education implemented through lectures, seminars, exercises and professional pedagogical practice. As part of scientific and professional education, students learn basic didactic, methodological, pedagogical and psychological skills. Exercises and professional pedagogical practice in kindergartens have an impact on the future professional development of students. After completing an undergraduate study program, the academic title of university Bachelor's degree is awarded, while upon completion of a graduate study program, the academic title of university Master's degree is awarded. In the Republic of Croatia, Early Childhood and Preschool Education study programs are not uniform. The Department for the Training of Preschool Educators is a constituent of the University of Slavonski Brod. Based on its vision and mission, the University is committed to the continuous development of its quality of study. The importance of developing study programs based on the results of scientific research is emphasized. The paper uses a questionnaire to examine the opinions of undergraduate part-time students enrolled in Early Childhood and Preschool Education study program on the quality of this study program. The questionnaire contains questions about qualification standards, sorted by key tasks and competencies of preschool educators. The aim of the research is to determine the quality of the study program from the perspective of students. The results of the research will help in planning future changes in the study program.

Keywords: study program, competencies, students, preschool, qualification standards.

1. INTRODUCTION

Early childhood and preschool education, as the first and fundamental basis in the vertical organization of the education system, has been a frequent topic of scientific research in recent decades. The initial education of preschool educators, as fundamental practitioners in this system, has undergone several systematic changes since the beginning of the 21st century, starting from a professional two-year study program, through a three-year university study program, all the way to the present university graduate study program Early Childhood and Preschool Education. The part-time undergraduate and graduate study program Early Childhood and Preschool Education at the University of Slavonski Brod has been implemented within the Department of Social Sciences and Humanities since the founding of the University in the academic year 2020/2021. These study programs include scientific and professional education of future preschool educators implemented in various forms of teaching: lectures, seminars, exercises and professional and pedagogical practical work of students, all with the purpose of acquiring educational competencies. In the classes conducted in the form of lectures, students acquire basic theoretical knowledge in the field of early childhood and preschool education, as well as in areas that are closely related to growth, development and learning

of children in early childhood and at preschool age. Practical work, that is, exercises and professional pedagogical practice in kindergartens, is focused on the future professional development of students. It enables them to upgrade their theoretical knowledge, i.e. to connect direct practical work with theory in a way that combines their own previous experiences and activities. In this way, students can discover how competent they are when it comes to organizing activities in the educational group, leading the group, and establishing contacts with children, peers and parents [1].

After completing the undergraduate study program, students are awarded an academic title of Bachelor, while upon completion of the graduate study program, they are awarded an academic title of Master. The syllabus and study program include defined learning outcomes at the level of individual subjects. These outcomes describe the key competencies - the expected knowledge, understanding, acquired professional values and practical skills that students should have after graduation [2].

These competencies enable students social inclusion and employment, but also represent the basis of lifelong learning. Within the professionalization of the education process of educators and the reform, processes of introducing standards in the form of competencies into the entire vertical organization of education are underway. Innovations are introduced in the program of teacher and educational studies by applying the CROQF. It is a project of national importance because the project participants are almost all higher education institutions in the Republic of Croatia that provide education for future preschool educators. The aim of the project is to improve the quality of initial and lifelong education of preschool educators, so it is expected that the issue of harmonization of study programs and the introduction of standards in the form of competencies into early childhood education will follow the demands of modern times.

In the following sections, the research methodology and the results of the student assessment of the level of mastery of competencies are presented.

2. METHODS AND MATERIALS USED FOR RESEARCH

2.1. Aim and hypothesis of the research

The aim of the research was to determine how part-time students in the final year of undergraduate study program Early Childhood and Preschool Education at the University of Slavonski Brod, Department of Social Sciences and Humanities, assess the level of mastery and satisfaction with the competencies acquired in undergraduate studies. Preschool educators' competencies are based on Qualification Standards [3], which define six sets of learning outcomes: play, child learning and development, curriculum design, learning environment, collaboration with family and community, professional development, reflection and self-reflection. The following research hypotheses derive from the stated research goal:

H1. Students are satisfied with the level of their professional competencies after completing their undergraduate studies.

H2. Older students will have a higher assessment of competencies.

H3. Students employed in kindergartens will have a higher assessment of competencies.

2.2. Research participants

The research was conducted at the end of the academic year 2021/2022 at the University of Slavonski Brod, on a sample of part-time students who are in the final year of the undergraduate study program Early Childhood and Preschool Education or who have finished it. Out of the total number of students (136 students in two academic years), 121 students (89%) participated in the research. All students are female. Table 1 shows the number of students by age, and Table 2 by employment.

Table 1. Number of students by age

Age of students	N	%
< 30 years	88	72.7
> 30 years	33	27.3
∑	121	100

Table 2. Number of students by employment

Employment	N	%
Unemployed	42	34.7
Employed in a kindergarten	56	46.3
Employed elsewhere	23	19.0
∑	121	100

2.3. Research instrument

The questionnaire used in the research consisted of two parts. The first part of the questionnaire contained questions about the socio-demographic characteristics of the respondents. The second part of the questionnaire contained two types of questions. Likert-type questions on a scale from 1 to 5 (1 = undeveloped competencies, 2 = underdeveloped competencies, 3 = moderately developed competencies, 4 = developed competencies, 4 = fully developed competencies) examined the self-assessment level of respondents' competencies in six sets of learning outcomes (play, learning and child development, curriculum design, learning environment, cooperation with family and community, professional development, reflection and self-reflection). Each set of learning outcomes also contained one open-ended question to give the respondents an opportunity to explain their answers.

An instrument for assessing the level of professional competencies of the respondents was developed for the purposes of this research. The questionnaire was available in digital form and was filled in voluntarily and anonymously by the respondents. A reliability test was conducted to confirm the reliability of the research instrument. The Cronbach alpha reliability coefficient for this study was 0.9.

3. RESULTS AND DISCUSSION

3.1. Descriptive statistics of selected dimensions of examined variables

The respondents assessed the contribution of the undergraduate study program Early Childhood and Preschool Education to the development of specific professional competencies based on the learning outcomes of the course during all three years of study. Overall satisfaction with the study was highly rated by students (M = 4.39; SD = .48), which confirmed the first research hypothesis. The assessment of satisfaction level by areas is shown in Table 3.

Table 3. Assessment of student satisfaction with the level of competencies in individual areas

Areas of learning outcomes	N	M	SD
Play, learning and child development	121	4.33	.55
Learning environment	121	4.48	.50
Curriculum design	121	4.22	.61
Reflection and self-reflection	121	4.41	.57

Collaboration with family and community	121	4.53	.54
Professional development	121	4.38	.59

Respondents believe that they have mostly developed competencies in the field of Cooperation with Family and Community (M = 4.53; SD = .54). The National Curriculum for Early Childhood and Preschool Education [4] contains the principle of cooperation and partnership of the institution for early childhood and preschool education with parents and the broader community. These competencies are contained in the outcomes of the course Family Education and Partnership with Parents for Cooperation with Families. Cooperation with the community includes cooperation with primary school. In the assessment of this competence, 54.3% of students assess the developed competencies very highly. In their answers to open-ended questions, in which they explained their assessment, students state that there are few examples of cooperation between kindergarten and primary school and they lack the competencies to develop this cooperation. Normally, students develop competencies for this type of cooperation throughout several courses (Psychology of Learning and Teaching, General Pedagogy, Pedagogy of Early Childhood and Preschool Education). This principle emphasizes the need to ensure direct, quality and encouraging communication between parents and preschool educators [5, 6]. In this way, preschool educators learn about children and gain insight into their strengths, interests and needs and adjust the environment of the institution to the child's family culture accordingly. Communication competencies are represented in the outcomes of the courses Pedagogical Communication, Croatian Language and Communication and Language Games. Scientific research [7, 8, 9] has confirmed the importance of cooperation between preschool educators and parents for child development. The authors, Petrović-Sočo [10] and Ljubetić [11], emphasize the importance of quality and continuous relationship, the clearly defined common goal and the importance of context and time in which this collaboration takes place. Scientific literature [5, 11, 12, 13, 14, 15] lists various modalities of cooperation that change over time and adapt to the needs of preschool educators and parents. The literature [5, 6, 14, 15] also discusses the competencies of preschool educators for successful cooperation. Preschool educators improve their competency for cooperation with parents during their professional development, through various forms of formal (workshops, conference presentations, professional events, reading professional literature) and non-formal (independent research on the topic) learning.

Students also rate very highly the level of their competencies in the field of Learning Environment (M = 4.48; SD = .50). This area encompasses both the spatial-material and the social environment in the kindergarten, in which a child in early childhood and at preschool age spends time. Competencies in this area are included in the course Integrated Preschool Curriculum in the second and third year of study and in Professional practice during all three years of study. In the individual assessment in this field, 45.7% of students assess very highly the competencies they have gained for identifying the culture of a kindergarten, which is the lowest percentage of students in this field. Culture is the accumulation of many individual values, norms, attitudes and beliefs, rituals, history, traditions, etc., which make unwritten rules about how to think, feel, behave and act [16]. There is little content in this area, and there are few stated learning outcomes in the courses as well. In their answers to open-ended questions, students also mention the insufficient representation of content for working with children with disabilities and the possibility of preparing the environment for them. Students can develop the competencies related to this area in the course Pedagogy of Children with Special Needs. However, this type of content should be included in several courses and learning outcomes. The contemporary scientific literature emphasizes the development and variability of the curriculum [17]. Design of such curriculum requires a rich, pedagogically prepared environment, a quality social context and a democratic structure of the educational institution. The conditions prepared in this way enable the satisfaction of individually and developmentally different interests and needs of children and the development of their potential in the learning process. All the requirements mentioned above have their foundations in

constructivism and social constructivism of the great scientists and founders of these theories of learning, Jan Piaget and Lev Semyonovich Vygotsky [18, 19]. Vygotsky recognized the importance of peer interaction and collaboration in learning. His socio-cultural attitudes emphasize the importance of building the knowledge of a child who is helped by peers who are more mature and adult [20]. The educator is an important factor that regulates the environment and encourages the upbringing and development of children. Preschool educators' approach to children's learning, learning environment and relationships with and among children depend on the image of the child they have. This image is built and developed by students throughout all years of study, by connecting the pedagogical practice with contemporary theory.

Reflection is the student's ability to think about pedagogical practice, review it, evaluate it systematically and make decisions on how to act [21]. It involves conversations and discussions among participants in an effort to reconstruct the meaning of certain situations and to create a basis for revising the plan [12]. Conversation reveals how an individual thinks and expresses feelings and values. Conversations ensure that students listen to each other, work in a team and respect different perspectives. Reflective dialogue is creative, caring and critical [22], but reflection is much more than conversation. It includes thinking, reviewing, systematic evaluation and decisions on new activities. Students develop the ability to reflect on courses and assess highly this ability (M = 4.41; SD = .57). The need to reflect on and analyze experiences, and examine values and pedagogical practice is necessary in the development of practice and curriculum. Therefore, students should practice this skill, either in groups (as learning communities) or individually (as self-reflection) [23]. Individually, students are least satisfied with their competencies in the analysis and evaluation of elements of the educational process (47.3% of students show a high level of competencies) and with application of their skills of reflection and self-reflection (48.9% of students show a high level of competencies). The learning outcomes in which reflection is represented are included in the course Integrated Preschool Curriculum. This area encompasses the competencies of digital literacy that students need in the process of reflection and self-reflection when presenting their practice and its analysis. Students develop this competency in the course Computer Literacy. Communication skills for reflection, democratic dialogue and debate are acquired in several courses in the field of communication (Pedagogical Communication, Croatian Language and Communication and Language Games).

Preschool educators in the Republic of Croatia have the obligation of continuous professional development, i.e. to follow a development program prescribed by the competent Ministry. Professional development implies continuous learning in order to improve their teaching practice, and it contributes to the level of quality of the curriculum for Early Childhood and Preschool Education [24]. Education is a complex profession, and it implies continuous professional development, autonomy and responsibility [25]. Students are prepared for this development during initial education, and in this research, this competence was assessed lower than the previous ones (M = 4.38; SD = .59). The problem for students (48.8%) is to present the work done in the kindergarten to parents, co-workers and other participants in professional meetings and to explain the basic assumptions of professionalism and professional identity (48.1% of students). Students can develop these competencies in the course Methodology of Pedagogical Research, where they develop their competencies for research in pedagogical practice and the study of professional and scientific literature. The Family Education and Partnership with Parents course enables students to prepare for meetings with parents and workshops for parents where they share their professional knowledge and thus develop professionally. Competencies for presenting the work done in a kindergarten will be developed by students during their professional development in kindergartens.

Play is a key activity for children, and it helps them to get to know the world, build relationships, develop social skills and improve cognitive abilities [19]. The significance of play for the overall development of a child is unquestionable. Competencies involving play, learning and child development are included in all courses during the study, and it is alarming that these competencies took next to the last place in student assessment (M = 4.33; SD = .55). In their answers to open-ended questions, students provide a number of explanations, the most

common of which is a need for more hours of practical work that allows students to connect theory with practice and question the values on which the practice is based.

The curriculum for Early Childhood and Preschool Education is open and dynamic, and it is constantly developing. It is complex due to the fact that education, care, protection and education of children in early childhood and at preschool age cannot be separated. In the development of this curriculum, it is necessary to take into account the overall quality of life of children in an institution for early childhood and preschool education. In addition to the complexity of the educational process in the institution for early childhood and preschool education, there are interrelationships between educators, children, parents and the wider social context [26]. In the contemporary literature, the context in which the curriculum is implemented and the specifics of learning of children in early childhood and at preschool age are emphasized. In order to develop the curriculum for Early Childhood and Preschool Education, it is important to analyze the initial state and find the ways to introduce changes. Due to this complex approach, Curriculum design as a competence is at the last level of assessment of student competences (M = 4.22; SD = .61), although this competence is included in the outcomes of several courses (Integrated Preschool Curriculum, General Pedagogy, Early Childhood and Preschool Education). In addition, this area includes preschool curricula design, for which students feel they have a low level of competencies, according to their answers to open-ended questions. In these responses, they also mentioned that they do not have appropriate competencies to prepare children for starting primary education or to implement preschool program. Individually, only 39.5% of students highly assess their competencies in identifying the key aspects of the child's educational needs, which is the basis for the development of activities in kindergarten. Also, a small percentage of students (41.1%) feel they have sufficiently developed competences to evaluate and implement special and alternative educational programs. These competences are developed through additional educational programs. During initial education, such content is covered in these two courses: General Pedagogy and Pedagogy of Early Childhood and Preschool Education. Kinesiology, art, language and communication, and research and cognitive areas are represented in most courses for all three years of study.

A T-test ($t = 0.46$; $p > .05$) was also performed, and it showed no statistically significant difference between older (>30 years) and younger respondents (<30 years) in terms of self-assessment of competencies. This rejects the second research hypothesis that older students (> 30 years old) will have a higher assessment of competencies.

One-way analysis of variance, ANOVA, was performed on the Employment variables and for each individual self-assessment of competencies. The results show that there is no correlation between the variables employment and play, learning and child development ($F = 1.09$; $p > .05$), learning environment ($F = .18$; $p > .05$), curriculum design ($F = .13$; $p > .05$), reflection and self-reflection ($F = .33$; $p > .05$), family collaboration ($F = .36$; $p > .05$) and professional development ($F = .36$; $p > .05$). This rejects the third hypothesis that students employed in kindergarten will have a higher assessment of competencies.

In conclusion, according to students, the study program Early Childhood and Preschool Education needs more content through which students will develop professional competencies in the field of working with children with disabilities, in the field of preschool, or preparing children for school and cooperation with primary school. Students also state that they need competencies to identify the culture of kindergarten, to identify key aspects of the child's educational needs and competencies to implement alternative programs. The skill of reflection and self-reflection is poorly represented in the learning outcomes of the course, and it is the basis for the development of critical thinking in students. Students will develop their professional identity through various forms of professional development, although initial education provides them with a foundation for this competence.

4. CONCLUSIONS

The study programs aim to enable students to independently apply and further develop the acquired knowledge, skills and attitudes upon completion of the study program. The competencies that students acquire during their

studies are the basis for professional work, development and lifelong learning. Therefore, it is extremely important to constantly improve and harmonize study programs in order to monitor changes and requirements of modern society. Self-assessment within self-evaluation is one of the important ways to measure the achievement of the outcomes of study programs. This research has shown certain shortcomings of the current study programs of educational studies from the perspective of students. The results of the research will serve as one of the indicators in which direction to move when designing new and modernizing old study programs.

5. REFERENCES

[1] M. Hmelak; J. Lepečnik-Vodopivec, Preschool teacher career and why individuals choose it. Innovative issues and approaches in social sciences 5(2) (2012), pp. 220-241.

[2] European Communities, Key competences for lifelong learning: European reference framework, https://www.britishcouncil.org/sites/default/files/youth-in-action-keycomp-en.pdf, last access 20/06/2022.

[3] J. Krstović; L. Vujčić; P. Pejić Papak, Qualification standards and improving the quality of study programs of educators and teachers (Standardi kvalifikacija i unapređivanje kvalitete studijskih programa odgajatelja i učitelja), Učiteljski fakultet Sveučilišta u Rijeci, Rijeka, (2016).

[4] Nacionalni kurikulum za rani i predškolski odgoj i obrazovanje, Narodne novine 5/2015.

[5] A. Jurčević Lozančić, Social competencies in early childhood (Socijalne kompetencije u ranom djetinjstvu), Učiteljski fakultet Sveučilište u Zagrebu, Zagreb, (2017).

[6] E. Rogulj, Educators' communication competencies, Challenges of cooperation. Development of professional competencies of educators for cooperation and partnership with parents (Komunikacijske kompetencije odgojitelja, Izazovi suradnje. Razvoj profesionalnih kompetencija odgojitelja za suradnju i partnerstvo s roditeljima), Alfa, Zagreb, (2018), pp. 111-144.

[7] J. L. Epstein; M. G. Sanders; B. S. Simon; K. C. Salinas; N. R. Jansorn; F. L. Van Voorhis, School, Family, and Community Partnerships: Your Handbook for Action, Thousand Oaks, CA: Corwin, (2002).

[8] N. Chavkin, Preparing educators for school-family partnerships: Challenges and opportunities, School-Family Partnerships for Children's Success, New York: Teachers College Press, (2005), pp. 164-180).

[9] G. Hornby, Improving Parental Involvement, London, New York: Continuum, (2000).

[10] B. Petrović-Sočo, A new paradigm of understanding the context of early childhood education, New paradigms of early childhood (Nova paradigma shvaćanja konteksta ustanove ranog odgoja, Nove paradigme ranoga odgoja) Filozofski fakultet Sveučilišta u Zagrebu - Zavod za pedagogiju, Zagreb, (2011), pp. 237-264.

[11] M. Ljubetić, From cooperation to partnership of family, educational institution and community, (Od suradnje do partnerstva obitelji, odgojno-obrazovne ustanove i zajednice), Element, Zagreb, (2014).

[12] G. Mac Naughton, Shaping Early Childhood, Learners, Curriculum and Contexts, Open University Press, London, (2003).

[13] K. A. Hansen; R. K. Kaufmann; K. Burk Walsh, Kindergarten curriculum (Kurikulum za vrtiće). Pučko otvoreno učilište Korak po Korak, Zagreb, (2004).

[14] V. Mlinarević; S. Tomas, Partnership of parents and educators - a factor in the development of a child's social competence (Partnerstvo roditelja i odgojitelja - čimbenik razvoja socijalne kompetencije

djeteta), Magistra Iadertina, 5(5) (2010), pp. 143-158.

[15] A. Višnjić Jevtić; I. Visković; E. Rogulj; K. Bogatić; E. Glavina, Challenges of cooperation: Development of professional competencies of educators for cooperation and partnership with parents (Izazovi suradnje: Razvoj profesionalnih kompetencija odgojitelja za suradnju i partnerstvo s roditeljima), Alfa, Zagreb, (2018).

[16] L. Vujičić, Research of the culture of an educational institution (Istraživanje kulture odgojno-obrazovne ustanove), Sveučilište u Rijeci, Mali professor, Zagreb, (2011).

[17] E. Slunjski, Beyond the framework, qualitative strides in understanding and shaping the preschool curriculum (Izvan okvira, kvalitativni iskoraci u shvaćanju i oblikovanju predškolskog kurikuluma), Element, Zagreb, (2015).

[18] D. M. Callejo Pérez; D. Adair Breault; W. L. White, Curriculum as spaces: aesthetics, community, and the politics of place, Peter Lang, New York, (2014).

[19] C. Gray; S. MacBlain, Learning theories in childhood, Sage, London, (2015).

[20] S. L. Krogh; K. L. Slentz, The early childhood curriculum, Lawrence Erlbaum Associates, Publishers, Mahwah, New Jersey, London, (2008).

[21] H. Guðjónsdóttir; S. R. Jónsdóttir; K. Rut Gísladóttir, Collaborative Supervision: Using Core Reflection to Understand Our Supervision of Master's Projects, Reflective Theory and Practice in Teacher Education, Springer, Singapore, (2017), pp. 3-26.

[22] I. Helleve, Online Learning Communities and Teacher Professional Development: Methods for Improved Education Delivery. Theoretical Foundations of Teachers' Professional Development, Online Learning Communities and Teacher Professional Development: Methods for Improved Education Delivery Hershey, New York: Information science reference, (2010), pp. 1-19.

[23] C. G. Powell; Y. Bodur, Teachers' perceptions of an online professional development experience: Implications for a design and implementation framework, Teaching and Teacher Education, 77 (2019), pp. 19-30.

[24] I. Siraj-Blatchford; K. Sylva; J. Laugharne; E. Milton; F. Charles, Monitoring and Evaluation of the Effective Implementation of the Foundation Phase (MEEIFP) project across Wales, WAG, Cardiff, (2006).

[25] J. Krstović, European perspective of teacher education or teacher education at the crossroads of European and national (Europska perspektiva obrazovanja učitelja ili obrazovanje učitelja na razmeđi europskog i nacionalnog), Pedagogijska istraživanja, 4 (2) (2007), pp. 269 – 282.

[26] M. Blaise; S.cRyan, Using critical theory to trouble the early childhood curriculum. Is it enough?, Curriculum in Early Childhood Education, Re-examined, Rediscovered, Renewed, Routledge, New York, (2012), pp. 80 – 92.

The effect of flipped learning method on the level of motor knowledge aquisition in primary school

T. Vidranski [a], I. Vrbik [a], P. Otković [b]

[a] University of Slavonski Brod, EDUDpt, Trg IBM 2,35000 Slav. Brod, Croatia, tvidranski@unisb.hr

[a] University of Slavonski Brod, EDUDpt, Trg IBM 2,35000 Slav. Brod, Croatia, ivrbik@unisb.hr

[b] University of Zagreb, Faculty of Kinesiology, Horvaćanski zavoj 15, Croatia, otkovic10@hotmail.com

Abstract

The main goal of this paper was to determine the effect of the flipped learning method on the level of acquisition of certain motor knowledge regarding the classic method. The research was conducted on 33 pupils of first graders in a rural elementary school, out of which, 16 boys and 17 girls aged 6 and 7 years. The pupils were divided in two groups: experimental – flipped learning method and classic method group. The variable sample was constructed of 6 motor tasks in order to examine motor knowledge: rope jump, forward role down the slope, free football toss, running over obstacles, shoulder stand and front crawl. After initial testing, three classes were conducted, after which the final testing was conducted with three independent evaluators. The analysis showed changes in variables rope jump, shoulder stand and forward crawl. The newly applied flipped learning method affected the higher level of acquisition of new motor learning tasks in relation to classical method.

Key word: „Flipped" learning method, Pupils' motivation, Motor learning, Acquisition, Information and communication technology

1. INTRODUCTION

Development and advancement, as well as the use of all technological aids in everyday life, accelerate and enhances communication, as well as execution of started actions and activities. The new modern environment applies to behavior of children and youth, who spend their free time more and more in passive and sedentary behavior, which causes less movement in humans, especially in children and youth [1]. Along the development and advancement of technology, the focus of new generations of students as well as their motivation and interest are steered towards that area. The adjustment and necessity of use of information and communication technologies that we all use in everyday activities should also be used in teaching process. Whenever there is a purpose and opportunity to integrate a teaching content into a digital world, a teacher allows their students a teaching process in which their education will be productive and in an adequate extent, will be motivating for the students for further work and development, as well as satisfying their needs which in the end will make the teaching process interesting and attractive in contrast of traditional teaching. During PE classes it is necessary to favorably use methods that are still not quite in the curricular system, but have a substantial impact on student's motivation before and during the classes, as an important factor connected with motor learning. According to recent studies, results show that motivation for PE participation decreases with age, and that there

are some indicators for different methods development which should change the current situation [2]. The praxis of information transition, when it comes to PE, usually consists of a task description and live demonstration, but from around one decade ago, different methods which use technological advancement and allow significantly better learning and acquisition of motor skills are being used. The ability of task demonstration is considered to be the most efficient factor in the learning process, therefor for the short-term information transition it is recommended for both coaches and teachers [3]. It is quite obvious that one learns observing others [4], and that along the standard live demonstration method, other methods that enhance learning and acquisition of motor skills should be used. In the research which dealt with comparison of model video demonstration with model point light video demonstration, the usefulness of performance video demonstration has been confirmed [5,6], and has not been confirmed in other research [7]. Moreover, the usage of model video demonstration of the performance in comparison to some other methods has been confirmed in research [8,9,10,11,12]. According to the PE curriculum the main goal of the PE is to enable students to apply theoretical and motor knowledge which allow independent physical exercise in order to accomplish higher level of quality of life, and also to efficiently change dimensions and develop skills which directly ensure health as an irreplaceable factor of all human activities [13]. In order to make PE classes more productive, primary goal was to fresh up the class with new methods which will along the certain physical features provide also the motivation of pupils for active participating in the class. Along the other already used methods, there is also a different method of teaching: the flipped classroom. Flipped learning is a method that can include the preparation of students for the class by watching published videos on a certain platform about the next theme that will be done on the next class. It means that the video has some explanations from the teacher and demonstration of the activities, along with the explanation of physiological changes and responses which appear during the activity execution, as well as the impact on personal health. At the beginning of the class, the pupils already know how the class or a particular part of the class will look like, which allows them to individually start certain activities without the teacher's guide. Researchers stated that switching the PE content on online platforms and using information and communication technology gives positive outcomes since it widens the time spent on practical activities and the time the teacher gives feedback to pupils [14]. Although there is a risk of students coming unprepared to the class, for the pupils who didn't quite understand the homework, the researchers nevertheless encourage innovative models of learning such as flipped learning as a possible answer [15,16]. The primary goal of this research was to explore the impact of the new teaching method in the educational process – the flipped learning method, and its influence on the level of acquisition of certain motor tasks at pupils in primary school.

2. METHODS

2.1. Participants

In this research, 33 primary school pupils participated, out if which 16 boys and 17 girls, aged 6 and 7 years old. The pupils were divided into two groups. Experimental group consisted of 11 boys and 6 girls, while the control group consisted of 11 girls and 5 boys.

2.2. Variables sample

The sample of variables was constructed from 6 motor tasks in order to investigate motor knowledge. The variables were: rope jump, forward roll down the slope, free football toss, running over obstacles, shoulder stand and front crawl.

2.3. Experimental procedure

Initial and final testing were carried out with the three evaluators. Before the initial testing, the written criterion was established regarding the initial and final testing for every variable. After the initial testing, the pupils were randomly divided into two groups, concerning the method used (experimental group – flipped method, and control group – classical method). Both groups carried out three PE classes learning and acquiring motor knowledge before the final

testing. Control group carried out the program of classical method of learning during the main A-part of the class. In that method, the teacher at the beginning of the main A part of the class explains and demonstrates motor tasks and methodical exercises and the pupils don't know what will they be learning on that particular class until it starts. Experimental group carried out the new flipped learning method of learning in the main A-part of the class. According to the method, the pupils receive a video clip before the class, with explained and demonstrated motor tasks and methodical exercises which are to be done on the next PE class. At the beginning of the A-part of the class, instead of teacher's explanation and demonstration, the pupils learning by this method immediately start with task. During this experiment, the pupils of experimental group received the video clip on the YouTube channel as a part of the homework, four days before the actual PE class. For every class separate video clip was made. The other parts of the class, the pupils spent in the same way, doing same exercises, on the same day and at the same time (same hour in their schedule), in order to have same conditions for both groups. After three days of motor task acquisition, the pupils underwent the final testing which was carried out by the same criteria as the initial testing by the same evaluators.

2.4. Statistical analysis

The data sample was analyzed by statistical software program Statistica 10.0. Basic descriptive parameters were calculated in all variables (mean, standard deviation, minimal and maximal result), in initial and final testing for both groups of subjects. In order to establish the differences in the results between groups in initial and final testing, t-test for independent samples was used. In order to establish the differences between initial and final testing within groups t-test for dependent samples was used. Furthermore, in order to establish effect size in obtained differences, Cohen's index of effect size was calculated. In order to establish reliability and homogeneity of the evaluators, the method of internal consistency of Cronbach's alpha was used as well as the average correlation between the evaluators (AVR).

3. RESULTS

Table 1. Descriptive parameters of variables in both groups.

Experimental	N	X	SD	Min.	Max.
Running over obstacles Initial	17,00	3,04	0,50	2,00	4,00
Running over obstacles Final	17,00	3,49	1,72	0,00	5,00
Forward roll Initial	17,00	2,65	0,93	1,00	4,00
Forward roll Final	17,00	3,51	1,76	0,00	5,00
Football Initial	17,00	3,00	0,65	1,33	4,67
Football Final	17,00	3,65	1,77	0,00	5,00
Control	N	X	SD	Min.	Max.
Running over obstacles Initial	16,00	3,17	0,64	2,00	4,67
Running over obstacles Final	16,00	3,38	1,41	0,00	4,67
Forward roll Initial	16,00	2,27	1,08	1,00	4,00
Forward roll Final	16,00	2,85	1,52	0,00	4,67
Football Initial	16,00	2,52	1,05	1,33	5,00
Football Final	16,00	3,33	1,47	0,00	5,00
Experimental	N	X	Min.	Max.	SD
Rope jump Initial	17,00	1,76	1,00	4,00	1,04

Rope jump Final	15,00	4,33	3,00	5,00	0,71
Shoulder stand Initial	17,00	3,14	1,33	5,00	1,19
Shoulder stand Final	15,00	4,64	3,33	5,00	0,51
Front crawl Initial	17,00	3,04	1,67	4,00	0,63
Front crawl Final	15,00	4,58	4,00	5,00	0,41
Control	N	X	Min.	Max.	SD
Rope jump Initial	16,00	1,31	1,00	4,00	0,80
Rope jump Final	14,00	2,98	1,67	5,00	0,92
Shoulder stand Initial	16,00	2,83	1,67	4,33	0,89
Shoulder stand Final	14,00	3,74	2,33	5,00	0,87
Front crawl Initial	16,00	3,08	1,67	4,33	0,76
Front crawl Final	14,00	3,36	2,00	4,33	0,65

N-subjects; X-mean; SD-standard deviation; Min.-minimal result; Max.-maximal result

Table 1. shows descriptive parameters for both groups in initial and final assessment of motor knowledge of the primary school first graders in 6 variables. The results of mean in both groups in initial testing proves equal knowledge in performance of all motor activities. In the variable jump rope, mean value is 1,31, while the mean value of the experimental group in the same variable is 1,76. The biggest aberration is seen in the variable free football toss, where the mean value of the control group is 2,52, and in the experimental group 3,00. Since this result is still considered to be for the grade good (3), it can be concluded that all deviations are within one grade. The smallest deviation was present at the variable front crawl, and the value was 0,04 (3,08 in control group, according to 3,04 in experimental group). Deviations in most variables were within one grade. There was a slightly bigger deviation in the variable running over obstacles (in experimental group 4, and in control 4,67), and also in the variable shoulder stand in experimental group in the final testing where the minimal grade was 3,33, and in control group the minimal grade was 1,67. It can be concluded that in initial testing both groups were equally graded. Furthermore, since most of the deviations, which concern the descriptive parameters of the initial testing in a certain variable, did not differ in more than one grade, it can be concluded that both groups started the program with the same level of motor knowledge acquisition.

Table 2. shows the results of the administered t-test for two groups of subjects – control and experimental with the established subject differences in initial and final testing.

Table 2. The results of the t-test for independent samples.

	X E	X K	t-value	p
Running over obstacles Initial	3,04	3,17	-0,64	0,53
Running over obstacles Final	3,49	3,38	0,21	0,84
Forward roll Initial	2,65	2,27	1,08	0,29
Forward roll Final	3,51	2,85	1,14	0,26
Football Initial	3,00	2,52	1,59	0,12
Football Final	3,65	3,33	0,55	0,59
	X E	X K	t-value	p
Rope jump Initial	1,76	1,31	1,39	0,17
Rope jump Final	4,33	2,98	4,46	0,00

Shoulder stand Initial	3,14	2,83	0,83	0,41
Shoulder stand Final	4,64	3,74	3,45	0,00
Front crawl Initial	3,04	3,08	-0,18	0,86
Front crawl Final	4,58	3,36	6,13	0,00

X E-mean Experimental group; X K-mean Control group; t- t value, p- level of significance

The results of the independent t-test in the variables rope jump, shoulder stand and front crawl in initial testing didn't show significant differences, while in the final testing they were established. The higher level of motor task acquisition in stated motor tasks was obtained in the experimental group.

In order to establish differences within groups, t-test for dependent samples was carried out and the result are presented in the Table 3.

Table 3. T-test for dependent sample.

Experimental Rope jump	X	SD	Diff.	t	P
AS Initial	1,87	1,07			
AS Final	4,33	0,71	-2,47	-9,21	0,00
Control Rope jump	X	SD	Diff.	t	P
AS Initial	1,36	0,85			
AS Final	2,98	0,92	-1,62	-8,63	0,00
Experimental Shoulder stand	X	SD	Diff.	t	P
AS Initial	3,22	1,25			
AS Final	4,64	0,51	-1,42	-5,87	0,00
Control Shoulder stand	X	SD	Diff.	t	P
AS Initial	2,86	0,94			
AS Final	3,74	0,87	-0,88	-7,10	0,00
Experimental Front crawl	X	SD	Diff.	t	p
AS Initial	3,07	0,64			
AS Final	4,58	0,41	-1,51	-8,50	0,00
Control Front crawl	X	SD	Diff.	t	p
AS Initial	3,12	0,78			
AS Final	3,36	0,65	-0,24	-1,38	0,19

X-mean; SD-standard deviation, t-t value; p-level of significance

The results in the Table 3. show statistically significant difference within every group in initial and final testing of every variable. The exception is the front crawl variable in the control group where the t value is -1.38, which indicates that no statistically significant difference between the initial and final testing was observed in this group. T values of other variables are highly above limit values, therefore it can be concluded that differences within the groups in each specific variable were significant. This is considered to be normal, considering both groups spent 3 classes where they acquired certain motor task before the final testing. After obtained statistically significant differences by groups, an evaluation was made in order to find out how big this shift of experimental group is in relation to control group. In that way we obtained the real difference between classical and flipped method, and also how much the flipped method influenced the level of acquisition in relation to classical method. In order to establish the differences in shifts in both groups, Cohen's index of effect size was used. By this method, all results (effect size), above the 0,8 are

considered to have the bigger shift of the experimental group in relation to control. The effect size for the rope jump variable was 1,46, while it was slightly lower for the variable shoulder stand (1,02). The highest result was in the variable front crawl and valued 1,84. It can be concluded that big shifts happened in the results of final testing of the experimental group in relation to control group, and that higher number of pupils of the experimental group got higher grades in relation to the control group, and also had bigger shift in motor task acquisition in relation to initial testing in control. In order to measure reliability, i.e. the three evaluators, the method of internal consistency was used. In the method of internal consistency all values were expressed through Cronbach's alpha coefficient, and all values over 0,7 state high reliability. High reliability confirms measurement accuracy between evaluators, their adherence with the given criteria and non-bias grading. In order to assess homogeneity, the method of average correlations between evaluators (AVR) was used.

Table 5. represents the reliability results (Cronbach's alpha) and homogeneity (AVR) in the variables rope jump, shoulder stand and front crawl.

Table 5. The results of internal consistency and average correlation between evaluators.

	Rope jump Initial	Rope jump Final	Shoulder stand Initial	Shoulder stand Final	Front crawl Initial	Front crawl Final
Cronbach's alpha:	0,95	0,97	0,90	0,90	0,75	0,87
AVR	0,88	0,92	0,79	0,78	0,56	0,69

Cronbach`s alpha- reliability coefficient; AVR- average correlation between evaluators

The table presents the reliability results far above the limit of 0,6. The lowest value (front crawl – 0,75) is considered to have satisfactory reliability since high levels of reliability presume 0,80 and higher [17]. The results of all other variables show high reliability of the evaluators. Homogeneity coefficient which was estimated by average correlation between evaluators (AVR) ranges from 0,56 in initial testing of motor task front crawl, to 0,92 in final testing of motor task rope jump. The results of the values of homogeneity coefficient of all variables, except initial testing of front crawl, were satisfactory concerning the limit value of 0,70. Therefore, a conclusion can be drawn that the evaluators have high level of homogeneity and reliability, i.e., all the evaluators had the same criteria, valued the same subject matter which was the level of acquisition of a certain motor task.

4. DISCUSSION AND CONCLUSION

According to descriptive indicators as well as t-test for independent samples we can establish that there were no significant differences between pupils in both groups in initiative knowledge. Further analysis indicated changes in the final testing in the variables of rope jump, shoulder stand and front crawl. Moreover, significant changes of acquisition of all motor knowledge in both groups have been confirmed, except for the variable front crawl in the control group. The newly applied flipped learning method influenced the higher level of motor acquisition of the motor task in comparison to classical method. The testing approach which was precisely defined and equal for all participants, manifests through high level of homogeneity and reliability. The aim of this research was confirmed, and the flipped learning method affected the level of acquisition of motor knowledge more in comparison to classical method in pupils of first grade in elementary school which is in compliance with the research in which they defined the effect of learning new motor task [10,12].

Concerning the learning method in primary school, by using flipped learning method, students arrived to the PE class already knowing what they will be doing on that particular class, which allowed them more time to improve certain motor knowledge, and allowed teacher to spend more time on explaining the mistakes to some pupils, and the details of performance of certain motor knowledge. The effective time of exercising was higher due to the higher number of repetition of certain motor task.

Significant number of repetitions on cognitive level can affect the result in certain motor activity, as well as enhancing neuromuscular coordination [18].

Flipped learning method allows teachers to give more time to the pupils and more feedback about key elements of their performance during class without taking away too much time from practical activities in their work [15].

Also, the analysis of influence showed that flipped classroom brought positive effects on learning activities in pupils such as accomplishment, motivation, engagement and interaction [16]. The same has been confirmed in the research on the students where the questionnaire results showed the ability of student's independent curricular engagement in PE classes up to 83% [19].

The teachers should prepare their teaching materials in advance, steer the students to an active debate and exercise and in the end guide and correct the students according to their individual differences. The flipped classroom can be recommended as an optimal approach in teaching that can be integrated in the PE classes according to the obtained results [20].

This research has also some limitations concerning the conclusion and also recommendations for future research. This research was limited by the relatively small number of participants, but also by the age of the participants, since school and everything related to school is a new situation and environment for them, so a manipulation check would be helpful to check if the students did their homework (going through the content of the next PE class). In the next research a complete of all four grades of primary school should be concerned, in order to establish the differences according to the age and sex, as well as prior familiarity of certain motor tasks and also participation in other sport activities.

5. REFFERENCES

[1] I. Vrbik; A. Vrbik; M. Andrijašević, Recreational habits and possibilities of high school students. In V. Babić (ed.), Proceedings of the 27th summer school of kinesiologists in the Republic of Croatia, Kinesiology's answer to the modern way of life, Zadar 26. do 29. june 2019. Zagreb: Croatian Kinesiology Association, (2019), pp. 313-318 (e.g. in Croatian)

[2] J.S. Eccles; A. Wigfield; R.D. Harold & P. Blumenfeld, Ontogeny of children's self perceptions and subjective task values across activity domains during the early elementary school years. Child Development 64 (1993), pp. 830-847

[3] F. Maleki; P.S. Nia; M. Zarghami; A. Neisi, The Comparison of Different Types of Observational Training on Motor Learning of Gymnastic Handstand. Journal of Human Kinetics 26 (2010), pp. 13-19

[4] N.J. Hodges; A.M. Williams; S.J. Hayes; G. Breslin, What is modelled during observational learning?. Journal of Sport Science 25 (5) (2007), pp. 531-545

[5] R.R. Horn; A.M. Williams; M.A. Scott; N.J. Hodges, Visual Search and Coordination Changes in Response to Video and Point- Light Demonstrations Without KR. Journal Of Motor Behavior 37(4) (2005), pp.265-274

[6] S.T. Rodrigues; M.C. Ferracioli; R.A. Denardi, Learning a complex motor skill from video and poin-light demonstrations. Perceptual and Motor Skills 111 (2010), pp.307-323.

[7] R.R. Horn; A.M. Williams;M.A. Scott, Learning from demonstrations: the role of visual search during observational learning from video and point-light models. Journal Of Sports Sciences 20(3) (2002), pp. 253-269

[8] M. Guadagnoli; W. Holcomb; M. Davis, The efficacy of video feedback for learning the golf swing. Journal of Sports Sciencesi 20 (2002), pp.615–622

[9] M. Cheraghidocheshmeh; Y. Mossavi; D. Noroozy; M. Izadi, The comparison of effect of video-modeling and verbal instruction on the performance in throwing the discus and hammer.

Procedia Social and Behavioral Sciences 1 (2009), pp.2782-2785.

[10] I. Vrbik, Effects of different testing protocols on motor skill tests in primary education, Graduate Theses and Dissertations, Zagreb, Faculty of Kinesiology, University of Zagreb (2015) (e.g. in Croatian)

[11] I. Vrbik; T. Krističević; G. Sporiš; D. Madić, The effects of live and video demonstration on the early acquisition of a new motor task. Exercise and quality of life 7(2), (2015) pp. 30-40

[12] T. Vidranski; I. Vrbik; G. Sporiš; I. Arsić; N.Stojiljković, Gender differences in learning motor skills following a video demonstration in primary school children. Facta Universitatis, Series: Physical education and sport 18 (2), (2020), pp. 283-293

[13] B. Neljak, Kinesiological methodology in primary and secondary education, Zagreb: Gopai d.o.o. (2013). (e.g. in Croatian)

[14] C.M. Killian; T.N. Trendowski; A.M. Woods, Students' perceptions of the use of flipped instruction in a university physical activity course. Poster presented at the 2016 AIESEP International Conference, 8–11 June, Laramie, WY, USA, (2016).

[15] O. Østerlie, Flipped learning in physical education: Why and how? In D. Novak, B. Antala, & D. Knjaz (Eds.), Physical education and new technologies Zagreb: Croatian Kinesiology Association (2016), pp. 166-176

[16] Z. Zainuddin; S.H. Halili, Flipped classroom research and trends from different fields of study. The International Reviewof Research in Open and Distributed Learning 17 (2016), pp. 313-340

[17] K. Momirović; J. Štalec; B. Wolf, (1975). Pouzdanost nekih kompozitnih testova primarnih motoričkih sposobnosti. Kineziologija, 5 (1975), pp. 169-192

[18] G. Sporiš; Z. Tomac; D. Omrčen; M. Baić; D. Harasin, Motor learning without external feedback when testing motor coordination. Sport Science4(1) (2011), pp.84-88

[19] Z.A. Bing, Survey analysis of the network flipped classroom model application in the optimization of the university physical education classroom system. Boletin Tecnico/Technical Bulletin 55(19) (2017), pp. 413-418

[20] T.H.C. Chiang; S.J.H. Yang; C.Yin, Effect of gender differences on 3-on-3 basketball games taught in a mobile flipped classroom. Interactive Learning Environments 27(8) (2019), pp.1093-1105

The farmers knowledge about legal regulations of plant protection in organic agriculture

S. Antunović [a], O. Živković [b], E. Štefanić [c], S. Rašić [c], M. Martić [d], Lj. Božić-Ostojić [a] and T. Benković-Lačić [a]

[a] University of Slavonski Brod, Trg Ivane Brlić Mažuranić 2, 35 000 Slavonski Brod, Croatia, santunovic@unisb.hr, ljbostojic@unisb.hr, tblacic@unisb.hr

[b] graduated of Biotechnical Department of University of Slavonski Brod, Trg Ivane Brlić Mažuranić 2, 35 000 Slavonski Brod, Croatia, ozana.zivkovic96@gmail.com

[c] Faculty of Agrobiotechnical Sciences Osijek J. J.Strossmayer University of Osijek, V. Preloga 1, 31 000 Osijek, Croatia, estefanic@fazos.hr, srasic@fazos.hr

[d] High school „M. A. Reljković", I. Cankara 76, 35 000 Slavonski Brod, Croatia, mirjana.martic1@skole.hr

Abstract

It is known that chemical plant protection products are the most effective against harmfull organisams. Although they are effective, their actions affect the environment in a bad way. Since consequences of the use of agrochemicals, it is increasingly encouraged farmers in an ecological way that is less harmful to nature, man and animals as well as enables the production of higher nutritional value food. This paper evaluates obtain survey data on the extent to which farmers are familiar with the legal regulations related to plant protection in organic agriculture. Based on a sample of a hundred respondents, the survey showed that about 70% of farmers are familiar with legal regulations, plant protection measures and allowed plant protection products in ecological agricultural production, while 46% believe that there are not enough of them in the Republic of Croatia.

Keywords: farmers, plant protection, organic agriculture, legal regulations

1. INTRODUCTION

There are three types of agricultural production: conventional, integrated and ecological. Conventional as the most prevalent in the world, it achieves maximum yields, but it is a big polluter of the environment and a drain on natural resources. About 16.7 million hectares which is half of Germany, is used for agriculture and some 285.000 farms grow crops in that area. Most farms (94%) operate on the conventional way which is characterised by the use of mineral fertiliser and chemical plant protection products [1]. According to Tirado, the definition of organic agriculture is: "Organic agriculture ensures healthy farming and healthy food for today and tomorrow, by protecting soil, water and climate, promotes biodiversity, and does not contaminate the environment with chemical inputs or genetic engineering" [2]. It is considered that organic agriculture is one that produces lower yields compared to conventional agriculture, but at the same time it is more profitable and environmentally acceptable, providing equally or more nutritious pesticide-free foods, and additional agroecosystem and social benefits. However, due to the yield gap between them, the differences in cost-

effectiveness are huge, so organic agriculture continues to be a minor alternative to conventional agriculture [3].

Legislatives that support organic farming have become widespread in Europe since the late 1980s in the context of agri-environmental and rural development measures [4].

In the period from 2013 to 2021, there is a growing trend of organic agricultural production in the Republic of Croatia. According to the National Bureau of Statistics, the number of organic agricultural entities increased from 1,608 in 2013 to 6,024 in 2021. In the same period, the total used areas increased from 40,660 ha to 121,924 ha. Looking at the share of areas under organic production in the total used agricultural areas, the increase was from 2.59% to 8.26%. [5].

According to the survey conducted in 2020 regarding organic agriculture in the Republic of Croatia conducted in 2020 of 100 surveyed farmers, 71% think that there are not enough organic agricultural producers, and 40% of them plan to switch to organic production [6].

The Ministry of Agriculture is in the process of drafting the National Action Plan for the Development of Ecological Agriculture 2023-2030 which aims to contribute to the preservation of the natural resources and biodiversity of the Republic of Croatia, as well as to reduce the impact of agriculture on the environment. It defines five specific goals and 40 measures. The fifth objective refers to the reduction of greenhouse gas emissions, the preservation of biodiversity, the preservation of soil, water and air from pollution from agriculture. The defined measures will try, among other things, to encourage agricultural producers to switch from conventional to organic production and provide them with the necessary education, counseling and informational support [7].

The plant protection in an ecological acceptable way implies the use of goods that are not harmful to humans and animals and whose effects do not pollute the environment on a short or long run. The choice of plant protection agents in organic agriculture is limited, compared to conventional agriculture, and therefore there is a greater risk of damages caused by harmful organisms on crops that are grown organically. The goal is to preserve the natural balance in the agro-eco system, and thus the natural enemies of harmful organisms in order to be able to control their numbers [8].

Preventive measures (crop rotation, cultivation of resistant varieties, proper fertilization with manure and green fertilization, selection of favorable locations) should work simultaneously to reduce harmful organisms and develop beneficial ones. Mechanical and physical measures are widely used tools in ecological protection. Alternative measures include the use of living antagonistic organisms or natural enemies and their products (biopesticides) as well as ecologically acceptable plant protection products (attractants and growth regulators) [8].

The availability of products that can be legally used in organic crop protection differs significantly among the Member States and there is a uniform list of 10 basic substances that can be used throughout the entire EU. The total number of qualified products per country varies from 11 in Lithuania to 576 in Italy [9].

The aim of this paper is to evaluate farmers opinions regarding legal regulations concerning plant protection in organic agriculture.

2. METHODS AND MATERIALS

The data was collected in 2020 through an anonymous survey. Farmers were asked to answer the questions regarding organic agriculture.

The introductory part of the survey covered the sociodemographic characteristics of the respondents (gender, age and level of completed education). Below are structured questions about farmers' familiarity with the current legal regulations related to the protection of plants in organic agricultural production.

One hundred respondents engaged in agricultural production participated in the research. The survey was conducted using the Google Form program interface, where basic statistical calculations were used, and the obtained results were presented in diagrams and tables.

3. RESULTS

Socio-demographic characteristics of respondents participated in the research are shown in Table 1. The respondents are mainly from Brod-Posavina County performing conventional agriculture.

Table 1. Socio-demographic characteristic of respondents.

	Variable	Percent
SEX	Male	61%
	Female	39%
AGE	< 25 years	37%
	26 – 55	40%
	> 55 years	23%
EDUCATION	Primary school	5%
	High school	46%
	Higher education	49%

When asked whether there is a clear legal regulation related to the protection of plants in ecological agricultural production, the majority of respondents answered in an affirmative (69%), and 31% in a negative way (Fig. 1.).

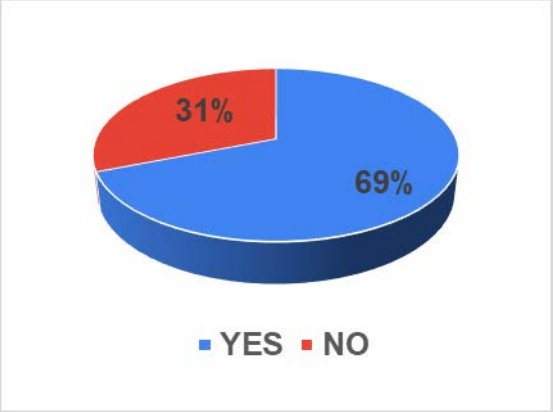

Fig. 1. Do you understand the legal regulations related to the protection of plants in organic agriculture?

The percentage of farmers familiar with the permitted plant protection measures in organic farming is 74%, and 36% are uninformed. (Fig. 2.).

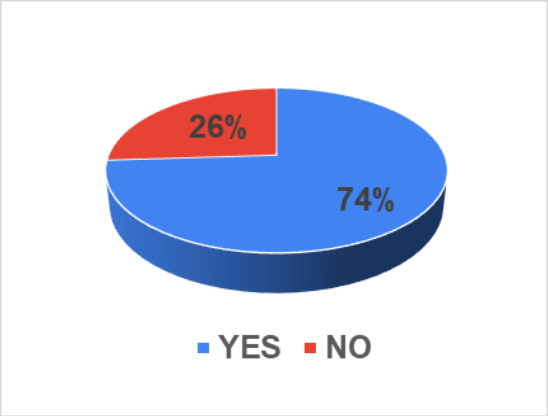

Fig. 2. Do you know which plant protection measures are allowed in organic agriculture?

When asked if they know which products can be used in organic farming, 71% of respondents answered yes, while 29% answered negatively (Fig. 3.).

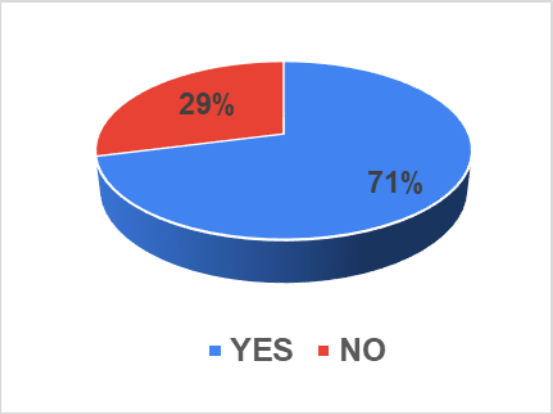

Fig. 3. Do you know which plant protection products can be used in organic agriculture?

26% of the respondents believe that there are enough plant protection products available in the Republic of Croatia, 46% of them answered that there are not enough, while 28% stated that they did not know (Fig. 4.).

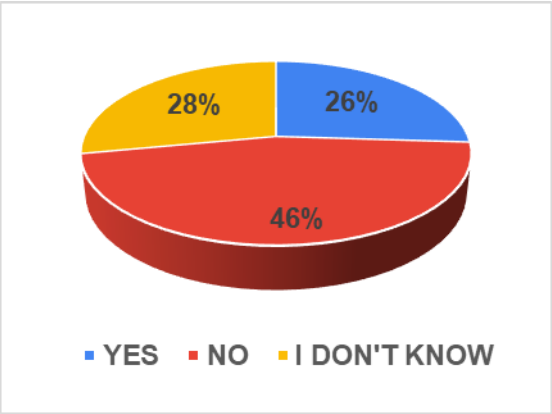

Fig. 4. Do you think that in the Republic of Croatia there are enough funds available for the protection of plants in organic agriculture?

Education on ecologically acceptable plant protection is considered useful by 82% of respondents, 4% consider it useless, and the remaining 14% do not know the answer (Fig. 5.).

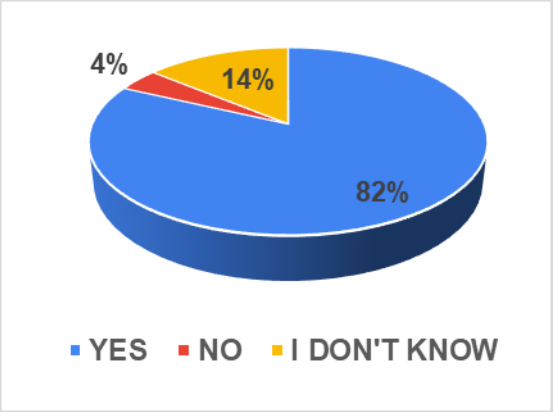

Fig. 5. Do you think that you would benefit from education about ecologically acceptable plant protection?

When asked about the timing of educations out of 100 respondents, 39% of them think that educations should be held before farmer's decision to switch to organic agriculture, 36% consider all the mentioned items important, 18% believe that occasional educations and educations during organic production would be useful, and 7% should be maintained during the transition period from conventional to ecological agricultural production (Table 2.).

Table 2. What do you think, when should education on permitted measures and available means for plant protection in organic agricultural production be held?

Offered answers	Percent
Before the decision to switch to organic agricultural production	39%
During the transition period from conventional to organic agricultural production	7%
Occasionally and during organic agricultural production due to knowledge about possible novelties	18%
All of the above	36%

Plant protection is easier to implement in conventional agriculture according to the opinion of 71% of respondents, in ecological agriculture (20%), and the remaining 9% do not know (Fig. 6.).

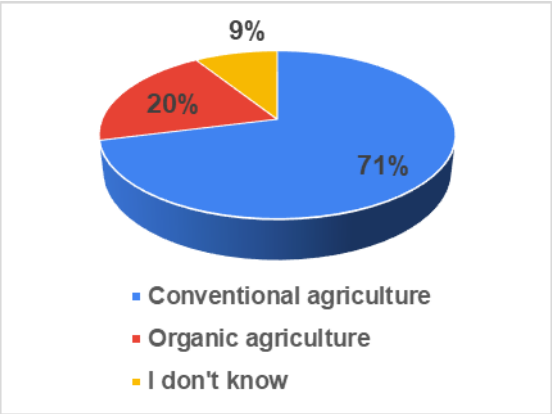

Fig. 6. The opinion of farmers in which type of agriculture is easier to implement plant protection.

The costs of plant protection are higher in conventional agriculture according to 37% of respondents, 54% believe that they are higher in organic agriculture, while 9% do not know the answer to this question (Fig. 7.).

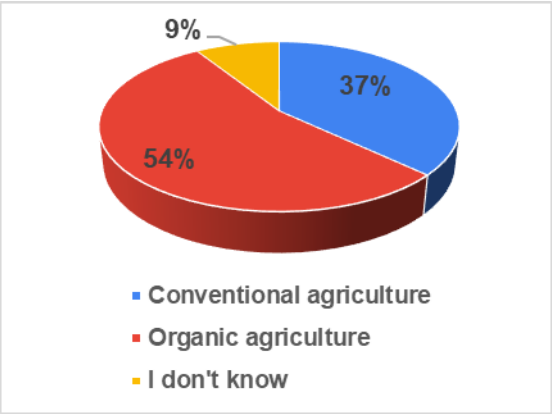

Fig. 7. The opinion of farmers in which type of agriculture the costs of plant protection are higher.

4. CONCLUSIONS

Ecological agriculture is a management method that strives to act in harmony with nature. As part of it, ecologically acceptable plant protection measures are not harmful to the environment, people and beneficial organisms. Care is also taken to preserve biological diversity and to minimize the disturbance of the established balance in nature.

Legal regulations related to plant protection in organic farming are clear to 69% of respondents. 74% of the respondents are aware of the permitted plant protection measures, and 71% of the respondents are aware of the available plant protection products, while 46% believe that there are not enough of them in the Republic of Croatia. The majority of respondents (82%) believe that they would benefit from education on environmentally friendly plant protection. Out of 100 respondents, 39% think that training on permitted measures and available prodacts of plant protection should be held before the decision to switch, while 36% both before and during the transition period and occasionally during ecological agricultural production due to novelty. Respondents believe that plant protection measures are easier to implement in conventional agriculture (71%) and that costs are higher in organic agriculture (54%).

5. REFERENCES

[1] T. Friche, S. Egerer, S. Matezki, C. Pickl, J. Wogram, 5-Point programme for sustainable plant protection, Environmental Sciences Europe 30, 8 (2018)

[2] R. Tirado, Defining Ecological Farming, Greenpeace Research Laboratories Technical Note 04/2009, (2009) https://www.greenpeace.to/publications/defining-ecological-farming-2009.pdf

[3] I. Tsvetkov, A. Atanassov, M. Vlahova, L. Carlier, N. Christov, F Lefort, K. Rusanov, I. Badjakov, I. Dincheva, M. Tchamitchian, G. Rakleova, L. Georgieva, L. Tamm, A. Iantcheva, J. Herforth-Rahmé, E. Paplomatas, I. Atanassov, Plant organic farming research – current status and opportunities for future development, Biotechnology & Biotechnological Equipment, 32:2, 241-260 (2018)

[4] N. Lampkin, Development of policies for organic agriculture. In: Powell, Jane and et al. (Eds.) Proceedings of the UK Organic Research 2002 Conference, Organic Centre Wales, Institute of Rural Studies, University of Wales Aberystwyth, pp. 321-324. https://orgprints.org/id/eprint/8313/1/lampkin_policies_organic_agriculture.pdf

[5] Republika Hrvatska, Ministarstvo poljoprivrede, https://poljoprivreda.gov.hr/ekoloska-poljoprivreda-96/96, last access 01/07/2022

[6] S. Antunović, O. Živković, Lj. Božić-Ostojić, E. Štefanić, K. Mirosavljević, T. Benković-Lačić, Ocjena stanja ekološke poljoprivrede u Republici Hrvatskoj prema mišljenju poljoprivrednika, Proceedings of 56th Croatian and 16th International Symposium on Agriculture, September 5 – 10, 2021, Vodice, Croatia

[7] Republika Hrvatska, Ministarstvo poljoprivrede, https://poljoprivreda.gov.hr/pristup-informacijama/e-savjetovanje/savjetovanje-

s-javnoscu-za-nacionalni-akcijski-plan-razvoja-ekoloske-poljoprivrede-2023-2030/5410, last access 01/07/2022

[8] A. Bokulić, Ž. Bundišćak, D. Čelig, B. Dežđek, D. Hamel, D. Ivić, M. Novak, A. Mrnjavčić, N. Nikl, N. Novak, V. Novaković, Z. Pavunić Miljanović, G. Peček, I. Poje, I. Prpić, T. Rehak, M. Ševar, M. Šimala, R. Turk, Priručnik za sigurno rukovanje i primjenu sredstava za zaštitu bilja, Ministarstvo poljoprivrede, Zagreb, (2015)

[9] E. Matyjaszczyk, Plant protection means used in organic farming throughout the European Union, Pest Management Science, Volume 74, Issue 3, Pages 505-510 (2018)

Analysis of consumer opinions and habits related to apple consumption

T. Benković-Lačić [a], B. Čuljak [b], R. Benković [a], S. Antunović [a], K. Mirosavljević [a]

[a] Biotechnical department, University of Slavonski Brod, Trg I. B. Mažuranić 2, 35000 Slavonski Brod, Croatia, tblacic@unisb.hr*, rbenkovic@unisb.hr, santunovic@unisb.hr, kmirosavljevic@unisb.hr

[b] graduate of Biotechnical department, University of Slavonski Brod, Trg I. B. Mažuranić2, 35000 Slavonski Brod, Croatia, bculjak@unisb.hr

Abstract

The successful sale of apple fruit implies a certain level of knowledge of consumer preferences and desires. The aim of the research was to determine the attitudes of young respondents about their preferences and behaviour in buying and consuming apples. Consumers voluntarily participated in the survey, and the questions were related to socio-demographic characteristics such as gender and age, respondents' preferences for colour, taste, size, and place of purchase and price of apples. Of the total number of consumers, 67.5% estimate that they eat between 10-20 kg of apples per year. Most consumers prefer the green colour of the fruit, 50% of them. The majority of consumers, 62.5% of them, prefer sweet and sour apples, and 55% of consumers prefer medium-sized apples. When examining consumers about their shopping habits, it was found that most of them buy in supermarkets (62.5%), and not a single consumer buys apple in specialized health food stores. When buying, the price of an apple is of medium importance to the majority of consumers (57.5%).

Keywords: apples, consumers, fruit production, survey

1. INTRODUCTION

Apple is a highly valued fruit species due to its aroma, shape, colour and smell, and is one of the most common fruit species in the diet in the world and in the Republic of Croatia. Successful sales and marketing of fresh apple fruit requires a certain level of knowledge of consumer preferences and perceptions, as the consumer is becoming increasingly demanding in the quality of apple fruit. Because of the quality, the consumer is willing to pay a higher price for the product. [1] Knowing customer preferences enables the industry, producers and breeding programs to choose new apple varieties. Visual appearance of apples was considered more important as a reason for purchase among consumers of Asian backgrounds, while previous experience was selected more often among consumers of European backgrounds as the reason for the purchase of apples. [2] The quality of apple fruit depends on its physical, chemical and organoleptic properties, and apple fruit has a high content of vitamins, sugars, dietary fibre and phenolic compounds. [3] When evaluating the quality of apple fruits, subjective and objective methods are applied. Subjective methods include sensory and visual-tasting evaluations of the fruit, and objective methods include analyses of the physical and chemical properties of the fruit. [4]

Apple is the most important fruit species in the Republic of Croatia, occupying 22% of the total area under fruit, and 36% of total fruit production. [5] In the Republic of Croatia, in

apple production, the most represented variety is Idared, which represents about 65% of production areas. In addition to the Idared variety, the Jonagold variety and its clones are grown in larger quantities and each of them occupies about 15% of the production area, and the Golden Delicious variety, which occupies about 10% of the production area. The remaining part of the assortment consists of: Melrose, Gala, Elstar, Gloster, Granny Smith and others. [6-7] When building new orchards, it is very important to follow the wishes of consumers. Consumers are an important factor in the creation of assortments, because commercial success of an individual variety can be predicted by the evaluation of fruit quality given by consumers. Also, consumers' tastes change over time, and this is also the reason why producers should listen to consumers' wishes and needs.

The aim of the research was to determine the tendencies of young consumers towards certain preferences, behaviour and habits in buying and consuming fresh apples.

2. METHODS AND MATERIALS USED FOR RESEARCH

The data in this research was collected using the survey method, and the survey was conducted on a sample of 40 respondents of the younger age group in Slavonski Brod. Respondents voluntarily participated in the survey. In the questionnaire, a group of questions were related to socio-demographic characteristics such as gender and age, as well as respondents' preferences for colour, taste, size, method of apple cultivation, as well as the importance of the origin of the apple, the place of purchase and the price of the apple. The survey questionnaire also consisted of questions about the assessment of one's own annual fresh apple consumption.

3. RESULTS AND ACHIEVEMENTS

The structure of consumers who participated in the survey according to socio-demographic characteristics is shown in Table 1. The structure of consumers by gender was 67.5% of male and 32.5% of female. The average age of the consumers was 23 years for men and 24 years for women.

Table 1. Sociodemographic characteristics of consumers

Gender	Men	67.5 %
	Women	32.5 %
The age of men	< 20 years old	7.7 %
	From 20 to 30 years	92.3 %
	> 30 years	0 %
The age of women	< 20 years old	14.8 %
	From 20 to 30 years	77.8 %
	> 30 years	7.4 %

Figure 1. shows the estimated annual consumption of apples in kg per consumer. The largest number of consumers, 67.5% of them, estimate that they eat between 10-20 kg of apples per year. This agrees with the available data on the average annual consumption of apples per inhabitant in the Republic of Croatia, which is 15 kg. [5] Only 12.5% of consumers estimate that they eat more than 20 kg of apples per year, while 20% of them estimate that they eat less than 10 kg of apples per year.

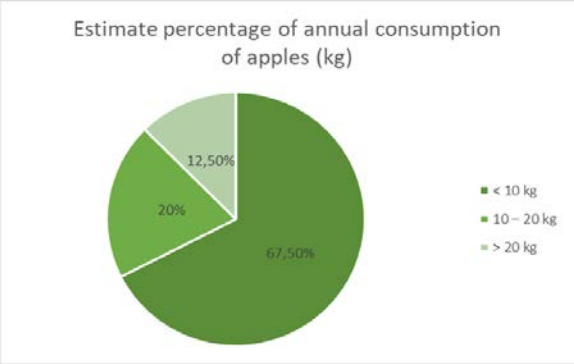

Fig. 1. Estimate percentage of annual consumption of apples (kg)

3.1. Assessment of preferences based on the appearance of apple fruit

Figure 2. shows consumers' preference for apple colour, and which colour of apple fruit they prefer and consume the most. Only 7.5% of consumers prefer yellow apples, 42.5% of them prefer red apples, while 50% of consumers prefer green apples the most. A younger consumer population with an average age of 23.5 took part in the survey, and the preference for green colour of apples is not surprising. In their research, Benković-Lačić et al. [7] concluded that the best rated fruits for young consumers are the variety Granny Smith, which has a green skin colour.

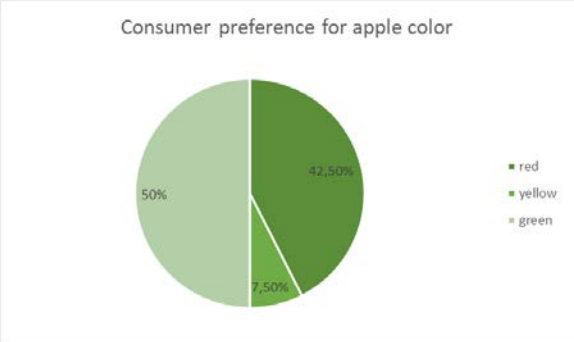

Fig. 2. Consumer preference for apple color

Figure 3. shows the assessment of consumer preferences according to apple taste. Most consumers, 62.5% of them, prefer sour-sweet apples, 22.5% of consumers prefer sweet apples, and only 15% prefer sour apples.

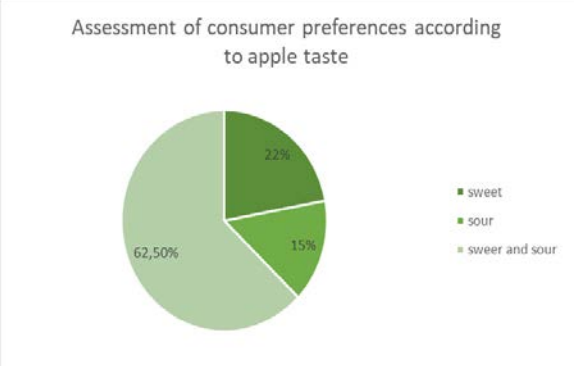

Fig. 3. Assessment of consumer preferences according to apple taste

Figure 4. shows consumer preference according to fruit size. Most consumers, 55% of them, prefer medium-sized apples, while 27.5% of consumers prefer small apples. Only 17.5% of respondents prefer large-fruited apples.

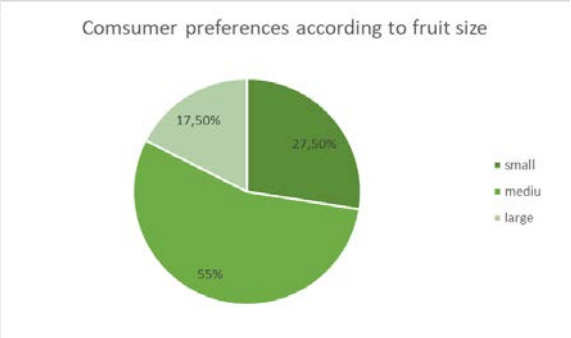

Fig. 4. Consumer preferences according to fruit size

3.2. Consumer buying habits

The survey examined consumer preferences about the importance of some shopping habits that encourage them to shop.

Figure 5. shows consumers' preferences according to the place of purchase of apples. The largest number of consumers buy apples in supermarkets (62.5%), 25% of consumers buy directly from the producer, while 12.5% of consumers buy at the market. No consumer buys apples from health food specialty stores, but this may be related to the lack of such stores in the study area.

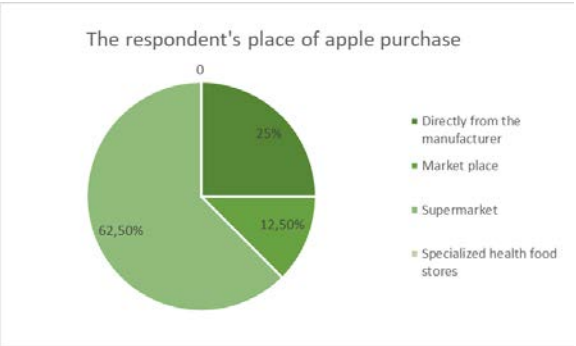

Fig. 5. The respondent's place of apple purchase

Figure 6. shows how important the price of apple fruits is to consumers when shopping. Price is moderately important to the largest number of consumers (57.5%), and 30% of consumers declared that price is very important to them when shopping. Only 12.5% of them declared that the price is not important to them when shopping, and for only 12.5% off them we

can conclude that the price does not affect their shopping habits.

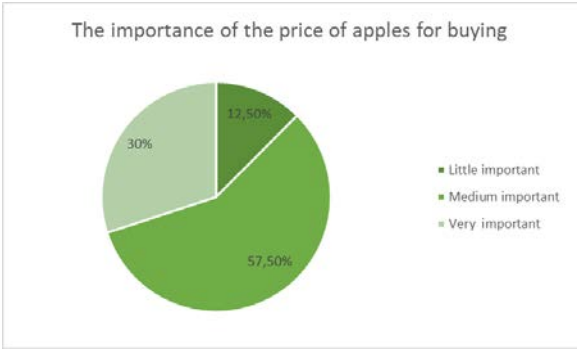

Fig. 6. The importance of the price of apples for buying

4. CONCLUSIONS

Fruit plantations are planted for several decades, and before planting or introducing a new variety to the market, it is important to know consumer preferences according to the organoleptic properties of the selected fruit. Consumer preferences can be found out by conducting various researches that include surveys.

The majority of the population that participated in the research was male (67.5%), while the female population was 32.5%. The average age of consumers was 23 years for men and 24 years for women. Out of the total number of consumers, 67.5% of them estimate that they eat between 10-20 kg of apples per year, and they mostly prefer the green colour of the fruit, even 50% of the total number of consumers. Most consumers, 62.5% of them, prefer sweet and sour apples, and 55% of consumers prefer medium-sized apples. When examining consumers about their shopping habits, it was found that most of them buy in supermarkets (62.5%), and not a single respondent buys apple in specialized health food stores. When buying, the price of an apple is of medium importance to the majority of consumers (57.5%).

5. REFERENCES

[1] Steenkamp, J.-B., van Trijp, H.C.M. (1996): Quality guidance: a consumer-based approach to food quality improvement using partial least squares. European Review of Agricultural Economics, 23: 195-215.

[2] Bejaei, M., Cliff, M.A., Singh, A. (2020): Multiple Correspondence and Hierarchical Cluster Analyses for the Profiling of Fresh Apple Customers Using Data from Two Marketplaces. Foods, 9: 1-14.

[3] Kolega, A. (1978): Prilog istraživanja i marketinga svježe jabuke u Jugoslaviji. Doktorska disertacija. Agronomski fakultet. Zagreb.

[4] Gliha, R. (1978): Sorte jabuka u suvremenoj proizvodnji. Zagreb, Radničko sveučilište Moša Pijade, 245 str.

[5] Krip, H. (2018): Situacijska analiza tržišta jabuka u Republici Hrvatskoj. Specijalistički rad, Poljoprivredni fakultet u Osijeku, Osijek.

[6] Cerjak, M., Vrhovec, R., Vojvodić, M., Mesić, T. (2014): Analiza hrvatskog tržišta jabuka. Zbornik radova 46. hrvatskog i 16. međunarodnog simpozija agronoma u Opatiji, pp. 311-314.

[7] Benković-Lačić, T., Antunović, S., Romanjek-Fajdetić, N., Japundžić-Palenkić, B., Mirosavljević, K., Musić, T. (2010): Potrošačka ocjena kvalitete plodova jabuke. Agroznanje, 11 (3): 197-202.

Cultivation of common and flower sage in different growing substrate

M. Blažinkov [a], M. Milanović [a], V. Ibraković [b], N. Romanjek Fajdetić [a], Lj. Božić-Ostojić [a]

[a] University of Slavonski Brod, Trg I. Brlić Mažuranić 2, 35 000 Slavonski Brod, Croatia, mblazinkov@unisb.hr

[b] High school "M.A. Reljković", I. Cankara 76, 35 000 Slavonski Brod, Croatia, vehid.ibrakovic@gmail.com

Abstract

The aim of this study was to determine the time period required for plant germination, growth and development of two types of sage under controlled conditions and different growing substrates. Common and flower species of sage were used in the research. Garden soil and universal substrate were used as substrates. The obtained results indicate that the flower sage has a faster plant and flower growth in the first year, while the common sage grows a bit slower and flowering in the second year. The obtained results indicate that sage has successfully growth on both types of substrate, but there are differences in sage species.

Keywords: common sage, flower sage, cultivation, substrate, growth and development

1. INTRODUCTION

Sage (*Salvia officinalis* L.) is a perennial evergreen plant and on of most commercially important species within family Lamiaceae. Sage leaves were used in medicine, which at the time of flowering have the largest amount of quality medicinal substances [1]. The main ingredient of the leaf is essential oil. Medicines made on the basis of sage are most often used in case of infectious and inflammatory processes. Sage tea can be used against sweating and tuberculosis and to boost immunity [1] [2]. Sage is also used in cooking as a spice and specially for preparing fatty dishes because it facilitates their digestibility.

Suitable soil for sage growth is humus, although different types of soil are suitable for it. It is not sensitive to the quality of the soil, but the best results on warm humus soils with a good water and air regime were obtained, considering that it requires a greater amount of moisture during initial development [3]. During the growth, sage uses all the nutrients from the soil, so fertilization and feeding are necessary for optimal plant growth [4]. It has been shown that the most suitable temperature for growth and development is 15-20°C. High daily temperatures enable better growth and development of sage [5] improve the quality and accumulate essential oil in the leaves. Snowless winters with frost can damage young sage plants, so it is recommended to mulch the crop after the second cut. Young plants from direct sowing require more moisture than older plants which tolerate drought [6].

In Croatia, we have several species of wild and cultivated sage: *S. nemorosa* L., *S. splendens* L., *S.sclarea* L., *S. prantensis*, *S. fruticosa* Mill. Common or Dalmatian sage (*S. officinale* L.) (Fig. 1.) is one of the most significant medicinal indigenus species in flora of eastern Adriatic coast, islands and Mediterranean karst of west Balkan [7]. Sage

biologically active compounds have broad range of medical activities, but the most important is essential oil which extremely complex mixture of different active ingredients [7]. Therefore, during cultivation, it is necessary to take care of the amount of essential oils in the sage [8] [9].

Fig. 1. Salvia officinalis L.

(https://upload.wikimedia.org/wikipedia/commons/5/5d/Salvia_officinalis_Habitus_DehesaBoyalPuertollano.jpg)

The most famous flower sage species is scarlet sage (*S. splendens* L.), originally from Brazil, brought to Europe at the beginning of the 19th century (Fig. 2.). It is grown as an annual plant because it does not tolerate cold. Various cultivars of scarlet sage, which differ in color of flower and height were cultivated. Seeds is sow in March and April in suny places and well-drained soil. Flower sage plants are decorative and primarily used in floriculture, landscape architecture and as decoration in parks.

The aim of this study was to determine the time period required for plant germination, growth and development of two types of sage under controlled conditions and different growing substrates

Fig. 2. Salvia splendens L. (foto M. Milanović)

2. METHODS AND MATERIALS USED FOR RESEARCH

In this research three species of sage were used, common sage (*Salvia officinalis* L.) and two types of flower sage (*Salvia farinacea* L., *Salvia splendens* L.). Nutrient substrate and garden soil as growing media were used. The plants were sowing in boxes filled with substrate. A universal substrate which is a mixture of humus and white peat enriched with microelements was used. Containers with sages were placed in a heated greenhouse. The temperature of the greenhouse was 20 °C to 25 °C, which is also the optimal temperature for sage germination. For the purpose of the research, the germination period of common and flower sage was monitored under the conditions of a heated greenhouse. After germination, the plants were transferred to an unheated greenhouse. The monitoring of the plants growth and development was determined in two types of growing substrates, i.e. part of the plants was transplanted into the garden soil after adaptation. The research parameters of sage growth and development were: plant height, number of branches, plant width, number of leaves and flowers.

3. RESULTS AND ACHIEVEMENTS

3.1. Growth and development of common sage

Common sage plants had a longer germination period than the flower species. It sprouted after 15 days and flower sage after 4 days from sowing. When the first leaves appeared on the common sage from the heated greenhouse, they were transferred to an unheated greenhouse and left for 10 days to create more leaves. They were in an unheated greenhouse for 10 days, during which the plants developed a pair of new leaves. They were transplanted from the container into pots and then into garden soil. The common sage had a longer period of sprouting than the flowering type. The average height of common sage in the garden soil was 20 cm, width 50 cm, the number of branches was 18 and the number of leaves was 174. In the first year of cultivation, no sage flowers has appired.

The average height of common sage in the substrate was 35 cm, width 20 cm, there were no flowers in the first year, the average number of branches was 8 and the average number of leaves was 63.

The number of branches, width and average number of leaves of common sage grown in garden soil was higher than plants grown in substrate, but the average height of sage grown in garden soil is smaller than sage grown in substrate. It is to be expected that the chemical composition of the substrate favors the growth of sage in height, but is not favorable for development of plants vegetative organs.

3.2. Growth and development of flower sage

Both flower sage types had faster growth and development than common sage. When the first leaves grew, they were placed in an unheated greenhouse. After 7 days, they were transplanted from the container into smaller pots filled with substrate. They were transplanted into larger pots after 10 days. When the plant grew and developed additional leaves, they were left in an open area. Flowered plants 30 cm high were transplanted into the garden soil. During the growing season, there was no need for treatment, because no pests were observed on the plants. After plants transplantation into the garden, the weeds around the plants were controlled by a mechanical method.

The average height of flower sage in the substrate *S. farinaceae* L. was 50 cm, width 7 cm, number of leaves 73, number of branches 2 and number of flowers 2. The average height of flower sage *S. splendens* L. in the substrate was 30 cm height, width 18 cm, number of leaves 22, number of branches 1 and number of flowers 1 (Fig. 3.).

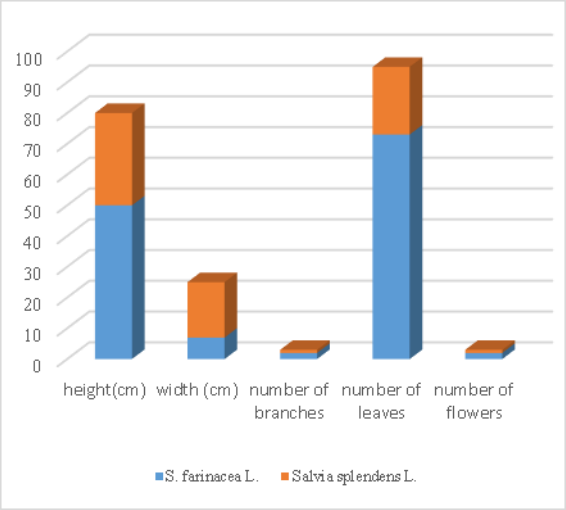

Fig. 3. Differences in growth and development between two types of flower sage in the substrate

Flower sage plants also had different growth and development in the substrates. Their growth was influenced by various factors such as seed quality, soil quality and weather conditions. The average height of flower sage *Salvia farinaceae* L. in garden soil was 40 cm, width 5 cm, number of leaves 60, number of branches 2 and number of flowers 2. The average height of flower sage *S. splendens* L. in garden soil was 35 cm, width 26 cm, number of leaves 37, number of branches 1 and number of flowers 1 (Fig. 4.).

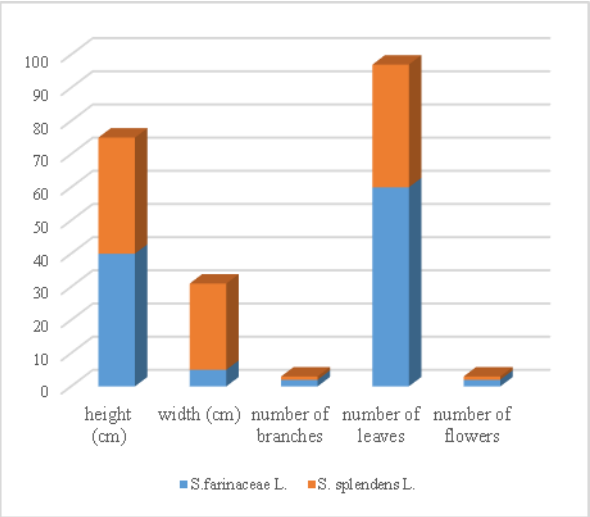

Fig. 4. Differences in growth and development between two types of flower sage in the soil garden

4. CONCLUSIONS

In this research, the growth and development of two sage types were monitored on different growing substrates. In the case of the common type of sage, differences have been found in the number of leaves and branches, width, while the height and number of flowers were equal regarding the growing medium. The height, width, number of branches and flowers of flower sage plants were equal in the garden soil and substrate. Cultivation of common sage in garden soil is more efficient than in the substrate, because the plant can spread, so it has more leaves. Flower sage is more suitable for growing in a substrate than in soil. Knowing that these are two different species of sage which have different uses, it is necessary to adopt growing conditions for successful production of both sage species.

5. REFERENCES

[1] K. G. Toplak, Domaće ljekovito bilje. Mozaik knjiga, Zagreb (2016).

[2] I. Lesinger, Kućna biljna ljekarna. Rijeka. (2006).

[3] I. Šilješ; Đ. Grozdanić; I. Grgesina, Poznavanje, uzgoj i prerada ljekovitog bilja. Školska knjiga, Zagreb, (1992).

[4] N. B. Rioba; F. M. Itulya; M. Saidi; N. Dudai; N. Bernstein, Effect of nitrogen, phosphorus and irrigation frequency on essential oil content and composition of sage (*Salvia officinalis* L.). Journal of Applied Research on Medicinal and Aromatic Plants 2 (2015), pp. 21-29

[5] V. Ibraković, Uzgoj ljekovitog, začinskog i aromatičnog bilja. Slavonski Brod (2019), pp. 46-48

[6] G. Tibaldi; S. Hazrati; S. J. Hasseini; A. Ertani; R. Bulgari; S. Nicola¸ Cultivation techniques and drying process can affect the inflorescence essential oil composition of three selection of *Salvia officinalis.* Industrial Crop s and Products 183 (2022) in press.

[7] M. Grdiša; M. Jug-Dujaković; M. Lončarić; K. Carović-Stanko; T. Ninčević; Z. Liber; I. Radosavljević; Z. Šatović, Dalmatian Sage (*Salvia officinalis* L.): A Review of Biochemical Contents , Medical Properties and Genetic Diversity. Agriculture Conspectus Scientificus 80 (2015), pp.69-78

[8] H. S. Abdu-Rabbu; H. E. Wahba; K. A. Khalid, Pomegranate peel modifies growth, essential oil and certain chemicals of sage (*Salvia officinalis* L.) herb. Biocatalysis and Agricultural Biotechnology 33 (2021) in.press.

[9] T. Tounekti; S. Munne-Bosch; A. M. Vabel; C. Chtara; H.Khemira, Influence of ionic interaction on essential oil and phenolic diterpene composition of Dalmatian sage (*Salvia officinalis* L.). Plant Physiology and Biochemistry 48 (2010). pp.813-821

The influence of turbulent environmental factors on the supply chain of agricultural food products

Lj. Božić-Ostojić [a], Ž. Mesić [b], N. Romanjek Fajdetić [a], M. Blažinkov [a], J. Vujčić [c], S. Antunović [a], B. Vujčić [d]

[a] University of Slavonski Brod, Trg Ivane Brlić Mažuranić 2, 35 000 Slavonski Brod, Croatia, ljbostojic@unisb.hr

[b] University of Zagreb, Faculty of agriculture, Svetošimunska cesta 25, 10 000 Zagreb, Croatia, zmesic@agr.hr

[c] High school "M. A. Reljković", I. Cankara 76, 35 000 Slavonski Brod, Croatia, jvujcic@unisb.hr

[d] Public Institution for the management of protected areas of Brod-Posavina County, P. Krešimira IV 1, 35 000 Slavonski Brod, Croatia, ravnatelj.natura-slavonica@bpz.hr

Abstract

Food that reaches consumers should be affordable, high quality and diverse, which requires an efficient, organized and controlled food system. Numerous turbulent environment factors affect the supply chains of agricultural food products, which consumers perceive differently in various countries. The strong influence of existing and the emergence of new factors require the ability to deal with unexpected changes.

Keywords: turbulent environment, supply chain of agricultural-food products

1. INTRODUCTION

The food system includes food production and processing, retail and end consumers. Food that reaches consumers should be safe, affordable, high quality and diverse. In order to achieve this, the food system must be efficient, organized and controlled [1].

Although food availability has improved in recent decades thanks to increased productivity, the agricultural sector is under increasing pressure today as various environmental, economic and social factors affect it [2]. In such conditions, it is necessary to provide food for the growing world population, while at the same time not endangering future generations [3]. Many countries today are once again facing increasing levels of food insecurity. Before COVID-19 disrupted supply chains, chronic and acute hunger was still present due to various factors, including conflict, socio-economic conditions, natural hazards and climate change. The war in Ukraine further adds to the risk to global food security, whose prices are likely to remain high for the near future [4].

In the supply chain, through a series of processes, producers distribute and produce goods to selected locations in the shortest possible time, with the aim of satisfying the needs of consumers [5]. Various factors affect the efficiency of supply chains: demand uncertainty, supply uncertainty, production, control and planning uncertainty, competitor behavior, political uncertainty, climate

uncertainty. Different countries perceive these factors differently [3]. The aim of the paper is to point out the most significant factors affecting the supply chains of agricultural - food products through a review of the existing literature.

2. DISCCUSION

Agricultural-food chains are parts that connect within the process, but also of mutual relations between different participants [6]. Living organisms make a base for agricultural production, which makes it variable and non-standardized. Unpredictable events such as disease outbreaks and climate change make it impossible for producers to follow predetermined rules [7].

Today, producers sell most of the produced and distribute through conventional supply chains, in which, due to the physical distance between producers and consumers, the creation of a greater amount of waste, reduction of food safety, damage to the environment, etc. can occur [8]. Compared to general supply chains, agro-food supply chains become exposed to additional sources of uncertainty due to product perishability, variable yields and the impact of climate conditions. Operational complexity due to variable consumer demand, uncertainty of production and supply dates, quantity and quality standards of products, etc. can expose the chain to serious disruptions [3].

Significant amount of research has focused on slow, predictable and controlled changes in food systems, and less has focused on the ability to cope with unexpected and unpredictable changes. [9].

2.1. Turbulent environment and its factors

Every business activity is an integral part of the ecology and social system and a certain environment influence it [10]. Environment is a term that implies the totality of phenomena and factors that directly or indirectly influence the action, behavior and development of a system or an organism [11].

The environment of a business entity can be stable, but also very unstable, that is, uncertain. The criteria that determine the stability of the environment are: 1. complexity, 2. number of changes and 3. dynamism and 4. unexpectedness of changes [12]. A turbulent environment is an environment in which changes are sudden and far-reaching [13]. In such an environment, changes are rarely predictable and new products, technologies and competitors threaten market stability. Long-term plans, vision and mission in a turbulent environment cannot guarantee successful business. Back in 1998, Conner pointed out that stability was not the prevailing state of the present time [14], and Oginni and Adesanya (2013) that the environment is increasingly dynamic, complex and unpredictable [15]. In the supply chain of agro-food products, many factors cause a turbulent environment. They can be external (exogenous), internal (endogenous) or act simultaneously. Some of them relate to globalization, consumer demands, market, and increased number of competitors, new technologies, sustainability requirements and food regulations [16].

According to Adeyeye et al. (2021), the supply chain of agricultural and processing products in Nigeria is under the influence of a highly turbulent environment caused by market, competitive, technological and regulatory factors, violent conflicts, and the COVID-19 pandemic and climate change [15].

In a study by Linn and Meenhout, 2019, conducted in the rice supply chain in Myanmar, the authors cite as the main sources of uncertainty for producers in the supply chain: climate change, inability to plan and operational control due to untimely and inaccurate information about production and stocks, government policy and inability predictions of competition behavior [3].

On March 11, 2020, the World Health Organization declared the COVID-19 pandemic, because of which the governments of many countries took measures that significantly affected the daily life of society and caused economic consequences in economies around

the world. In industries such as healthcare, demand has increased sharply, but general purchasing power and household consumption reduced significantly [17]. A health crisis such as the COVID-19 pandemic affects the entire food system and final demand [15] and one can view as a new factor in the turbulent environment. According to Rahmawati and Santoso (2021), the COVID-19 pandemic affected price stability, unemployment, increase in poverty, exchange rate and other economic results, with developing countries feeling this impact more than developed countries [18].

In a study conducted with Greek peach producers, Despoudi et al., (2018) indicated the existence of six turbulence factors then present in the supply chain: regulatory, market, competitive, weather, political and economic [19].

2.2. Regulatory turbulence

The frequent changes and diversity of food regulations cause regulatory turbulence. The regulations that producers need to comply with are food safety regulations, food quality regulations, food labeling and packaging regulations, food traceability regulations, food transport and handling regulations, and organic farming regulations [19].

2.3. Economic turbulence

Economic factors such as economic trends, the general economic situation, the structure of consumption, market trends, taxes and the level of GDP can create economic turbulence. Stagnation of economic activity with negative consequences on production, income, living standards, unemployment growth, GDP decline and inflation characterise an economic crisis.

Price volatility can be the result of various phenomena such as market imperfection, globalization, supply volatility, climate change, and health risks. It can equally negatively affect both producers and consumers. Low prices threaten producers' incomes and their long-term sustainability, while high prices in the worst case can deny consumers access to basic foodstuffs.

Instability of prices discourages modernization, innovation, hinders the entry of young farmers and generational renewal. Unexpected changes in the exchange rate are one of the factors that can affect the prices of inputs and outputs in agriculture. Price variability can originate from external factors such as war, weather disasters, conflicts on the market, etc.

Economic disturbances in economically strong countries affect global and local economic trends. The international associations such as the European Union also influence local economic activities, which implies legislative, economic and socio-cultural adaptations of its members [20].

A number of countries are currently experiencing high food price inflation, which has a greater impact on populations in low and middle-income countries because they spend a larger proportion of their income on food than people in high-income countries do [4].

2.3. Market turbulence

Market turbulence is the degree to which the composition and preferences of consumers change and is generated by the speed with which customer needs change [21].

De Clercq et al. (2018) point out that the main driving forces of market turbulence are consumers and new technologies [15]. Changes in customer preferences often lead to market turbulence, which affects relational (trust, credibility, mutual respect, commitment) and operational outcomes such as profitability and increasing market share [22].

In addition to changes in customer preferences, market turbulence most often causes certain lack of knowledge about the final customer and his wishes and needs, lack of traceability and transparency, customer unreliability and ignorance of the market [16].

Due to the specificity of agricultural production, agricultural markets are prone to instability, which is harmful for producers due

to income uncertainty and uncertain market indicators, but also for consumers because it affects their choice of diet [23].

After two years of market volatility due to the global coronavirus pandemic, Russia's invasion of Ukraine has led to market turbulence in the red meat supply chain, with the potential for further disruption [24].

2.4. Political turbulence

The political-legal system ensures a compromise between individuals and groups [25]. Political factors include laws, agencies, and government groups that may restrict the activities of individuals or organizations. The state creates the foundations for business and it regulates it with regulations and can make it easier, more difficult or prohibited [20]. With the help of monetary and fiscal policy instruments, the state can prevent economic stagnation and inflation, reduce unemployment and accelerate economic growth. Tax breaks, subsidies, investment in research and development of new technologies can stimulate economic activity, but also significantly limit it due to political instability, revolutions, coups, and changes in the political system, etc.

Political changes make it difficult to make business decisions, and different pressures can come from subjects of the political-legal environment such as political parties [25].

Legislation can play an important role in protecting against unfair competition, unfair business practices and unbridled business behavior, but poorly legitimate legislation can lead to a weakening of economic growth [26].

Hendry et al. (2019) investigated the resilience of supply chains to constitutional change by examining the impact of Brexit on local supply chains in the UK. Although it is an event, known and deliberately caused, its impact on the wider environment expected, and cooperation in supply chains needed to mitigate its consequences [27].

2.5. Technological turbulence

Technological changes enable new ways of production and the creation of better quality products, change the ways of distribution and storage and affect economic growth and development [28]. Throughout history, numerous and diverse innovations in agriculture have enabled producers to face challenges more easily. However, the rapid change of products and production technologies can lead to technological turbulence [15].

Factors hindering the adoption of technologies include economic unprofitability of technology, farmers financial constraints, knowledge and education levels; uncertainty of agricultural support policies, conservative attitudes of farmers, structural factors such as farm size and the cost of new technologies [29].

2.6. Competitive turbulence

Competitive turbulence results from a lack of knowledge about competition among producers and competition in the market [16].

Competitive turbulence refers to the resources and behavior of competitors. According to Schumpeter's theory, competition has a negative effect on innovation, and the opposite point of view believes that competition drives innovation efforts.

When there is strong competition, customers have a number of options available to satisfy their needs and desires [15].

2.7. Weather turbulence

Extreme weather conditions are already leading to harvest losses and disruptions in food distribution, and will affect the quality, nutrient content of some plant products and the security of the food supply in the coming decades [30].

3. CONCLUSIONS

Various factors of the turbulent environment affect the supply chains of agricultural-food products, such as regulatory, market, competitive, weather, political and others, which different countries perceive differently. The COVID 19 pandemic has made it difficult for these chains to function, and the war in Ukraine has further contributed to the risk of global food security. The prices of many foodstuffs are on the rise, which has a greater impact on the population in low- and middle-income countries. Although previously numerous researches focused on slow and predictable changes, the strong influence of existing and the emergence of new factors of the turbulent environment require additional research and the ability to deal with unexpected changes.

4. REFERENCES

[1] R. J. Lehman, R. Reiche, G, Schiefer, Future internet and the agri-food sector: State of the art in literature and research, Computers and Electronics in Agriculture, 89, 158-174, (2012)

[2] M. Zurek, A. Hebinck, O., Swelomane, Looking across diverse food system futures: Implications for climate change and the environment, A Journal of Agricultural, Climate, Environmental, Food, Resource and Rural Development Economics, Volume 1, Issue 1, (2021)

[3] T. Linn, B. Maenhout, The impact of environmental uncertainty on the performance of the rice supply chain in the Ayeyarwaddy Region, Myanmar, Agricultural and Food Economics, (2019)

[4] Worl bank, Food security update, https://www.worldbank.org/en/topic/agriculture/brief/food-security-update, last access 07/06/2022

[5] J. C. Perez-Mesa, E. Galdeano-Gomez, L. Piedra Munoz, C. Giagnocavo, Management strategies and collaborative relationship for sustainability in the agrifood supply chain, Sustainability, 13 (7), 749 (2021)

[6] O. Varchenko, Problems of functioning and directions of agro-food chains development in the conditions of turbulence strengthening, Ekonomika, No 1, 18-28 (2020)

[7] A. Carbone, Food supply chains: coordination governance and other shaping forces, Agriculture and Food Economics 5, Article number 3 (2017)

[8] M. Kneafsey, U. Schmutz, B. Balasz, L. Venn, Short Food Supply Chains and Local Food Systems in the EU. A State of Play of their Socio-Economic Characteristics. Publications Office of the European Union (2013)

[9] I. Darnhofer, Resilience or how do we enable agricultural systems to ride the waves of unexpected change? Agricultural Systems, Volume 187 (2021)

[10] F. Cherunilam, Business environment, Himalaya Publishing (2021)

[11] M. Buble, M. Cingula, M. Dujanić, Strategic management, Synergy, Zagreb (2005)

[12] P. Sikavica, F. Bahtijarević-Šiber, N. Pološki Vokić, Foundations of management, Schoolbook, Zagreb (2008)

[13] T. Giljević, The environment of administrative organisation, Legal gazette, 31, 3-4 (2015)

[14] C. Hedlöf, U. Janson, How to cope with a Turbulent Environment, Linköping University, (2020)

[15] A. Adeyeye, O. Kolade, D. Obembe, A. Ogunsade, Agriculture value chain in a turbulent environment, Institute for Small Business and Entrepreneurship, Cardiff (2021)

[16] S. Despoudi, G. Papaioannou, S. Dani, Producers responding to environmental turbulence in the Greek agricultural supply chain: does buyer type matter? Production Planning&Control, 1-14 (2020)

[17] S. Kraus, T. Clauss, J. Gast, A. Zardini, V. Tiberius, The economics of COVID-19: initial empirical evidence on how family firms in five European countries cope with the corona crisis, International Journal of Entrepreneurial Behavior&Research (2020)

[18] F. Rahmawati, F. Dwi Putra Santoso, The Vulnerability of Developing Countries to the Economic Crisis Due to the Pandemic: What can Indonesia Do? International Research Conference on Economics and Business, Volume 2021 (2021)

[19] S. Despoudi, G. Papaioannou, G. Saridikas, S. Dani, Does collaboration pay in agricultural supply chain: an empirical approach. International journal of production research (2018)

[20] N. Rupčić, Modern management, University of Rijeka, Faculty of economics and Business (2018)

[21] D. Ojha, E. Struckell, C., Ascharya, P. C. Patel, Menaging environmental turbulence through innovation speed and operational flexibility in B2B service organizations, Journal of Business&Industrial Marketing (2020)

[22] A. Arora, J. Anyu, J. McIntyre, Global Value chains, Disaggregation through Supply Chain Collaboration, Market Turbulence and Performance Outcomes, Sustainability (2021) 13 (8), 4151

[23] EU parlament (2016) https://www.europarl.europa.eu/doceo/document/A-8-2016-0339_HR.html, last access 10/06/2022

[24] P. Hunter, Farming sectors face disruption due Russian invasion, (2022) https://www.thescottishfarmer.co.uk/news/19992129.farming-sectors-face-disruption-due-russian-invasion/, last access 10/6/2022

[25] D. Čičin-Šain, Management lectures, University of Rijeka http://www.unizd.hr/portals/4/nastavni_mat/2_godina/menadzment/predavanja_menadzment.pdf, last access 10/06/2022

[26] P. Kotler, K. L. Keller, Marketing management, Zagreb School of Economics and Management (2008)

[27] L. C. Hendry, M. Stevenson, J. MacBryde, D. Ball, M. Sayed, L. Liu, Local food supply chain resilience to constitutional change: the Brexit effect, International Journal of Operations&Production Management, Volume 39, Issue 3 (2019)

[28] M. Škrtić, M. Mikić, Entrepreneurship, Zagreb: Synergy (2011)

[29] OECD, Adoption of technologies for sustainable farming systems (2001), https://www.oecd.org/greengrowth/sustainable-agriculture/2739771.pdf, last access 10/06/2022

[30] K. F. Davis, S. Downs, J. A. Gephart, Towards food supply chain resilience to environmental shocks, Nature food 2 (2021) 54-65

Climate adaptation and landscape architecture in urban environment

E. Hoyk[a], A. Palkovics[b]

[a]John von Neumann University, Faculty of Horticulture and Rural Development, Izsáki út 10., 6000 Kecskemét, Hungary, hoyk.edit@kvk.uni-neumann.hu

[b]John von Neumann University, Faculty of Horticulture and Rural Development, Izsáki út 10., 6000 Kecskemét, Hungary, palkovics.andras@kvk.uni-neumann.hu

Abstract

Today's climate change affects all segments of the social, economic and natural environment. In our study, we examine the possibilities of using plants among the methods of adaptation to climate change in an urban environment. Green infrastructure, which is a strategically planned network of natural and near-natural areas in an urban environment, is a priority in urban climate adaptation. For this reason, it is important to know what plants are worth using and under what conditions. One of the most serious problem connects to heavy rainfalls. These cause urban flash floods, which could appear everywhere, independently from the topography or rivers. Against flash floods, use of vegetation is very effective; creating rain gardens is a good method of defence. However, it does matter under what conditions and which kind of plants the rain gardens could be established. For this reason, we have to investigate soils and vegetation of rain gardens. Our aim is to contribute to the solution of this task in this present work. Therefore we show the soil problems that are to be faced in the case of Kecskemét (Hungary), and the methods available to deal with it. In addition, the applicability of some native plant species and the vegetation composition of the existing rain gardens in Kecskemét should be investigated. Beside the importance of the adaptation, the integration of this „tool" into the urban environment and the aesthetic appearance are also emphasized, which makes it necessary to take into account the practice of landscape planning.

Keywords: landscape architecture, climate adaptation, green infrastructure, rain gardens, soil permeability

1. INTRODUCTION

More and more severe extreme weather events are taking place in our settlements, which can result in urban flash floods, prolonged heat waves, storm damage, damage to buildings and critical infrastructure (water, gas, electricity, road and rail networks). Immediate action is needed to keep the global average temperature increase below 1.5% [1]. This should include the development and maintenance of urban green-blue infrastructure. This task also strongly affects Kecskemét, which – as the most populous city in the Danube-Tisza Sand Ridge – faces many environmental problems even without the challenges of climate change.

The 21st century is the century of water. The future of countries, settlements and cities that can provide the right quantity and quality of water for the natural and built environment, the economy and society can be taken for granted. Therefore, water retention and water management that satisfies the needs is the number one task in Kecskemét as well. What needs to be done is to increase open water surfaces, expand underground storage, and facilitate infiltration.

Based on the climate models [2], the increase in the average annual temperature in Kecskemét, the sharp decrease in the number of frosty days (Tmin <0) and the hot days (Tmax> = 35 °C)

seem to be a clear trend for the future. This clearly indicates that the winter will be warmer and shorter and the summer will be longer and hotter. This will go hand in hand with a shortening of the length of spring and autumn.

Urban green infrastructure consists of different elements, e.g. parks, alleys, green facades etc. In an urban environment the space-saving solutions (green roofs, green walls) have a great importance also. However, in addition to green infrastructure, we must not forget about water, which is necessary to maintain a green environment on the one hand, and the management of extreme rainwater on the other. The complex of vegetation and water is called as green-blue infrastructure [3].

The green-blue infrastructure approach implements the retention of rainwater and the treatment of green spaces in an organic unit [4]. Expanding green spaces as much as possible and maintaining existing urban vegetation are essential elements of climate adaptation. In doing so, it is necessary to focus not only on the creation of parks and rows of trees, but also on the introduction of urban meadows. Among these, both intensively maintained and close-to-nature wildflower grasslands has a significant role. They has ecological diversity, which is also a great value in the city. In addition to their recreational function, these types of habitats also play an important role in nature conservation and climate adaptation, as they increase infiltration, so they retain moisture and have significant CO_2 sequestration.

Heavy rains and the resulting flash floods will be more and more common in our climate in the future. Handling the flash floods is the responsibility of urban storm water management [5]. One element of this is the construction of rain gardens. These are artificially formed, deeper surfaces in the soil, with the function of collecting, temporary storing and filtering rainwater, and desiccation [6].

Urbanization has several adverse hydrological effects, among which rainwater management is a complex problem. In order to reduce adverse effects, both Best Management Practice and Low Impact Development should be kept in mind [7]. There are a number of possible solutions, most of which require the combined use of different solutions to deal effectively with the problem. The traditional solution is to build storm water drainage channels. But building the network is extremely expensive, which imposes a significant financial burden on the water utility company, the municipality and the dwellers too.

The issue has long been known internationally. The topic has been addressed in the past mainly in countries where the natural feature of the climate is extremely high rainfall, e.g. some areas of the USA, or the oceanic regions of Western Europe. For this reason, the development of possible solutions is also linked to these countries [8]; [9].

Till nowadays, few studies have quantified how the hydrological performance of rain gardens is affected by vegetation type. However, even in the absence of measurement results, it is recommended that in rain gardens have be taxonomically and structurally diverse species [10].

In our study we examined the permeability of the typical soil types in Kecskemét – humus sandy soil, solonetz meadow soil and a mixture of these with compost (which was a normal gardening compost type) in order to decide what proportion of soils and compost can be considered ideal for rain gardens. In addition, experiments were performed with three broad-tolerant species (*Inula britannica*, *Aster tripolium subsp. pannonicus* and *Limonium gmelinii*) planted in the studied soil types, as well as in a mixture of these.

2. METHODS AND MATERIALS USED FOR RESEARCH

To investigate the permeability of soil types and compost, 0.5 kg of the samples was weighed into plastic containers to which 0.5 liter of water

was poured. The samples were air dry. Infiltration was recorded using a stopwatch, was followed visually and the results were represented on Excel charts.

To study the viability of selected broad-tolerant plant species (*Inula britannica, Aster tripolium subsp. pannonicus* and *Limonium gmelinii*), we planted the plants into different soil types (humus sandy soil, solonetz meadow soil and flower soil as a benchmark) and 50-50% mixture of soils and compost. The solonetz meadow soil comes from sewage treatment plant of Bácsvíz Zrt., the humus sandy soil from Csabagyöngye street in Kecskemét. Peaty flower soil is a common type and available in florists.

The plantation of *Inula britannica* and *Aster tripolium subsp. pannonicus* was on April 15, 2021, while the *Limonium gmelinii* was planted on September 3, 2021. In order to model the unpredictability of precipitation, samples were watered without regularity, weekly, every ten days, and between May 3-7. on a daily basis. The experiment extended to one month after planting for *Inula britannica* and *Aster tripolium subsp. Pannonicus*, because the plants had dried out after one month.

The irrigation experiment to examine the viability of *Limonium gmelinii* lasted for nine months, as the plant species proved to be more tolerant compared to the other two species, and the plants survived.

Beside our plantation test, we counted the existed rain gardens in Kecskemét. The city has three public rain gardens at this moment. First garden is in „Homokbánya" district, which is a recultivated residential area from former soviet barracks. The garden was designed in October 2020. The rain garden here can be found in a natural depression, which is not a planned rain garden; existing facilities have been used in its design. The used plant species are herbaceous plants only, which were the following:

Achillea filipendulina 'Coronation Gold'; Alchemilla mollis; Anemone x hybrida 'Honorine Jobert'; Geranium macrorrhizum; Hemerocallis fulva'Stella d'Oro'; Hosta ventricosa; Iris sibirica; Iris pallida 'Variegata'; Kniphofia uvaria; Ligularia stenocephala; Ligularia dentata 'Otello'; Persicaria bistorta 'Superba'; Physostegia virginiana; Sedum 'Matrona'; Prunella grandiflora; Tradescantia x andersoniana; Veronicastrum virginicum 'Album'; Calamagrostis acutifolia 'Carl Forester'; Pennisetum alopecuroides 'Moudry'; Miscanthus sinensis 'Silberfeder'; Miscanthus sinensis 'Yaku Jima'; Miscanthus sinensis 'Zebrinus'; Lythrum salicaria

The second rain garden is in a new housing estate (Gerlice street). The constant problem of the residents here was the flash floods following the heavy rains, as a result of which a significant part of the street was under water. As a solution to the problem, rain gardens were created in November 2021, along the entire length of the roadway in the framework of municipal and public cooperation. The used plant species were the following:

woody plants: *Tilia tomentosa; Tilia cordata; Fraxinus Ornus; Fraxinus Angustifolia; Fraxinus angustifolia subsp. pannonica; Pyrus calleryana 'Chanticleer'; Ulmus hollandica 'Wredei'; Prunus cerasifera; Prunus padus 'Albertii'; Prunus serrulata 'Kanzan'*

shrubs: *Hydrangea macrophylla; Amelanchier alnifolia; Cornus alba; Euonymus alatus; Spiraea japonica 'Albiflora'; Viburnum opulus; Hibiscus*

herbaceous plants: *Aster; Callistephus chinensis; Leucanthemum vulgare; Hemerocallis; Geranium; Monarda bradburiana; Salvia nemorosa; Nepeta; Gramineae; Thymus serpyllum; Echinacea; Sanguisorba; Imperata cylindrica; Miscanthus sinensis Gracillimus*

The steps for the establishment of the rain garden were as follows:

- digging a 1-1.5 meter deep pit

- mixing the excavated soil with compost in a proportion of 50-50%
- planting the selected plants
- finally covering the soil surface with mulch

The third rain garden is a very new construction which was finished in June 2022. This garden can be found between multi-storey houses in „Vacsiköz" district.

The plant species are the following here:

woody plants: *Betula pendula; Alnus glutinosa; Tilia cordata; Pyrus pyraster*

shrubs: *Taxus baccata; Viburnum prageuse; Berberis thunbergii 'Erecta'; Cornus alba; Spiraea japonica 'Albiflora'; Viburnum opulus*

herbaceous plants: *Nepeta; Lythrum salicaria; Miscanthus sinensis purple fall; Miscanthus yaku dwarf; Echinacea; Aster; Hemerocallis; Salvia nemorosa; Alchemilla mollis; Salvia officinalis*

The method of the construction was similar to the second case. A 1-1.5 meter deep depression was formed, after that 50-50% mixture of original sandy soil and compost was filled in it. This was followed by planting with the selected species and then mulching.

3. RESULTS AND ACHIEVEMENTS

3.1. Examination of soil permeability and plant viability

Based on the results of the infiltration measurement (Fig. 1.), it can be seen that the water permeability and water holding capacity of different samples vary within very wide limits.

The solonetz meadow soil sample passed 300 ml of water in four hours. The rest of the water remained on the surface of the sample, so the soil functioned practically as a waterproof layer. The common flower soil and the humus sandy soil permeated and retained water in a similar manner. Solonetz meadow soil mixed with compost in 50-50%, passed 250 ml of water very quickly – in about half an hour – and then absorbed the remaining amount of water. After adding more water, the leakage started again, so like the flower soil and humus sandy soil, it stores moisture and then releases it gradually.

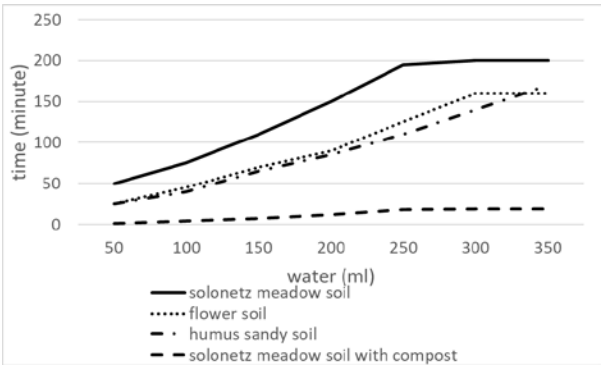

Fig. 1. Permeability of studied samples

Based on this, it can be said that by improving the water permeability and water holding capacity of the solonetz meadow soil, which provides poor living conditions for the plants, more favorable conditions can be ensured for the plants as well. In case of creating a rain garden, mixing the soil with 50% compost, the water holding capacity of the area and the living conditions for the plants are also significantly improved. In this way the rain gardens can perform its function.

During the viability study of the plants, we used the same soil samples which were included in the permeability study. The worst conditions were provided by the solonetz meadow soil, in which all three plant species had difficulty coping with the soil conditions. From the three plant samples, *Inula britannica* proved to be the least resistant, it was drying out in the solonetz meadow soil within one week. The most resistant was *Limonium gmelinii*, which endured poor soil conditions even in the solonetz meadow soil.

The viability of plant samples in soil-compost mixture were better than in the sample without compost, which is a good indication that

compost also significantly improves plant living conditions (Fig. 2.).

Fig. 2. Limonium gmelinii *in mixture of solonetz meadow soil + compost at the time of planting (left), four weeks (middle) and nine months (right) after planting*

3.2. Investigation of rain gardens in Kecskemét

The first rain garden of Kecskemét was in „Homokbánya" distict. As we can see in the plant list, only herbaceous plants were used. These plants are suitable for ordinary gardens, some of them for rain gardens also, but not all. Because of it, after a few months we can not find all planted species in this rain garden (Fig. 3.).

Fig. 3. Rain garden in „Homokbánya" district in October 2020 (left) and June 2022 (right)

The survived plant species are: *Alchemilla mollis; Anemone x hybrida 'Honorine Jobert'; Geranium macrorrhizum; Hemerocallis fulva'Stella d'Oro'; Hosta ventricosa; Kniphofia uvaria; Sedum 'Matrona'; Prunella grandiflora; Calamagrostis acutifolia 'Carl Forester'; Miscanthus sinensis 'Silberfeder'; Lythrum salicaria*

It means, only about half of the original vegetation is still here after one and half year of the creating the garden. It shows, not the all choosen plant species were suitable for rain gardens.

Second rain garden in the city was in Gerlice street. The plant species are heterogeneous, which means a more diverse environment. Plants are on their place since seven month, and they are in good condition (Fig. 4.). It means, these plants are suitable for rain gardens – with appropriate initial plant care works.

Fig. 4. Rain garden in Gerlice street in November 2021 (left) and June 2022 (middle and right)

The condition of the third rain garden is shown in Figure 5.

Fig. 5. New rain garden in „Vacsiköz" district in June 2022

This rain garden is a new construction, this way results would be only after a couple of months about how well the plants have grown here. The reason of the rain garden was the waterlogging of the residential buildings after heavy rains was coused by collected water at the bottom of the buildings. Now this new rain garden is a kind of

community garden which is taken care of by the inhabitants here and its role in landscape architecture and aesthetics is not negligible either.

4. CONCLUSIONS

As a result of our plant experiment, we can conclude, that the solonetz meadow soil – which is common in Kecskemét – alone provides poor conditions for the vegetation, even in the case of basically salt-tolerant species. In the case of humus sandy soil, general flower soil and compost, the soil conditions are already suitable for plant life. If we mix the solonetz meadow soil with compost in 50-50% ratio, the living conditions – nutrient supply, water management – are significantly improved, which allow the plants to survive. Before the establishment of a rain gardens, soil tests – especially the examination of permeability – are essential, which helps to decide what proportion of compost mixture and what type of plants should be used in the rain garden.

Nowadays (June, 2022) Kecskemét has three public rain gardens. Of these existing rain gardens, the „garden-chain" in the Gerlice street is in a very good condition, seven months after the construction. The plants are heterogeneous here (woody plants, shrubs, herbaceous plants) and we can say, the selection of the used plants were more careful than in „Homokbánya" district. The very new third rain garden needs some months for a measurable result.

These gardens also have an aesthetic function. Based on this, we can conclude that Gerlice street's rain garden created an attractive street scene, thanks to the landscape architectural approach, in addition to its many useful functions. The aesthetic function is very important, because the acceptance with the dwellers can only work if it is not „only" useful, but they also like what they can see. This aspect can be use also in the formation of the required attitude.

5. REFERENCES

[1] https://eur-lex.europa.eu/content/paris-agreement/paris-agreement.html?locale=hu, last access 15/06/2022

[2] https://nater.mbfsz.gov.hu, last access 15/06/2022

[3] M.U. Din Dar, A.I. Shah, S.A. Bhat, R. Kumar, D. Huisingh, R. Kaur, Blue Green infrastructure as a tool for sustainable urban development. Journal of Cleaner Production, Vol. 318., (2021), 128474.

https://doi.org/10.1016/j.jclepro.2021.128474

[4] K.H. Liao, S. Deng, P.Y. Tan, Blue-Green Infrastructure: New Frontier for Sustainable Urban Stormwater Management. In: Tan, P., Jim, C. (eds): Greening Cities. Advances in 21st Century Human Settlements. Springer, Singapore, (2017), pp. 203-226.

https://doi.org/10.1007/978-981-10-4113-6_10

[5] Y. Zhang, W. Zhao, X. Chen, C. Jun, J. Hao, X. Tang, J. Zhai, Assessment on the Effectiveness of Urban Stormwater Management. Water, 13, 4., (2021)

https://doi.org/10.3390/w13010004

[6] H. Haris, M.F. Chow, F. Usman, L.M. Sidek, Z.A. Roseli, M.D. Norlida, Urban Stormwater Management Model and Tools for Designing Stormwater Management of Green Infrastructure Practices. IOP Conference Series: Earth and Environmental Science, Vol. 32., (2016), 012022.

https://doi.org/10.1088/1755-1315/32/1/012022

[7] S. Zhang, Y.M. Guo, Explicit Equation for Estimating Storm-Water Capture Efficiency of Rain Gardens. Journal of Hydrologic Engineering, (2013), 18:1739-1748.

https://doi.org/10.1061/(asce)he.1943-5584.0000734

[8] B.C. Asleson, R.S. Nestingen, J.S. Gulliver, R.M. Hozalski, J.L. Nieber, Performance assessment of rain gardens. Journal of the American Water Resources Association. Vol. 45., No. 4., (2009), pp. 1019-1031.

https://doi.org/10.1111/j.1752-1688.2009.00344.x

[9] L. Autixier, A. Mailhot, S. Bolduc, A.S. Madoux-Humery, M. Galarneau, M. Prévost, S. Dorner, Evaluating rain gardens as a method to reduce the impact of sewer overflows in sources of drinking water. Science of The Total Environment. Volume 499., (2014), pp. 238-247.

https://doi.org/10.1016/j.scitotenv.2014.08.030

[10] J. Yuan, N. Dunnett, V. Stovin, The influence of vegetation on rain garden hydrological performance. Urban Water Journal, Vol. 14, Issue 10., (2017)

https://doi.org/10.1080/1573062X.2017.1363251

Effect of substrates on growth and development of Zinnia (*Zinnia elegans*)

B. Japundžić-Palenkić [a], I. Biondić [a], R. Benković [a], N. Romanjek Fajdetić [a], M. Marković [b]

[a] University in Slavonski Brod, Trg Ivane Brlić Mažuranić 2, 35000 Slavonski Brod, Croatia, bjpalenkic@unisb.hr

[b] Faculty of agrobiotechnical sciences, Vladimira Preloga 1, 31000 Osijek, Croatia

Abstract

Zinnias are ornamental species which are not demanding for breeding, sunny and warm position with loamy well-drained soil is sufficient. The aim of the research was to compare the growth and development of Zinnia (*Zinnia elegans* Jacq.) in a sunny place, during spring and summer period, in three substrates of various physical and chemical properties (Potgrond H, Florabella and soil). The seeds were sown in PVC containers (Pöpellmann TEKU (EP 2128/20) 28 cm x 21cm x 6 cm) with 20 sowing places (volume 150 ml). After developing four leaves, plants were transplanted into PVC pots (Φ 9 cm) filled with the same substrate. The pot trial was conducted as a randomized complete design with four repetitions. Four weeks later on the developed plants, following values has been measured: plant mass, plant height, plant height above ground, mass of the above-ground part of the plant and the number of leaves. Plants grown in Florabella substrate had higher values than plants grown in Potgrond substrate and soil. Statistically significant difference ($P \leq 0.01$) has been found between the values of plants grown in soil and substrates Potgrond H and Florabella.

Keywords: Zinnia, substrate, growth, developement

1. INTRODUCTION

Contemporary production of transplants demands certain conditions to develop high productive plants [1] meaning a choise of adequat substrate which provide nutrients and is not heavy for growth [2, 3]. The substrate have to be uniform in texture, hold sufficient moisture, and should be well drained (porous) [4]. Nowadays hortycultural production is based on usage of ready-made supstrates (do not cause much labor, time, and money loss). Commercial combinations are every so often used because they are purified, ready to use and might straight comprise some fertilizer [4]. They comprise of mixture of single components with different content of conditioners depending of purpose (sort of plant and/or stage of plant development). Different substrate are usualy used but soil is still the most importante and ireplacable multidisperzion system made of liquid, solid, gas and live phase [5]. Soils change in natural cycles therefore differs by physical, chemycal and biological properties and also keeps favorable structure and release nutrient elements necessary for plants [6]. In hortycultural production praxis two mistakes ussualy apears. One is wrong soil choise for some sort of plant and the other is unkonowing needs of certain plants which are determined with landscape planing on certain soil. Both have a negative impact on growth and development of plants and resulting with plant decay. Among the rest it also decreasing the overall visual aspect of certain landscape [5]. Zinnia elegans is native to Mexico and is grown commercially as a bedding plant and cut flower. The plant has 20 varieties and genus Zinnia and

Zinnia elegans are the most widely known among them [7]. It is one of the most frequent species in tradiotional gardens of northwest Croatia [8]. Zinnia is a floral species with a large potential because of seed production, rapid growth and minimal labour requirements. It is known for its tolerance to hot and dry conditions [7]. Also, Zinnia is tolerant for different soil types except for intense moisture and poorly ventilated soils that can cause root rot [9]. The best production of plants needs proper nutrition, irrigation along with other cultural practices [10]. Optimum amount of nutrient and environmental factors affect the plant development and growth [11]. According Riaz et al. (2014) Zinnia flowering pattern is greatly affected by the growth media [12]. In literature Zinnia is described as a plant easy for growing which demands warm and sun with well drained soil, so for this study Zinnia has been growth on a suny place, during spring and summer time period, with adequate amount of water in three types of substrates different in physical and chemycal properties. This study was carried out to compare the effects of different growth media such as soil, and ready-made substrates (Potgrond H and Florabella) forms on Zinnia growth parameters.

2. METHODS AND MATERIALS USED FOR RESEARCH

Potgrond H (Rp. No 30) substrate used for cultivation of Zinnia had a fine structure (0 mm - 7 mm), density of 100 kg/m3, total porosity of 85 %, pH_{H2O} 6 and EC 40 mS/m. It was a mixture of frozen black and white sphagnum moss with aded fertilizer containing 1.5 g/l (S 150 mg/l, N 210 mg/l, P2O5 150 mg/l, K2O 270 mg/l, Mg 100 mg/l). Florabella substrate is mixture of week decomposted white sphagnum moss, high quality black sphagnum moss and clay granulas with water soluble fertilizer. Florabella is moderatly fine to moderatliy coarse structure. Chemical properties were: pH_{H2O} 5.5 to 6, EC 45 mS/m (+/- 25%), Mg 100 mg/l, N 210 mg/l, P2O5 150 mg/l, K2O 170 mg/l to 390 mg/l. The soil used in study folowing laboratory analysis have been conducted on: preparation of samples HRN ISO 11464:2004 [13], pH (HRN ISO 10390, 2005.) [14], humus (HRN ISO 14235, 1998.) [15], P_2O_5 and K_2O (Egner et al., 1960.) [16], hydrolytic acidity (Hy) [17] and soil texture (ISO 11277, 2009) [18].

Research has been conducted with Zinnia elegans mix seeds by Royal seeds from Italy (declared germination 89%) which has been sowed in PVC containers (Pöpellmann TEKU (EP 2128/20) 28 cm x 21 cm x 6 cm) with 20 sowing places (volume 150 ml) filled with Potgrond H and Florabella substrates and soil. According to declared germination was 89% in every sowing place a few seeds have been placed with purpose of geting a seedling in each sowing place. When a seedlings apeared in every sowing place one plant has been left and others were remowed. At the four-leaf stage, seedlings were transplanted into PVC pots (Φ 9 cm) filled with the same substrate (Potgrond H, Florabella or soil). Substrate for filling the pots have been measured and a same mase of substrate have beeen placed in pots.The pot trial was conducted as a randomized complete design with four repetitions. After four weeks, on developed plants, following properties have been measured: mass of plant (g), height of plant (cm), number of leaves, above ground plant height (cm), mass above ground (g). Statistical data was performed by variance analyzes (F test) and differences between treatments have been determined with LSD-test by GLM procedure using SAS System Softver.

3. RESULTS

3.1. Characteristics of substrates

Results of chemical properties of soil are shown in Table 1. pH reaction of analyzed soil was very acid (Thun) [5] while ready-used substrates had slightly acid reaction. Supply soil available phosphorus and potassium was in bounduries of very poorly supplied (Wunderer) [19].

Substrates were well supplied with phosphorus and well to richly supplied with potassium (Wunderer) [19]. Analysed soil was slightly humous (Gračanin) [19].

According to expectations (regarding low pH reaction) in soil was determined high hydrolytic acidity (Table 1).

Table 1. Chemical properties of soil: $pH_{(H2O)}$, $pH_{(KCl)}$, AL-P_2O_5 (mg/100g), AL-K_2O (mg/100g), humus (%), hydrolytic acidity (mmol/100g)

Chemical properties	pH (H2O)	pH (KCl)	AL-P_2O_5 (mg/100g)	AL-K_2O (mg/100 g)	Humus (%)	Hk (mmol/100g)
	4.4	3.12	2	2.51	2.62	16.19

Texture of soil (Table 2) was silt loam [20]. According to product declaration substrates had easier texture composition then the soil regarding physical properties and had higher porosity then the soil.

According to Soil Map of Croatia (BSCM) 1:50000 and based on the soil analyses (Table 1 and 2), soil used in this research, classifies as a soil type Dystric cambisol (WRB) (Husnjak et al., 2004) [21].

Table 2. Texture of soil: coars sand (%), fine sand (%), coarse silt (%), silt (%), clay (%)

Physical properties	Coarse sand (%)	Fine sand (%)	Coarse silt (%)	Silt (%)	Clay (%)
	3.97	16.95	28.53	31.47	19.08

3.2. Morphological characteristic of Zinnia elegans

For calculation and comparison of average plant mass between substrate Potgrong H and substrate Florabella the mass of complete plant with substrate have been used. Because every plant has been growing in the same mass of substrate it was ignored.

The plants of Zinnia growth in Florabella substrate had a higher mass then those growth in Potgrond H substrate for 12.54 g (Table 3). The mass of the plants growth in soil was in average 0.27 g. Because the plants growth in soil were very small, which enable rinsing of the soil from roots the masses of plants from substrate and soil have not been compared.

Table 3. Difference of growing variants on mass of plant (MP), height of plant (HP), number of leaves (NL), above ground plant height (APH), mass above ground (MAG) Zinnia elegans

Substrate	MP (g)	HP (cm)	NL	APH (cm)	MAG (g)
Potgrond H	232.12A	26.67A	20.00A	20.31A	8.41A
Florabella	244.76A	28.03A	21.00A	21.59A	8.98A
Soil	0.27B	8.16B	4.00B	4.81B	0.25B

A, B $P \leq 0.01$

In the study, average height of plants was between 8.16 cm and 28.03 cm (Table 3.). The significant statistical difference ($P \leq 0.01$) have been determined between average height of plants growth in Florabella substrate (28.03 cm) and soil (8.16 cm) which was 19.87 cm. Height of plants growth in substrate Potgrond H was 26,67 cm (Table 3.). Difference in height of plants growth in Florabella substrate and Potgrond H substrate was 1.36 cm and it was not statistically significant ($P \leq 0.01$). However, the significant statistical difference ($P \leq 0.01$) have been determined between plants growth in Potgrond H substrate and soil and it was 18.51 cm.

Number of leaves of Zinnia plants was in average between 4 and 21 on a plant (Table 3). Statistically significant difference (P≤0.01) has been determined between plants growth in Florabella substrate (21 leaf) and those from soil (4 leaves) (Table 3). In Potgrond H substrate plants developed in average 20 leaves per plant (Table 3). Therefore, there was no statistically significant difference (P≤0.01) in number of leaves between plants growth in Florabella and Potgrond H substrates. Between plants growth in Potgrond H substrate and growth in soil a significant statistically difference (P≤0.01) has been determined and it was in average 16 leaves.

Comparising average length of above the ground part of plant the highest value was 21.59 cm and the lowest 4.81 cm (Table 3.). The longest plants were those growth in Florabella substrate (21.59 cm), and the shortest were in soil (4.81 cm), so the difference was statistically significant and it was in average 20.31 cm. In Potgrond H the length of above the ground part of plant was 20.31 cm (Table 3). Difference between Florabella substrate and Potgrond H substrate was 1.28 cm and it was not statistically significant. Difference between Potgrond H substrate and soil was in average 15.59 cm and it was statistically significant (P≤0.01).

Average mass of above the ground part of plant was between 0.25 g and 8.98 g (Table 3). In substrate Florabella plants developed highest mass (8.98 g), while the lowest mass was of the plant growth in soil (0.25 g.) (Table 3). In Potgrond H plants had in average mass of 8.41 g (Table 3). The biggest difference has been determined between Florabella substrate an the soil (8.73 g), while the difference between Potgrond H substrate and soil was 8.16 g. Therefore, the statistically significant difference (P≤0.01) has been determined between substrates (Florabella and Potgrond H), and soil. There was a difference of 0.57 g between substrates Florabella and Potgrond H which was not statistically significant.

4. DISCUSSION

Numerous studies emphasize the importance of substrates as well as the availability of nutrients for optimum plant growth [22]. In this study, nutrients content in soil was very low (Table 1) in comparison to ready-made supstrates which could be a reason for very low values of morphological properties of Zinnia growth in soil then those from ready-used substrates (Table 3). Nutrients content in Potgrond H and Florabella substrates is adjusted for optimal transplant growth and plants and therefore morphological properties of Zinnia growth in those substrates have not been significantly different (Table 3.). Besides the presence of nutrients, the pH and EC values of the substrates are also important factors [23]. Generally, plants shows the best growth and development in range 5.9-7.0 [24], but weakly acid to neutral soil reaction (5.5-7.2) is adequate for most ornamental plants [5]. The pH of growing environments, affects the availability of plant nutrients. In acid soils there could be a shortage of phosphorus, calcium, magnesium, molibden and bor. Insufitient nutrients results with several morfological deformities as well as decreased decorative value [5]. In this study, very low pH reaction of the soil and shortage of macronutrients (phosphorus and potassium) (Table 2) probably caused significantly lower values of measured morphological properties of plants from the soil (Table 3). Difference of pH reaction of ready-made substrates is not significant and it is not to expect differences in morhological properties of plants growth in Potgrond H and Florabella substrates (Table 3). Also, used ready-made substrates had pH reaction optimal for Zinnia growth, acording to literature, and therefore had no infleunce on morphological properties of plants. Electrical conductivity (EC) allows measurement of dissolved salts in soil affects plant growth, e.g. Zinnia is sensitive to salinity stress, even with lower (3 dS m^{-1}) salinity levels [25]. Regarding very low pH reacion of the soil, it has not been expected that EC influenced on plants morphology in negative way because of its

increased values. Among used ready-made substrates, Florabella had on product declaration, EC value higher then optimal qouted in research of Marković et al. (2022) [25]. Never the less, plants developed in ready-made substrates had no lower values of morphological properties. Mineralisation of humus have a cosequnce releasing of nutrients to the soil so the content of humus is in corelation with growth and development of the plant. The genesis of formation is a reason of different content of humus between ready-used substrates and soil. Generally substrates have high content of organic metter/humus and soil used in this research was slightly humous. Therefore, the better growth and development of Zinnia in ready-used substrates can be explained by higher humus conent within.

Also, every substrate should have appropriate physical characteristics, in particular high porosity, high water capacity, durable structure, and availability of nutrients [26]. Porosity, infiltration and hydraulic conductivity wich are determined by texture of the soil influence directly to plant nutrition by water and air suply to the root [27]. Soils with loamy texture are loose soils with sufficient porosity, low organic metter and with high proportion of silt tends to compresse [28]. In this study, soil was silt loam with high content of silt which influence on its density. Compact soils disables regular development of roots beacause there are no poores in it. Therefore, better growth and development of Zinnia plants was in u ready-made substrates with high porosity then in the soil with silt loam texture. Generally influence of physical-chemical properties of substrates has beeen prooved in field crops [29, 30] as well as ornamental [2,31] and horticultural plants [3, 20, 31].

5. CONCLUSIONS

In conclusion, different growth medium applications significantly affected on plant growth parameters of Zinnia elegans plants, and ready-used substrates have been determined as the most suitable environment in terms of nutrient uptake, plant growth and development parameters. This medium was the most convenient for the cultivation of Zinnia elegans plants. In Croatia there are many different soils with different physical-chemical properties it is necessary to conduct further research regarding Zinnia cultivation on soils throughout Croatia in order to contribute a visual appearance of landscapes.

6. REFERENCES

[1] S. Zeljković, Biostimulants application in production begonia (Begonia semperflorens Link et. Otto) and marigold (Tagetes patula L.) (2013), http://nardus.mpn.gov.rs/bitstream/handle/123456789/8761/Disertacija13435.pdf?sequence=1&isAllowed=y, last access 16/6/2022

[2] B. Japundžić-Palenkić; K. Jagodar; N. Romanjek Fajdetić; Lj. Božić-Ostojić, Effect of growing media on Tagetes patula nana plants quality. Proceedings 9th International Scientific and Expert Conference TEAM (2018), pp. 314-320

[3] B. Japundžić-Palenkić; K. Širajčić; N. Romanjek Fajdetić; B. Popović, Influence of two soil types with different physicochemical characteristics on root parsley (Petroselinum crispum ssp. tuberosum Mill) quality. Proceedings&abstracts 13th international scientific/professional conference Agriculture in nature and environment protection (2000), pp. 174-179

[4] A. Gola; M. Jakhro; M. Habib; S. Ahmed; M. Mohammed Wafa Shahwani; N. Naseer; S. Shah, 2. Influence of various growing media on growth and flowering of zinnia (Zinnia elegans) Dreamland. Pure And Applied Biology (PAB), 7(3) (2018), pp. 946-954, Retrieved from https://www.thepab.org/index.php/journal/article/view/556

[5] M. Herak Ćustić; L. Čoga; T. Ćosić; M. Petek; M. Poljak; V. Jurkić; S. Ćustić, Soil reaction a crucial precondition for choosing horticultural plants. Agronomski glasnik, 67 (2-4) (2005), pp. 235-253. Retrieved from https://hrcak.srce.hr/2242

[6] A. Škorić, Priručnik za pedološka istraživanja. Fakultet poljoprivrednih znanosti Sveučilišta u Zagrebu, (1982).

[7] J. M. Dole; H. F. Wilkins, Floriculture: Principles and Species. Second Edition, Pearson/Prentice Hall, N.J., USA, (2005)

[8] I. Veić; V. Šimunović; A. Hodalić, Flower beds in traditional gardens of northwest Croatia. Agronomski glasnik, 65 (3-5) (2003), pp. 241-252. Retrieved from https://hrcak.srce.hr/111453

[9] C. N. Johnson; J. R. Kessler, Green house production of bedding plant Zinnias. Albama Cooperative Extension System, ANR-1311, (2008).

[10] M. A.; Khan, K. Ziaf; I. Ahmad, Influence of nitrogen on growth and flowering of Zinnia elegans cv. Meteor. Asian Journal of Plant Sciences, 3(5) (2004), pp. 571-573.

[11] A. Esringü; M. Ekinci; M. Turan, Effects of Different Growing Media on Growth Parameters of Zinnia (Zinnia elegans). Yuzuncu Yıl University Journal of Agricultural Sciences, 32 (1) (2022), pp. 175-185 DOI: 10.29133/yyutbd.1034425

[12] A. Riaz; U. Farooq; A. Younis; A. Karim; A. Riaz Taj, Growth responses of zinnia to different organic media. Acta Hortic. 1018 (2014), pp. 565-571 DOI: 10.17660/ActaHortic.2014.1018.62

[13] HRN ISO 11464 (2004.). Soil quality. Pretreatment of samples for physico-chemical analyses. Croatian Standards Institute Zagreb

[14] ISO (2005.): Soil quality. Determination of pH. International standard. ISO 10390

[15] ISO (1998.): Soil quality. Determination of organic carbon by sulfochromic oxidation. HRN ISO14235

[16] H. Egner; H. Riehm; W. R. Domingo. Untersuchungen über die chemische Bodenanalyse als Grundlage für die Beurteilung des Nahrstoffzustandes der Boden II. Chemische Extractionsmetoden zu Phosphor- und Kaliumbestimmung. Lantbr. Hogsk. Annlr. W.R. 26: 199-215, (1960).

[17] L. Čoga; S. Slunjski, Soil diagnostics in plant nutrition [Dijagnostika tla u ishrani bilja]. Priručnici Sveučilišta u Zagrebu Agronomskog fakulteta, (2018). https://urn.nsk.hr/urn:nbn:hr:204:925835

[18] ISO (2009.): Soil quality. Determination of particle size distribution in mineral soil material – Method by sieving and sedimentation. ISO 11277

[19] L. Čoga; M. Herak Ćustić; L. Čoga; T. Ćosić; V. Jurkić; S. Slunjski; M. Poljak; D. Radman, Plant nutrient capacity of soils at Vrana valley. Agronomski glasnik, 68 (4) (2006), pp. 335-352. Retrieved from https://hrcak.srce.hr/176012, last access 12/6/2022

[20] Soil texture: https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/soils/?cid=nrcs142p2_054167 , last access 15/6/2022

[21] S. Husnjak; D. G. Rossiter; T. Hengl; B. Miloš, Soil inventory and soil classification in Croatia: historical review, current activities, future directions. (2004) http://www.css.cornell.edu/faculty/dgr2/_static/files/pdf/Overview_Soil_survey_HR_2004_334.pdf , last access 12/6/2022

[22] L. M. Brito; M. Reis; I. Mourao; J. Coutinho, Use of Acacia waste compost as an alternative component for horticultural substrates. Communication in Soil Science and Plant Analysis, 46 (2015), pp. 1814-1826.

[23] R. Caballero; J. Ordova´s; P. Pajuelo; E. Carmona; A. Delgado, Iron chlorosis ingerber as related to properties of various types of compost used as growing media. Communication Soil Science and Plant Analysis, 38 (2007), pp. 2357–2369

[24] Y. Awang; A. S. Shaharom; R. B. Mohamad; A. Selamat, Growth dynamics of Celosia cristata grown in coir, burnt rice hull and kenaf core fiber mixtures. American Journal of Agrculture and Biological Sciences 5 (2010), pp. 70-76.

[25] M. Marković; J. Šoštarić; A. Kojić; B. Popović; A. Bubalo; D. Bošnjak; A. Stanisavljević, Zinnia (*Zinnia elegans* L.) and Periwinkle (*Catharanthus roseus* (L.) G. Don). Responses to Salinity Stress, Water, 14 (2022), pp. 1066. https://doi.org/ 10.3390/w14071066

[26] M. Maślanka; R. Magdziarz, The influence of substrate type and chlormequat on growth and flowering od marigold (Tagetes L.). Folia Horticulturae 29/2 (2017), pp.189-198

[27] V. Vukadinović; V. Vukadinović, Soil, ferilization and crop production [Tlo, gnojidba i prinos] (2016) http://tlo-i-biljka.eu/Gnojidba/eKnjiga_Tlo-gnojidba-prinos.pdf, last access 16/6/2022

[28] V. Vukadinović, Soil and plant [Tlo i biljka], http://tlo-i-biljka.eu/Tekstovi/Tekstura_tla.pdf, last access 16/6/2022

[29] I. Rapčan; D. Galić Subašić; M. Marković; S. Grljušić, Influence of cultivar, seed inoculation and irrigation on agronomic properties of field pea in eastern Croatia. Agronomski glasnik 80 (4) (2018), pp. 257-271. https://doi.org/10.33128/ag.80.4.3

[30] I. Rapčan, D. Galić Subašić, S. Grljušić, M. Marković (2019): Influence of cultivar, seed inoculation and irrigation on soybean agronomic properties in eastern Croatia. Agronomski glasnik, 81 (3), pp. 173-185 https://doi.org/10.33128/ag.81.3.3

[31] B. Japundžić-Palenkić; M. Štivičić; K. Širajčić; N. Romanjek Fajdetić; R. Benković; M. Marković; A. Atilgan, Influence of Physical and Chemical Properties of Growing Media on the Quality of French Marigold (Tagetes patula L.) and Carrot (Daucus carota L.). Proceedings&abstracts International Congress on Agriculture in Alanya, (2021), pp. 37-46.

Tomato cultivation technology at the Lović OPG in 2021

M. Martić [a], L. Lović [b], S. Antunović [b],

J. Vujčić [a], V. Ibraković[a]

[a] High school Matije Antuna Reljkovića, Ivana Cankara 76, 35000 Slavonski Brod, Hrvatska, mirjana.martic1@skole.hr

[b] University of Slavonski Brod, Trg Ivane Brlić Mažuranić 2, 35 000 Slavonski Brod, Croatia, llovic@unisb.hr

Abstract

Tomato (*Lycopersicum esculentum* Mill.) is the most important vegetable crop intended for fresh consumption and processing. At OPG Lović, tomatoes grow in the open field on PE foil from seedlings produced in a protected area (tunnel) in shallow boxes. The variety Oxheart and the hybrid Hector F1 are used. Cultivation technology carries out according to the principles of conventional agriculture, with an effort to use as little as possible chemical agents for adequate plant protection. Temperature extremes did not favour cultivation, but in the end, producers achieved a satisfactory yield. They produced 6.5 kg/plant of hybrid Hector F1 tomato and 8 kg/plant of Oxheart. The goal of the work is to present the tomato growing technology at OPG Lović in 2021.

Keywords: cultivation technology, tomato, varieties, hybrid, OPG

1. INTRODUCTION

Tomato (*Lycopersicum esculentum* Mill.) is an annual plant from the Solanaceae family. It is one of the most important vegetable crops intended for fresh consumption and processing.

The yield and quality of tomatoes depends on a number of factors: soil, weather, assortment, cultivation technology, fertilization, mulching and irrigation. It is a self-fertilizing culture with high requirements for heat, and its outdoor production is determined by the frost-free period. Optimal temperatures for the growth and development of tomatoes during the day are 20-25°C, and during the night 15-18°C. Tomatoes are particularly sensitive to temperature conditions during seedling cultivation. When the three true leaves are developed, flowering starts, so if, at that time, the seedlings expose to temperatures of 13-15 °C, the first flowers will appear low on the plant already after 5-6 leaves, but flowering will prolong if the low temperatures last longer. Temperatures above 30°C slow down the photosynthesis process, and if the leaves do not protect fruits well, they become damaged due to intense light and high temperatures. High temperatures accompanied by low relative air humidity cause the flowers to fall off [1]. It has a well-developed root system and moderately demands water.

Producers can grow tomatoes in sheltered areas and in open areas, growing on bare soil or soil covered with polyethylene (PE) film. PE film prevents the growth of weeds, and protects the soil from excessive drying, fruiting occurs earlier, and the crop is less prone to diseases [2].

Mulching with black PE-foil results in better growth, earlier harvest and overall higher yield compared to straw mulch and cultivation on bare soil. Growing on bare soil can expect a significantly higher number of non-marketable fruits compared to tomatoes mulched with straw or PE film [3]. Under the film, the producers placed a drip irrigation system. In the open field, the sprinkling method irrigates surface and localizes tomatoes. According to Tan et al.

(2009), tomato yield does not vary depending on the irrigation method. The authors conducted a study in which tomatoes were irrigated using surface and subsurface methods. They studied how the irrigation method will affect the yield and quality of the tomato fruit. The average yield of tomatoes irrigated with the surface method was 35 to 37% higher compared to the control treatment (not irrigated); while with the subsurface irrigation method, the yield was higher by 43 to 47%, although not statistically justified [4] [5].

The soil for cultivating tomatoes must be loose, well structured, fertile, neutral or slightly acidic with a pH of 6.0 to 7.0 [6]. Tillage depends on the pre-crop and producers do them according to the system for spring crops.

Fertilization of tomatoes depends on soil fertility, and depending on this, it is necessary to add 120-180 kg/ha N, 80-120 kg/ha P_2O_5, 120-180 kg/ha K_2O [7]. On medium-fertility soil, it is necessary to plow 40 t/ha of manure and add about 800 kg/ha of NPK 5:20:30 and 150 kg/ha of UREE to the soil before planting. Furthermore, with additional feeding at the beginning of intensive growth and after seeding and the beginning of ripening of the first fruits with 100 kg/ha of KAN [1]. According to Ban et al. (2008) for the cultivation of tomatoes for processing, fertilization with 120 kg/ha N and mulching with black PE-film is recommended. [3].

In the production of tomatoes, producers use varieties and hybrids of low stem, limited growth and hybrids of unlimited stem growth, which grow with a support. Planting of short varieties of tomatoes the producers do with a planter at an inter-row spacing of 150 cm and a row spacing of 50 cm. When growing tomatoes of unlimited growth, it is necessary to install a support in the form of wooden or metal (plastic) stakes or in the form of wire reinforcement.

The aim of the paper is to present the technology of tomato cultivation at OPG Lović in the year 2021.

2. METHODS AND MATERIALS USED FOR RESEARCH

OPG Lović is located in Brod-Posavina County in Gornja Bebrina. The farm owns 80 ha of arable land, where field crops are mainly grown. Producers cultivate tomatoes on 2,500 m^2 in an open field.

Weather conditions, low temperatures during seedling production in March and April and high temperatures during the growing season in July and August, significantly affected the quality and yield of tomatoes. Temperatures in March and April 2021 were significantly lower, but in June and July significantly higher than the multi-year average. The amount of precipitation was 147 mm lower than the multi-year average, Table 1, [8].

Table 1. Average monthly air temperatures (°C) and precipitation totals (mm) for the year 2021 and multi-year average (2010-2020)

Month	Slavonski Brod (2010-2020)		Slavonski Brod (2021)	
	Temperatures (°C)	Precipitation (mm)	Temperatures (°C)	Precipitation (mm)
March	7.6	48.5	6.0	33.4
April	12.7	53.3	9.3	58.5
May	16.4	111.3	15.2	66.9
June	21.0	83.2	22.4	17.2
July	23.0	70.7	24.4	71.6
August	22.7	49.2	22.0	70.1
September	17.1	68.2	16.8	20.1
Total		484		337

In the year of observation, the OPG Lović planted the hybrid tomato Hector F1 and the old tomato variety Oxheart. Hector F1 is a determinant, medium-early tomato intended for outdoor cultivation. The fruits are large, very tasty, with a yield of about 10 kg/plant. The Oxheart is an old, late tomato variety that OPG Lović has grown in the garden for many years. It is a late variety, tall and very lush, with large, juicy and fleshy heart-shaped fruits [9].

OPG Lović cultivates tomatoes from seedlings produced by direct sowing in shallow boxes in an unheated tunnel and remain in them until the time of planting. In the research year,

due to lower temperatures, sowing was done at the beginning of March, Table 1. The protection of seedlings carried out against Pythium spp. was with a systemic fungicide based on the active substance propamocarb 605 g/l, Proplant in the amount of 20 ml/100 m^2.

In the research year, the main crop was wheat. Producers carried out shallow ploughing immediately after the harvest, and basic cultivation in the fall at a depth of 30 to 35 cm. The producers' left ploughed soil in an open furrow over the winter, and in the spring, closed the furrow by harrowing. During supplementary processing, mineral fertilizer NPK 5:20:30 was incorporated for 800 kg/ha and UREA 150 kg/ha. Producers carried out top dressing at the beginning of fruit ripening with 100 kg/ha of KAN, Table 2 [9].

Table 2. Quantity of fertilizers and pure nutrients in tomato fertilization at OPG Lović in 2021.

Fertilization/ Pure nutrients	N	P	K
800 kg/ha NPK 5:20:30	40	160	240
150 kg/ha UREA 46%	69	0	0
100 kg/ha KAN 27%	27	0	0
Total	136	160	240

After the supplementary treatment, producers installed an irrigation system and black PE film manually to prevent weed growth and soil drying. Weeds between the beds, producers suppressed mechanically, by cultivation, Figure 1. Producers do not pick tomato seedlings and they are well soaked with water before planting in order to damage the roots less. The producers carried out planting when the seedlings had 5 to 6 leaves, in mid-May, in previously prepared flowerbeds, with an inter-row spacing of 100 cm and a row spacing of 50 cm. They planted a total of 5,000 seedlings, 2,500 Hector F1 hybrids and 2,500 Oxheart varieties. After that, next to each plant, producers placed a wooden support, Figure 1. During the growing season, producers took care measures to remove the tips, and dry leaves. Producers took out all plant material outside the plantations in order to reduce the possibility of disease spreading. Protection against disease was preventive, by spraying with milk and water in a ratio of 1:10 as preventive protection against blight. Fertilization was during the growing season with KAN and nettle preparation, foliar in a ratio of 1:50 or watering 1:10. Producers carried out irrigation daily in the early morning hours.

Figure 1. Growing tomatoes on PE foil, OPG-Lović

3. RESULTS AND ACHIEVEMENTS

Low temperatures in the unheated tunnel during March had a negative impact on the production of seedlings. Although the sowing dates moved to March 10, about 10% of the seedlings failed due to lower temperatures. Soil treatment is in accordance with the Matotan recommendation (2004.) [11]. A total of 136 kg/ha of N, 160 kg/ha of P_2O_5 and 240 kg/ha of K_2O introduced into the soil by fertilization and top dressing, which according to Lončarić et al. (2013) met the nitrogen and phosphorus needs of tomatoes, but potassium was less compared to the planned needs [7]. The absence of precipitation and high temperatures affected the yield reduction, but also the absence of diseases, and preventive protection with milk was

sufficient. The first crop was wheat, so there were no prerequisites for diseases. Producers achieved an average of 8 kg/plant of the Oxheart variety and 6.5 kg/plant of the Hector F1 hybrid, a total of 36,250 kg, Table 3. According to Černe et al. (2003), the achieved yield of Ox heart is in accordance with the achieved yield of the Milka variety, which is in the type of the researched variety in terms of characteristics. [9].

Table 3. Average yield per variety Oxheart and hybrid Hector F1 at OPG- Lović in 2021

Sort/ Yield	Oxheart (kg)	Hector F1 (kg)	Total (kg)
Yield/plant	8	6.5	
Yield/2500b	20 000	16 250	36 50

4. CONCLUSIONS

Tomato yield depends on agro-ecological conditions and applied cultivation technology. At OPG Lović, producers grow tomatoes on an area of 2,500 m2, and since the additional production is in addition to arable production, there are no plans to increase the area for growing tomatoes. Producers carry out cultivation technology according to the principles of conventional agriculture, with an effort to use as little as possible chemical agents for plant appropriate plant protection. Temperature extremes did not favour cultivation, but in the end, producers achieved a satisfactory yield.

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6. REFERENCES

[1] Z. Matotan, Utjecaj okolišnih uvjeta na razvoj rajčice i pojavu fizioloških poremetnji, Stručni rad, Glasnik zaštite bilja 3/2008., (2008.).

[2] Z. Matotan, Plodovito povrće 1, Agro hit, ISBN 978-953-6698-43-1, str. 111-179.

[3] D. Ban, M. Zovko, M. Sraka, I. Kaluđerović, D. Žnidarčić, Impact of mulching and nitrogen rates on growth and yield of processing tomatoes, Proceedings, 43rd Croatian and 3rd International Symposium on Agriculture Opatija, Croatia, (2008.), 425 – 429.

[4] Tan C. S., Zhang T. Q., Reynolds W. D., Warner J., Drury C. F. (2009): Farm-scale processing tomato production using surface and subsurface drip irrigation and fertigation. ISHS Acta Horticul. 823, 77-82.

[5] K. Šarlija, Navodnjavanje rajčice (*Lycopersicon esculentum* Mill.) na primjeru staklenika „Belje“ d.d., Poljoprivredni fakultet, (2017.), https://urn.nsk.hr/urn:nbn:hr:151:925504, 26.06.2022.

[6] N. Parađiković, Opće i specijalno povrćarstvo, Poljoprivredni fakultet Osijek, (2009.), 120718096, str.195 – 228.

[7] Z. Lončarić, N. Parađiković, B. Popović, R. Lončarić, J. Kanisek, Gnojidba povrća, organska gnojiva i kompostiranje, Poljoprivredni fakultet u Osijeku, ISBN 978-953-7871-36-9, str.32-33, (2013.).

[8] Državni Hidrometereološki Zavod

[9] L. Lović, Zaštita rajčice od bolesti na OPG-u Lović u 2021.godini, Završni rad, BTO-H-7/2021, Sveučilište u Sl. Brodu (2021.) .

[10] M. Černe, N. Kacjan Maršić, U. Pečar, Stare i priznate sorte u ekološkoj proizvodnji povrća, Zbornik sažetaka 38. Znanstvenog skupa agronoma, Opatija (2003.)http://www.povrce.com/doc/clanak01.doc, 2.07.2022.

[11] Z. Matotan, Sortiment i tehnologija proizvodnj rajčice, krastavaca, salate i špinata, Glasnik zaštite bilja 4/2004. Str.21-62., https://hrcak.srce.hr/file/242176.

Natural causes of environmental degradation in Požega-Slavonia County in 2021

L. Mirković [a], K. Mirosavljević [b,*], T. Benković-Lačić [b]

[a] Regional Development Coordinator of Požega-Slavonia County, Županijska 7, HR-34000 Požega, Croatia, lea.mirkovic@panora.hr, student of University of Slavonski Brod

[b] Biotechnical Department, University of Slavonski Brod, Trg Ivane Brlić Mažuranić 2, HR-35000 Slavonski Brod, Croatia, kmirosavljevic@unisb.hr*, tblacic@unisb.hr

Abstract

Environmental degradation is present due to the exploitation of water, soil and air, which includes the destruction of ecosystems, the destruction of natural habitats and the reduction of biodiversity to the point of extinction of certain species. Natural causes of degradation affecting the environment are earthquakes, hail, soil erosion, floods, volcanic eruptions, fires, droughts, typhoons, hurricane winds and frost. In the area of Požega-Slavonia County in 2021, damage was reported for four natural disasters, namely: earthquake, flood, hail and frost. On June 6 and 10, rain curves accompanied by thunder caused torrential floods that affected the area of the City of Požega and the Municipality of Velika. In April 2021, extremely low temperatures appeared, which caused the appearance of frost and caused damage to the entire Požega-Slavonia County. The biggest recorded damage caused by a natural disaster in 2021 is hail damage. On June 25, a storm followed by hail hit the area of the City of Požega, the City of Pleternica, the Municipality of Jakšić, the Municipality of Kaptol and the Municipality of Velika, causing great damage. The earthquake is the only one of these disasters that did not occur during 2021, but the report of the damage was received until January 29, 2021. The Government of the Republic of Croatia has provided the funds needed for the complete remediation of damages caused by natural disasters according to the estimated amounts.

Keywords: environment protection, degradation, hail, natural disasters, remediation.

1. INTRODUCTION

The technological progress of our civilization and society leads to various negative phenomena and processes in nature. Degradation of the environment is ubiquitous due to the exploitation of water, soil and air, which includes the destruction of ecosystems, the destruction of natural habitats and the reduction of biodiversity to the point of extinction of certain species.

In addition to the environment, degradation mainly affects human health. Through his actions, humans seriously impair the quality of life, and thus affects the planet and the natural factors of the environment. It is undeniable that anthropogenic influence is the biggest culprit for the state of the climate and climate change in the world nowadays. The politics of EU are turning more and more to green innovations and green technologies in the hope of saving the planet and maintaining the quality of life that is already impaired.

The environment is natural and any other surroundings of living organisms and their communities, and it also includes humans who are responsible for the existence of these communities and their further development. The components of the environment are air, water,

soil, landscape, flora and fauna, the stone crust of the Earth, energy, material goods and cultural heritage [1].

Biodiversity is defined as the totality of all living organisms that by their existence form an integral part of the ecosystem, and their morphological and physiological characteristics make up the diversity within species, between species, living communities and the diversity of ecosystems. [2] Biodiversity for food and agriculture is essential for food security, sustainable development and the provision of many vital ecosystem services and makes production systems and livelihoods more resilient to shocks and stresses, including the effects of climate change. It is a key resource in efforts to increase food production while limiting negative impacts on the environment.

Many highlight the role of diversification – using more species, integrating the use of crops, livestock, forest and water resources, and conserving and managing habitat diversity at the landscape or marine level – in promoting resilience, improving livelihoods and supporting food and nutrition security. [3]

Due to the problem of biodiversity, the European Union presented the Biodiversity Strategy for 2030, which represents a comprehensive and long-term plan for the protection of nature and stopping the degradation of the ecosystems. It contains certain actions, measures, obligations and plans aimed at restoring biodiversity by 2030. [4]

Major threats to biodiversity are natural disasters, which are increasingly causing the destruction of individual habitats, ecosystems and biosystems. Frequent accidents have a cause-and-effect relationship with human actions on the exploitation of the environment. Natural phenomena that threaten the environment and human health are mostly independent, but today it can be safely said that natural phenomena are influenced by anthropogenic factors. The natural causes of degradation that affect the environment are earthquakes, fighting, soil erosion, floods, volcanic eruptions, fires, droughts, typhoons, hurricane winds and frost. Natural factors of environmental degradation, damage from floods, earthquakes, hail, soil erosion and fires has been recorded in Požega-Slavonia County in recent years.

According to the geographical location in the Republic of Croatia and the indentation that consists of the above: Papuk, Krndija, Dilj gora, Požeška gora and Psunj, as well as the number and diversity of water resources, Požega-Slavonia County have diverse habitats, i.e. habitat types and numerous plant and animal species that, due to their distribution, make the County rich in biodiversity.

The climate of Požega-Slavonia County is moderately warm and humid with warm summers (Cfb according to Köppen) and moderately cold winters. The least amount of precipitation occurs during winter, and the most precipitation occurs in late spring and autumn. Thunderstorms are also common in summer, sometimes accompanied by heavy hail. There are no extremely wet periods in the County. Mountain areas have more rainfall and lower temperatures.

The aim of this research was to identify natural causes of environmental degradation in Požega-Slavonia County in 2021.

2. ENVIRONMENTAL DEGRADATION IN POŽEGA-SLAVONIA COUNTY IN 2021

In 2021, residents of the Požega-Slavonia County were affected by four natural disasters, namely: earthquake, flood, hail and frost. The earthquake is the only one of the listed disasters that did not occur during 2021, but the report of the resulting damage was received until January 29, 2021, so it was registered in the register of the Ministry of Finance, and the damage was recorded during the earthquake with an epicenter in the vicinity of Petrinja that occurred December 28, 2020. The earthquake did not cause damage to the entire County, but only to

the Pakrac-Lipik area in the amount of HRK 12,458,951.92. Damage was recorded to construction facilities.

On June 6 and 10, torrential rains accompanied by thunder caused flash floods that hit the area of the City of Požega and the Municipality of Velika in the amount of HRK 6,295,770.69.

In April 2021, extremely low temperatures for that time of year appeared, which caused the appearance of frost and caused damage to perennial plantations in the entire Požega-Slavonia County. Damages that year amounted to HRK 6,919,369.47.

The largest recorded damage caused by a natural disaster in 2021 is hail damage. On June 25, a storm accompanied by hail struck the area of the City of Požega, the City of Pleternica, the Municipality of Jakšić, the Municipality of Kaptol and the Municipality of Velika and caused extensive damage estimated at HRK 173,478,561.17. In total, estimated costs of damage was HRK 199.152.653,25.

2.1. Floods

Flash floods, as well as other natural disasters, are proof that climate change adversely affects the environment. A significant cause of climate change is mankind, and the cause-and-effect relationship of human's adverse impact on the environment is natural degradation. Considering the records of torrential floods in the City of Požega, it is a fact that floods recur on average every five to ten years. Flash floods bring with them another danger, which is soil erosion, which increases with the amount of precipitation, and the erosion factor is determined by the strength of the substrate, i.e. the soil, the stronger the substrate, the less erosion.

On June 6, 2021 (Sunday) in the morning, between 7:45 and 9:00 a.m., heavy rain accompanied by thunder fell. The weather calmed down, but the soil remained quite saturated with moisture. However, shortly after noon, at around 12:20 p.m., the rain began to fall again, increasing in intensity, by 1:00 p.m. it reached its maximum intensity, and then until 4:00 p.m. in unbalanced intervals of weaker and stronger intensity. The rain gauge at the County Hospital in Požega measured 37.5 l/m² by 1:00 p.m. that day. It was estimated that locally on the slopes of Požeška Gora, the total amount of precipitation was at the level of 80-100 l/m² and that in a very short period of time of only 60 minutes. For the sake of comparison, for the measuring station Požega, the average precipitation in the month of June (1959 - 1983) is 95.6 mm. For the periods 2013 - 2021. average precipitation in June is 90.1 mm. [5]

On June 10, 2021, a lot of rain fell again in a very short time in the eastern part of the city of Požega, and above the villages of Vidovci and Dervišaga.

2.2. Hail

Hail is solid precipitation that forms in cumulonimbus clouds that have a strong vertical development. Hail grains are a mixture of ice, water and air with a diameter greater than 5 mm, which are mostly opaque and have a layered structure. The size of hailstones depends on the number of supercooled droplets in the cloud, that is, the diameter of the grains will be larger with the higher concentration of supercooled water. Also, the concentration of aerosols in the air greatly affects the size and quantity of hailstones.

The main obstacle in a more accurate forecast of the state of cloud development is the large number of unknowns in the knowledge of cloud physics. Physical and mathematical methods make it possible to predict approximately the location and time of the development or formation of storm clouds. With good radar and satellite measuring devices, the exact time and location and intensity can be predicted at most one to two hours in advance. [6]

The most intense instabilities occurred on June 5, 6, 11, 24, 25 and 30. Hail defence began operating on June 15, 2021, and the largest operation was carried out on June 25.

Table 1. Hail damage in Požega-Slavonia County

YEAR	HAIL DAMAGE / HRK
2010.	1.453.234,83
2011.	2.391.116,00
2012.	0
2013.	15.024.553,62
2014.	77.542,40
2015.	0
2016.	26.252.339,70
2017.	0
2018.	5.389.193,76
2019.	0
2020.	0
2021.	173.478.561,17
Total	224.066.541,48

Table 1 shows the total amount of reported damage to property owned by individuals and legal entities caused by hail in Požega-Slavonia County in the period from 2010 to 2021. The table shows that in 2021, the largest damages were recorded in the last ten years, and this damage actually accounts for 77% of all damages from 2010 to 2021.

In recent years, activities related to hail defence have been conditioned by reduced financial resources and the unresolved status of the hail defence activity for several years with constant projections of its abolition. Also, the existing system is problematic from the point of view of environmental protection due to the uncontrolled seeding of the atmosphere with silver iodide and, consequently, its deposition on the ground.

2.3. Frost

Farmers in the continental part of the Republic of Croatia suffered a severe frost at the beginning of April, which had great consequences for the crops, especially for fruit production. In Požega-Slavonia County, some fruit species as well as micro-localities experienced complete crop destruction caused by temperatures lower than -6 °C for six hours. The most significant damage was recorded on stone fruits, especially in apricot plantations where total damage was recorded. Plum plantations were in full bloom in April and caused total damage up to significant damage from the freezing of flowers, and such damage was also recorded in cherry and pear plantations where there was complete freezing of the carpels in the protected flower. Apples suffered enormous damage from low temperatures, mostly on the main flower and other more closed buds along the entire length (the height) of the fruit tree. Also, complete damage was recorded in walnut plantations whose buds were chased, namely they completely froze and fell off.

As shown in Table 2, it is evident that extremely low temperatures occurred between April 7 and 9 and lasted until April 16. It caused frost and caused damage to the entire Požega-Slavonia County.

Table 2. Temperatures in April that caused the appearance of frost in Požega-Slavonia County in 2021.

hour	KAPTOL			BERTELOVCI			MARINDVOR			SKENDEROVCI			BRODSKI DRENOVA			SLOBOŠTINA			PREKOPAKRA			BEKTEŽ		
	7.4.	8.4.	9.4.	7.4.	8.4.	9.4.	7.4.	8.4.	9.4.	7.4.	8.4.	9.4.	7.4.	8.4.	9.4.	7.4.	8.4.	9.4.	7.4.	8.4.	9.4.	7.4.	8.4.	9.4.
8	1,6	-1		2,1	-2,1		0,7	-1,7		0,9	-2,2		-1,9	-3		-1,4	-2,2		2,5	1,6		1,3	-1,3	
7	-2,6	-2,6	0,2	-0,5	-2,3	-0,7	-2,1	-3,4	-2,6	-2,7	-3,3	-2,7	-2,8	-5,8	-5	-2,2	-3		-0,8	0,3	0,8	-3,1	-4,5	
6	-3,4	-4,6	-1,8	-2,6	-4,6	-2,8	-2,7	-3,5	-4,1	-3,9	-4,9	-3,6	-2,8	-5	-5,2	-1,8	-3,9	-2,3	-1,8	-1,5	-0,7	-3,8	-4,7	2,16
5	-2,6	-4,2	-1,8	-2	-4,2	-2,7	-2,8	-4,5	-3,8	-3,4	-4,7	-3,5	-2,4	-4,9	-5,2	-1,9	-3	-1,3	-1	-2,5	0,1	-3,1	-4,2	2,32
4	-3,3	-4	-1	-2,2	-3,5	-2	-1,6	-4,7	-3,2	-2,8	-4	-2,9	-1,7	-4,1	-4,5	-2,1	-3,54	-1,1	-0,7	-1,5	0,2	-3	-3,9	2,43
3	-2,8	-3,4	1,1	-1,2	-3,1	-1,5	-1,7	-3,8	-2,4	-2,6	-3,5	-2,6	-2,1	-3,4	-3,74	-3,1	-2,4	-1,2	-0,5	-1,4	0,7	-2,7	-3,9	2,78
2	-3	-2,7	-1,2	-1,8	-2,6	-0,5	-2,2	-2,8	-1,7	-2,2	-3	-2	-2,5	-1,6	-3,1	-2,5	-2,6	-0,2	-0,4	-0,9	0,9	-2,4	-3,5	2,65
1	-1,3	-2,4	2,2	0,2	-1,7	1,1	-1,3	-2,3	-0,7	-1,4	-2,8	-1,3	-1,3	-1,7	-1,9	-2,1	-2,3	0,2	-0,9	-0,9	2,3	-2	-3,3	3

Due to the considerable damage caused in agriculture and the almost impossible recovery of long-standing plantations, the Ministry of Agriculture provided help in the amount of HRK 20 million at the expense of the State Budget of the Republic of Croatia.

3. CONCLUSIONS

The way modern people live in coexistence with nature creates a big problem for nature. Namely, people today use all natural resources, renewable and non-renewable, drains them and permanently damages the environment. Degradation is increasing every day and there is no way to recover the earth's resources, only to slow down the overexploitation of resources. Through their actions, people damage his own health and the "health of the Earth". In the last few years it has been evident of how nature repays to mankind for their negligent behaviour towards the environment that surrounds them. There have been major climate changes and increasingly frequent occurrences of natural disasters that significantly affect the health and quality of people, plants and animals. Thus, in the last few years, in the Republic of Croatia, a devastating earthquake appeared several times, numerous counties recorded a major drought and flood in the same year, even month, and Slavonia was hit by a hail that will unfortunately be remembered for a long time.

For the year 2021, the Požega-Slavonia County has reported total damage from natural disasters in the amount of HRK 199,152,653.25, which is the highest amount since 2010, when data from the Ministry of Finance are available. Namely, natural disasters cause major problems immediately after they occur, but also open up some outdated problems such as fighting and how to prevent natural disasters, reducing the possibility of large damages and many others. In the wider area of Požega, numerous residential houses were discovered that were built in an uncontrolled manner without prior arrangement of watercourses in the immediate vicinity. Furthermore, due to the large increase in the prices of raw materials, people are clearing nearby forests that are not their property, thus accelerating the flow of water from the nearby slopes to the houses at the foot.

The problem of defence against natural disasters is certainly also a question of the effectiveness of anti-hail protection, that is, the firing of rockets with silver iodide, the effect of which is still the subject of numerous discussions. The Republic of Croatia has decided to prepare programmes with the aim of mitigating climate change, which would help reduce damage from hail and other extreme weather events, and to find more favourable insurance models in case of damages caused by weather disasters.

4. REFERENCES

[1] Environmental Protection Law (Official Gazette 80/13, 153/13, 78/15, 12/18, 118/18)

[2] https://mingor.gov.hr/o-ministarstvu-1065/djelokrug/uprava-za-zastitu-prirode-1180/bioraznolikost/1216, last access 19/04/2022

[3] Biodiversity Report, https://www.fao.org/documents/card/en/c/cb1928en/, last access 19/04/2022

[4] https://ec.europa.eu/environment/strategy/biodiversity-strategy-2030_hr, last access 08/06/2022

[5] Complete report on defence against flash floods in the defended area D.3.3. area of VGI Orljava-Londža, Hrvatske vode, 2021 (in Croatian)

[6] Analysis of the hail defense system - Report and opinion on the justification of further operation of the hail defense system in the Republic of Croatia, Zagreb, 2018 (in Croatian)

Problems of organic agricultural products placements

N. Romanjek Fajdetić [a], Lj. Božić-Ostojić [a], M. Blažinkov [a], J. Vujčić [b], B. Japundžić Palenkić[a],B. Vujčić [c], Melita Grgić [a]

[a] University of Slavonski Brod, BTODept Trg Ivane Brlić Mažuranić 2, 35 000 Slavonski brod, Croatia,
nrfajdetic@unisb.hr

[b] High school "M. A. Reljković", I. Cankara 76, 35 000 Slavonski Brod, Croatia,
jvujcic@unisb.hr

[c] Public Institution for the management of protected areas of Brod-Posavina County at Brod-Posavina County "
ravnatelj.natura-slavonica@bpz.hr

Abstract

The aim of this paper was to investigate the results of surveys conducted to examine the issue of marketing of organic products. Organic production of agricultural products is becoming increasingly important as it raises public awareness for the importance in the quality of consumed food. However, such production requires more investment than conventional production and therefore the price of such products is higher. In addition, investing in marketing and packaging design further increases the cost of such products. The ecoproducers in Croatia do not invest enough in presentation and packaging. Beside that products are more expensive than conventional so they have to find a target customers that are willing to pay for it. The only way is to organize themselves and act an as association because in that way they would reach customers more easily.

Keywords: organic products, placement

1. INTRODUCTION

The Republic of Croatia also follows world and European trends in the development of organic agricultural production. However, this trend of production growth does not follow the trend of reaching organic products to final consumers. The first and most important step after the eco-product has been produced until it enters the market is to exercise the right to a certificate. Manufacturers receive them after the controls performed by the Control Bodies that monitor the production, and based on them they are allowed to use the prescribed eco-label that is in accordance with national and European regulations. The certificate guarantees to the buyer that the product has no traces of illegal plant protection products in organic production. [1]

2. LINK RESEARCH: PRODUCER – CONSUMERS OF ORGANIC PRODUCTS

Several researches have been conducted in the Republic of Croatia regarding the placement of organic products. The research of students from the Faculty of Science in Zagreb, Department of Geography, in 2008, resulted in a study entitled "Organic agricultural production

in Croatia - problems and opportunities for development." During the study, eco-producers from the Požega-Slavonia County were examined, where students asked producers questions related to education, motives for dealing with organic production, problems they face, and continuing to engage in organic production. [2] Among other things, the respondents stated that economic profitability is very important for them (eco-producers). The majority of agricultural holdings (40.6%) state that placement in local markets (markets and fairs) is in the first place due to direct contact between the consumer and the seller (producer) where they will inform them about their products. This is followed by eco-associations and sales in the tourism market, followed by retail chains, meat industries, butchers, resellers, restaurants, dairies and internet sales. According to the producers, the biggest problem in organic production is the unorganized market and placement of goods. Namely, most producers, due to no connectedness and unorganized purchase, enter the market independently. The group of leading problems also includes underdeveloped environmental awareness. Manufacturers believe that consumers are very skeptical about organic products, and also their higher price is the reason for their lower sales. [2] Furthermore, the research of the Institute of Agriculture and Tourism from Poreč and the Ethnographic Museum of Istria from Pazin conducted at the event "Watch what you eat" held in Pula in 2015, provided general information on organic farming, production and marketing of organic food products. The participants were exhibitors, i.e. eco-producers from Croatia. The participants in the research had an average age of about 48 years, mostly from high school (53.66%), other participants had a university degree. 48.78% of them completed some of the trainings, most often training on biodynamic production. The most represented entities in organic agricultural production are family farms with 87.8%, and they are mostly engaged in fruit growing (58.54%) and vegetables (41.46%). [1] In the part of this research related to the sale of their own eco-products, all respondents agreed that the most common way of selling is at fairs, then on the doorstep, by selling through solidarity environmental groups, markets, intermediaries and the Internet. [13] The problems with the sale of organic products are that eco-producers come out with small quantities of products for sale, is that the market is disorganized, and the market competition is weak, eco-producers are not connected, procurement is difficult and the price of raw materials is high and the consumers are not educated enough about organic production and organic products. Regarding these problems, 92.68% of respondents agreed that all these problems would be smaller if eco-producers joined forces, and even if that means that this association is at the level of the Republic of Croatia. [1]

· By merging, eco-producers could solve the following problems:

- Easier marketing of products,
- Reduction of production costs,
- Better bargaining power,
- Providing larger quantities of products,
- Achieving higher prices,
- More customers [1]

The third research related to the placement of eco products was conducted at the eco-market Šijana in Pula, which opened in 2013. The research conducted the Faculty of Agriculture in Zagreb, and the aim of the research was to examine the satisfaction of producers and customers. 9 producers-sellers of organic products and 100 buyers took part in the survey. The age of producers-sellers was on average 43 years, 2/3 had higher education, and 1/3 had high school. Producers are mostly engaged in growing vegetables, fruits, then beekeeping and processing of medicinal herbs. [3] Respondents most often place their products through the Solidarity Exchange Group, then at fairs and eco-markets, and on their farms. Less represented are sales at tourist points, small hotels or stands in camps. [3] Surveyed

customers, 90% of them said they regularly buy organic products, most often fruits and vegetables, then various types of flour, honey and bee products. However, 37% of respondents stated that they believe only in some eco-labels, but that they mostly trust well-known local producers, while 60% of respondents mostly trust labeled eco-labels. Buyers of organic products have stated that they are willing to pay a higher price for the product, which means that the price is not a limiting factor for loyal customers. [3] Surveyed customers expressed satisfaction with the possibility of this method of direct sales, product offerings and reasonable prices. Producers-sellers see the problem in the weak representation of eco-producers, which indicates weak competition, no organized sales through smaller fairs, while customers say they are satisfied with them as well as the profile of customers since they are mostly customers who know what eco-product and know what they want. [3] With a gap of more than 10 years after the first research, one can conclude that, although the number of eco-producers has increased significantly, the problem has remained almost identical. Looking at all three studies, it is evident that they have common positive and negative points. Manufacturers - sellers are approximately similar in age, the educational structure is identical. The offer of organic products at fairs and markets offered directly to customers is very similar since it is a direct sale. Markets and fairs are still the main places for sale, especially in the areas by the sea which in this part of Croatia are closely connected with tourism and the purchasing power of customers. The problem of placement is identical everywhere, insufficiently organized and poorly marketed sales of organic products, lack of manpower, and eco-producers primarily rely on their own strengths. However, the only motivating point seems to be high support through rural development measures.

2.1. Sales of organic products in retail chains

Most food buyers in Croatia get supplies in consumer retail chains, where they can also buy fresh products (fruits and vegetables). For this reason, there could be a decline in sales of agricultural products in the markets, which of course also applies to organic products. Although analyzes of the eco-products market in Croatia show that eco-products are most often bought in markets (60%), then in supermarkets (46%) and in specialty stores (37%), consumers say they are very satisfied with shopping in specialty stores, and it is desirable to expand the range of products in supermarkets, i.e. consumer goods stores and direct sales in markets. [4] A survey of the representation of eco-certified products in retail chains found that such products are still underrepresented. Mostly on the shelves of shopping malls you can find some ready-made products such as pasta, bread, milk, juices, jams, honey. Most of these products stores import from Germany, Austria and Italy. A small proportion of organic products relate to fresh products such as fruits and vegetables. However, the tendency of retail chains is to increase the supply of these types of products as they are increasingly sought after and recognized as a source of healthy food. [5] Customers are most satisfied with the service in specialty stores and buying directly from manufacturers, they are most satisfied with the range of products in the markets as well as the price, while product quality is best when buying directly from manufacturers. They are most dissatisfied with the price of eco-products in specialty stores and supermarkets, as well as the quality of products in supermarkets. [4] In the future, sales of organic products in retail chains will certainly be increasing in order to meet the trends and demands of customers. One of the problems that further confuses buyers of organic products in retail chains is the incorrect labeling of eco-products, which creates mistrust among customers. Products with "domestic", "organic" or "natural" labels can often be found on the shelves, but none of them indicate an organically produced product. [5]

2.2. Marketing needs in the marketing of organic products

In order for a Croatian organic product to be recognized and competitive on both the domestic and foreign markets, it must go through several phases. Product quality must be uniform, it must have a marketing strategy and go through a branding process. [6] A survey conducted on 75 farms certified for organic production showed how our ecoproducers think in terms of marketing as a factor in increasing the competitiveness of organic production in the Republic of Croatia. [7] In this research, the age and education of eco-producers, as well as the representation of the type of organic production are in line with previous research. However, in this research, the respondents stated that they conduct promotions of their own products. As can be seen, product promotion is most often done through recommendations, fairs and the Internet, while most eco-products are sold on the doorstep, organized purchase and at fairs. Most promotional activities are done by recomendations (36 %), than fairs with (34,7 %), WEB page (22,7 %), Facebook (18,7 %), TV (5,3 %), Radio (4 %) and newspaper (4 %) and (26,7 %) does not participate. According to characteristics and identity of the product, it is still insufficiently used, so often manufacturers sell their eco-products at conventional prices. Although (60 %) of respondents believe that it is necessary to gain the trust of customers for further production and sales, the investment in the promotion and marketing of organic products is not carried out by respondents, citing limited financial resources. [7] these most of products are sailed at doorstep (64 %), agreed purchase (37,3 %), specialized fairs (25,3 %), internet (14,7 %), retail chains (12 %), restaurant (5,3 %) and market (4%). It is known that the use of the eco-label confirms the As can be seen, product promotion is most often done through recommendations, fairs and the Internet, while most eco-products are sold on the doorstep, organized purchase and at fairs. It is known that the use of the eco-label confirms the characteristics and identity of the product, it is still insufficiently used, so often manufacturers sell their eco-products at conventional prices. Although 60% of respondents believe that it is necessary to gain the trust of customers for further production and sales, the investment in the promotion and marketing of organic products is not carried out by respondents, citing limited financial resources. [7]

These studies have concluded that education of eco-producers is still needed in terms of information, promotion and marketing, distribution channels as well as encouraging associations for integrated market access. [7]

2.3. Distribution and sale of Croatian organic products in the European Union

Although Croatia has great opportunities and predispositions for successful and quality production of organic products, there are still many obstacles both in the legal framework and in the way of growing organic products on farms.

Increased demand for eco-products in the European Union requires higher production, which can be both an advantage and a disadvantage for Croatia. One of the shortcomings seems to be the application of technologies and knowledge in which some EU Member States are at the forefront. Therefore, one of the proposals is that Croatia should take advantage of the diversity and uniqueness of its indigenous products such as Viška pita, Pag cheese, Paprenjaci, Dalmatian prosciutto, Baranja and Slavonian kulen in combination with domestic eco-products. In this way, some indigenous product can successfully pull other products that would not pass on the market on their own. [5] The distribution of Croatian organic products in the European Union would be most efficiently achieved through joint advertising. This method reduces costs and achieves a high level of promotion, especially when it is known that organic producers are mostly small and medium-sized producers. Furthermore, one of the very important factors that should attract the customer is the packaging. Our ecoproducers do not pay enough attention to this factor because it raises the price of their products even more, and they do not opt for them or their use is reduced to a minimum.

Packaging that would be used to sell organic products should be attractive, modern and in line with the product in order to attract as many customers as possible. As mentioned earlier, tourism can greatly contribute to the distribution of organic products. Through it, the placement of organic products in combination with indigenous products should be expanded. The development of tourism in Croatia throughout the year would create continuity in the production and consumption of organic and indigenous products, which would certainly find its way to the market in the European Union. [6]

3. CONCLUSIONS

The research used in this paper shows that organic products are most often sold in markets, fairs, directly on the doorstep, and only then in retail chains and specialty stores and online. This indicates that direct contact with customers is extremely important for manufacturers who also act as sellers, because it is also product promotion. All surveyed eco-producers agree that it would help to unite either locally or at the state level, because it would make it easier to market products, reduce distribution and marketing costs, and have better bargaining power to achieve better conditions. sales and would provide easier access to customers. Sales in retail chains are still not sufficiently represented, although the representation is growing from year to year. For now, most eco products are imported, and vegetables and fruits are the most common domestic products.

There is also the problem of incorrect product labeling; as “domestic”, “organic” or “natural” which causes distrust of customers. One of the proposals for better distribution and sale of organic products outside the Republic of Croatia is the joint appearance of indigenous organically grown products. In this way, the value of the product would be raised and the path to the consumer would be safer. For eco products, packaging is crucial, which must meet all organic criteria, but it must also have a modern look in order to attract customers. However, eco-producers are investing very little in this part as well, which is certainly not good for entering more serious markets. One of perhaps the most important ways of marketing organic products is tourism, which opens the door to the European Union market and beyond. Therefore, the recommendation would certainly be that this branch of the economy should definitely be addressed more by ecoproducers.

4. REFERENCES

[1] T. Šugar, K. Brščić, T. Kocković Zaborski: Mišljenje proizvođača ekoloških prehrambenih proizvoda o mogućnostima razvoja ekološke poljoprivrede u Hrvatskoj. Zbornik Veleučilišta u Rijeci, Vol. 8, Rijeka, str. 455-469, (2020). W.M. Smith, Surface Materials Processing. Second Edition, Backmann Verlag, Berlin–London–Paris–Warsaw, (2006).

[2] D. Pejnović, A. Ciganović, V. Valjak, Ekološka poljoprivreda Hrvatske: problemi i mogućnosti razvoja. Hrvatski geografski glasnik 74/1, str. 141-159, (2012). J. Kopač; S. Šali, Tool wear monitoring during the turning process. Journal of Materials Processing Technology 113 (2001), pp.312-316

[3] D. Siljan, M. Cerjak, Prva eko tržnica u Hrvatskoj – zadovoljstvo proizvođača i kupaca. Agroeconomica Croatica 7. str. 88-97 (2017). Roller Burnishing Technology, Yamasa, http://www.yamasa.com.tr, last access dd/mm/yyyy

[4] M. Kopić, M. Cerjak, Ž. Mesić, Zadovoljstvo potrošača ponudom ekoloških proizvoda u Zagrebu. 43. Hrvatski & 3. međunarodni znanstveni simpozij agronoma, Zagreb, Sveučilište u Zagrebu, Agronomski fakultet str. 256-259 (2008).

[5] L. Samardžija, R. Lončarić, Analiza ponude proizvoda s ekološkim certifikatom u velikim trgovačkim

lancima maloprodaje u gradu Osijeku. Zbornik radova 50. Hrvatski i 10. međunarodni simpozij agronoma u poljoprivredi, Opatija, str. 143-147 (2015).

[6] I. Pugelnik, R. Lončarić, T. Sudarić, Marketing kao čimbenik povećanja konkurentnosti ekološke proizvodnje u Republici Hrvatskoj. Zbornik radova, 52. Hrvatski i 12. međunarodni simpozij agronoma, Dubrovnik, str. 164-167 (2017).

[7] A. Rengel, Hrvatski eko-proizvodi na tržištu EU. Agronomski glasnik, Vol. 75 No.1, str. 55-68 (2013).

Pollen concentration of invasive tree of heaven (Ailanthus altissima) in Hungary

V.J. Vojnich [a], Á. Ferencz [a], A. Szarvas [a], L. Makra [a], E. Pölös [b], T. Tóth [c], K. Tempfli [c], O. Udvardy [d], D. Kajtor-Apatini [d], D. Magyar [d]

[a] University of Szeged, Faculty of Agriculture, Andrássy Street 15, 6800 Hódmezővásárhely, Hungary, E-mail: vojnich.viktor@mgk.u-szeged.hu

[b] John von Neumann University, Faculty of Horticulture and Rural Development, Izsáki Street 10, 6000 Kecskemét, Hungary, E-mail: polos.endre@kvk.uni-neumann.hu

[c] Széchenyi István University, Faculty of Agricultural and Food Sciences, Vár Square 2, 9200 Mosonmagyaróvár, Hungary, E-mail Address: tempfli.karoly@sze.hu

[d] National Public Health Center, Laboratory Department, Albert Flórián Road 2, 1097 Budapest, Hungary, E-mail Address: magyar.donat@gmail.com

Abstract

Nowadays, there is an increasing emphasis on the problem of invasive species. In areas where the tree of heaven (*Ailanthus altissima*) appears and multiplies, the original vegetation degrades and transforms. In addition, it is worth mentioning that the pollen of *A. altissima* is an allergenic, although less important than ragweed pollen. Pollen concentration of tree of heaven was measured in three counties of the Southern Great Plain region (Bács-Kiskun county, Kecskemét; Csongrád-Csanád county, Szeged; Békés county, Békéscsaba) in 2019-2020 and in the Northern Great Plain region (Jász-Nagykun-Szolnok county, Szolnok; Hajdú-Bihar county, Debrecen; Szabolcs-Szatmár-Bereg county, Nyíregyháza), Hungary, with a 7-day Hirst-type pollen trap. The highest annual total pollen count was detected in the Southern Great Plain region in 2019 in Bács-Kiskun county (66 pieces) and Csongrád-Csanád county (36 pieces), while in Békés county (16 pieces) in 2020. In Békés county, a trap error was detected when measuring the pollen count of *Ailanthus altissima* in 2019, therefore the results cannot be used. The highest total pollen count in the Northern Great Plain region of *A. altissima* was measured in all three years in Nyíregyháza (1,114 pollen in 2016; 788 pollen in 2017; 635 pollen in 2018), while the lowest value was measured in Szolnok in all three years (99 pollen in 2016; 78 pollen in 2017; 93 pollen in 2018). In Debrecen, the annual total pollen concentration varied between 109-127 pollen grains in the studied period. The extent of the prevalence of *A. altissima* can be deduced from its pollen concentration. For this purpose, multi-year pollen data are displayed on a result map in which areas characterized by different pollen concentrations are represented by colour codes. Pollen monitoring provides information on the size of *A. altissima* stands and provide a basis for proposals and plans for measures to control this invasive tree species and mitigate the damage caused by it.

Keywords: Tree of heaven (*Ailanthus altissima*), invasive plant, Hungary, pollen concentration, pollen monitoring data

1. INTRODUCTION

The tree of heaven (*Ailanthus altissima* (Mill.) Swingle) (Fig. 1.) belongs to the family *Simaroubaceae*. The genus, numbering about 10 species, has a focal point of distribution in the front and back of India, as well as in the Far East. The basic variant of the species, *A. altissima* var. *altissima*, is native to China. The bark of *A. altissima* var. *tanakai*, which is widespread in Taiwan, is yellower than the base species and has shorter leaves. It is recognized by the reddish branches of *A. altissima* var. *sutchuenensis*. In addition to the tree of heaven, the downy tree of heaven (*A. giraldii* Dode) and the thorny tree of heaven (*A. vilmoriniana* Dode) are also among the temperate species of the genus [1,2,3].

Fig. 1. Ailanthus altissima in Kecskemét (2019).

Three of heaven is dioecious, with male and female flowers being borne on different individuals. The flowers open in loose endless buds, greenish-yellow, woolly on the inside, consisting of 5 or 6 cups, petals and fruit leaves. The numbers of stamens per flower is 5+5 or 6+6. The flowers produce a lot of nectar [4,5]. Its flowering time is in June and July [6]. Pollen grains are medium-sized (26-50 μm), tricolporate, striato-reticulate. The flowers are ambophilous (both wind and insect pollinated) [7]. The main factors that enable the invasiveness of *Ailanthus altissima*: 1, rapid propagation from seed; 2, strong root formation; 3, rapid growth [8,9].

The tree of heaven is native in areas along the lower reaches of the Yangtze River to north-eastern, central China (Hubei, Honan, Anhui, Jiangsu; Hunan, Jiangxi, and Zhejiang provinces) and Korea. The distribution this species is currently between 22°N and 43°N up to 1,500-1,800 m above sea level. Its worldwide spread began in the 1740s, when its seeds were transported to Paris on a land journey through Siberia (Russia). It was planted in London in 1751 as an ornamental tree. It came to North America in the 18th century, where it was first planted as an ornamental tree in northern cities. In 1856, it was reported [10] that the stock was already in a natural forest at the territory of South Tyrol (Austria). It was planted in Paris to replace the hybrid plane or London plane tree (*Platanus*) in 1875. *Ailanthus altissima* is widespread in most of the western hemisphere today. It is often planted in the subtropical and northern temperate zones, including throughout East Asia and Europe, as well as North America. Due to its favourable properties, it has spread to all inhabited continents [11,12,13,14].

The first data on the occurrence of *A. altissima* in Hungary is available from a documentation of planting experiments of this species in Villány in 1841-1843 [15,16]. It has been established in the Great Plain since the middle of the 20th century, due to its stock-like, conscious settlements and spontaneous outbursts. Today, it occurs almost everywhere in the hilly, lowland areas of the country with a warmer climate. It is relatively rare in Western Transdanubia and in the higher regions of the central mountains [17,18].

The tree of heaven is considered to be an invasive species [19]. Nowadays, the problem of invasive species is gaining more and more

attention. In areas where the *A. altissima* appears and multiplies, the original vegetation degrades and transforms. The tree of heaven is also of great importance in urban environments, where it causes building damage, static problems and endangers utilities. In addition, it is worth mentioning that *A. altissima* pollen is an allergen [20].

The aim of our study is to investigate the pollen concentration of *Ailanthus altissima* (tree of heaven) in the Southern Great Plain region and in the Northern Great Plain region of Hungary.

2. METHODS AND MATERIALS

2.1. Southern Great Plain region

The pollen concentration of *Ailanthus altissima* was measured at the three county capitals (Kecskemét, Szeged, Békéscsaba) of the Southern Great Plain region (Bács-Kiskun county, Csongrád-Csanád county, Békés county) (Fig. 2.) with the 7-day Hirst-type (Burkard) pollen trap (Fig. 3. and Fig. 4a and 4b), for the 2-year period 2019-2020.

Fig. 2. The South Great Plain region (Bács-Kiskun county, Csongrád-Csanád county and Békés county) in Hungary.

Fig. 3. Hirst-type (Burkard) pollen trap.

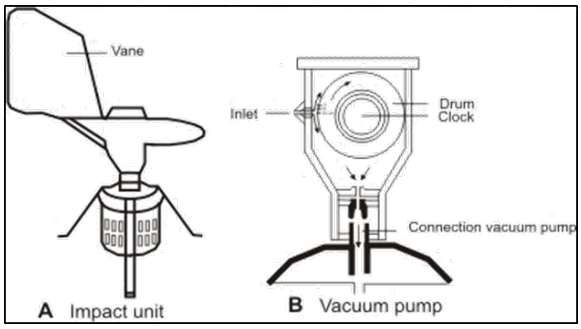

Fig. 4a Impact unit in Hirst-type (Burkard) pollen trap. Fig. 4b Vacuum pump in Hirst-type (Burkard) pollen trap.

2.2. Northern Great Plain region

The pollen concentration of *Ailanthus altissima* was measured at the three county capitals (Szolnok, Debrecen, Nyíregyháza) of the Northern Great Plain region (Jász-Nagykun-Szolnok county, Hajdú-Bihar county, Szabolcs-Szatmár-Bereg county) (Fig. 5.) with the 7-day Hirst-type (Burkard) pollen trap, for the 3-year period 2016-2018.

Fig. 5. The Northern Great Plain region (Jász-Nagykun-Szolnok county, Hajdú-Bihar county and Szabolcs-Szatmár-Bereg county) in Hungary.

The device collides the pollen content of the intake air onto a tape with a sticky surface (Melinex tape). The tape is divided into two-hour bands and the pollen grains stained with basic fuchsine, are counted in two 0.5 mm bands 6-6 mm from the edges at 400×magnification. The results are given as a 24-hour average, expressed in pollen grains / m^3 of air.

The pollen season was defined as the day on which the sum of the daily average pollen concentration reaches 1% of the final amount and the end of the season when it reaches 99% [21].

3. RESULTS AND ACHIEVEMENTS

3.1. Results of the Southern Great Plain region (Bács-Kiskun county, Csongrád-Csanád county, Békés county)

Pollen data for Bács-Kiskun county

In Kecskemét, the pollen trap caught a total of 66 *A. altissima* pollen grains in 2019. The highest amount of pollen grains was counted on 7th of June (14 pollen/m^3). One year later, the pollen count of annual tree of heaven was 54, when the highest daily amount (7 pollens/m^3) were detected on the 11th and 14th of June. In 2019, the highest daily amount 4.4 pollen grains/m^3, and one year later 1.4 pollen grains/m^3.

Pollen data for Csongrád-Csanád county

In Szeged, the total number *A. altissima* pollen was 36 in 2016. The highest daily concentration was detected on June 7th (15 pollen/m^3). In the following year, a total of 33 *Ailanthus altissima* pollen grains were counted. The highest daily concentration were detected on June 24th and on July 4th (4 pollen/m^3). In 2019, the average value was 3.2 pollen/m^3, while in 2020 this value decreased to 0.5 pollen/m^3.

Pollen data for Békés county

In 2019, we detected a trap error when measuring the pollen count of *Ailanthus altissima*, therefore the results cannot be used. In Békéscsaba, the highest daily pollen count of 3 pollen m^3 was recorded on 18th June, in 2020. The annual total pollen count was 16. In 2020, the average for the pollen season is 0.7 pollen/m^3.

3.2. Results of the Northern Great Plain region (Jász-Nagykun-Szolnok county, Hajdú-Bihar county, Szabolcs-Szatmár-Bereg county)

Pollen data for Jász-Nagykun-Szolnok county

In Szolnok, the pollen trap caught a total of 99 *A. altissima* pollen grains in 2016. The highest amount of pollen grains were counted on the 3rd and 6th of June (15 pollen/m^3). One year later, the pollen count of annual tree of heaven was 78, when the highest daily amount (14 pollens/m^3) was detected on June 6th. In 2018, 93 pollen grains were counted as an annual sum. The highest daily pollen count of 15 pollen m^3 was recorded in the city of Szolnok on May 24th, 2018.

Pollen data for Hajdú-Bihar county

In Debrecen, the total number of *A. altissima* pollen was 127 in 2016. The highest daily concentration was detected on June 5th (19 pollen/m^3). In the following year, a total of 110 *Ailanthus altissima* pollen grains were counted. In 2018, the annual total pollen count of the tree of heaven was 109, while the highest daily amount (19 pollen grains /m^3) of *A. altissima* pollen was measured on May 26th.

Pollen data for Szabolcs-Szatmár-Bereg county

In Nyíregyháza, the total number of *Ailanthus* pollen was 1114 in 2016. The highest daily concentration of pollen grains (405 pollen/m^3) was measured on June 6th. One year later, the total *A. altissima* pollen count was 788, while the highest daily concentration (229 pollen/m^3) was detected on June 5th. In 2018, we counted 635 *Ailanthus* pollen grains. The highest daily value (peak value) was recorded on May 19th (82 pollen/m^3) in Nyíregyháza.

4. CONCLUSIONS

4.1. Conclusions of the Southern Great Plain region

The highest annual total number of pollen was detected in Bács-Kiskun county (66 pcs) and Csongrád-Csanád county (36 pcs) in 2019, while in Békés county (16 pcs) in 2020. In Békés county, a trap error was detected when measuring the pollen count of *Ailanthus altissima* in 2019, therefore the results cannot be used.

Data on the extent of plant populations can be obtained in two ways: by direct survey of vegetation (e.g., National Weed Survey in Hungary) or indirectly by summarizing and mapping other data related to the potential distribution of plants. The latter group may include environmental variables (suitable soil type and pH, precipitation, etc.) that determine the plant's needs on the site as well as anthropogenic factors (crop structure, urbanization level, etc.), at the same time, data from atmospheric pollen concentration measurements also provide important information for anemophilous plants [22,23]. For this purpose, the multi-year pollen data may be displayed on a result map in which the areas characterized by different pollen concentrations are represented by colour codes. Based on our studies, pollen monitoring data could also be used to study the distribution of *A. altissima*. Our work draws the attention to the differences in the distribution of the tree of heaven in the Northern Great Plain, based on which it can be seen that there can be more than a tenfold difference between the monitoring areas in terms of the total annual pollen count. Further research is needed to examine data from more monitoring stations and years that would allow for greater accuracy. In addition, we plan to include pollen data from other Hungarian cities, which can be explored on a national map to reveal the spatial differences in plant distribution.

The total pollen count of genera planted as urban rowan (Tab. 1. and Tab. 2.) is generally higher than that of the tree of heaven [24,25].

Table 1. Total pollen number of plant species planted as urban ornamental trees in the Southern Great Plain region (2019).

Allergen species	Kecskemét	Szeged	Békés-csaba
Acer spp.	1,358	1,215	429
Betula spp.	5,234	3,402	4,965
Fraxinus spp.	1,797	2,615	1,859
Moraceae	2,704	1,175	1,622
Platanus spp.	2,411	5,815	903
Tilia spp.	---	---	---

Table 2. Total pollen number of plant species planted as urban ornamental trees in the Southern Great Plain region (2020).

Allergen species	Kecskemét	Szeged	Békés-csaba
Acer spp.	996	673	343
Betula spp.	4,263	4,251	3,811
Fraxinus spp.	2,065	2,957	1,818
Moraceae	---	---	---
Platanus spp.	565	2,290	294
Tilia spp.	727	312	81

4.2. Conclusions of the Southern Great Plain region

The highest total pollen count of *A. altissima* was measured in all three years in Szabolcs-Szatmár-Bereg county (1,114 pollen in 2016; 788 pollen in 2017; 635 pollen in 2018), while the lowest value was measured in Jász-Nagykun-Szolnok county in all three years (99 pollen in 2016; 78 pollen in 2017; 93 pollen in 2018). In Hajdú-Bihar county, the annual total pollen concentration varied between 109-127 pollen grains in the studied period.

The total annual pollen count (Tab. 3. and Tab. 4.) of other pollen-producing woody plants (*Acer, Betula, Fraxinus, Moraceae, Platanus* species) common in urban environments is generally higher than that of the tree of heaven [26,27]. This is probably because these plants are mostly planted as urban ornamental trees and therefore have higher numbers of individuals and higher pollen emissions than *A. altissima*. As the tree of heaven is an invasive species, there is no so-called *Ailanthus altissima* containing species proposed for planting in urban green spaces in the List of Public Row Wood [28].

The size of the trees (height, radius of the crown projection) is proportional to the amount of pollen release according to some model calculations [29,30]. The tree of heaven, like other noxious plants/weeds, is often removed before it reaches a larger size. This also results in lower pollen counts compared to other urban tree species, whose large specimens emit significant amounts of pollen (e.g. old sycamore trees).

The situation of *A. altissima* is somewhat similar to that of *Broussonetia papyrifera*, which is also an invasive, anemophilous tree species in urban environments [31]. However, their pollen production is not comparable because the pollen grains of *B. papyrifera* are pooled with other tree species having similar pollen grains (*Morus alba, Morus nigra*) as "*Moraceae* pollen" during aerobiological monitoring.

Table 3. Total pollen number of plant species planted as urban ornamental trees in the Northern Great Plain region (2017).

Allergen species	Szolnok	Debrecen	Nyíregyháza
Acer spp.	447	251	1,381
Betula spp.	1,815	2,183	5,412
Fraxinus spp.	1,353	705	629
Moraceae	2,164	2,333	3,109
Platanus spp.	10,228	2,139	5,485

Table 4. Total pollen number of plant species planted as urban ornamental trees in the Northern Great Plain region (2018).

Allergen species	Szolnok	Debrecen	Nyíregyháza
Acer spp.	484	119	366
Betula spp.	3,560	4,906	7,946
Fraxinus spp.	3,775	1,606	1,690
Moraceae	3,167	1,830	3,024
Platanus spp.	8,891	2,029	4,969

The mass appearance of *A. altissima* is a serious problem in almost all areas (national parks, forests, inner city zones and towns), where its control/eradication would cost millions of euros. Pollen data provide information on the size of *A. altissima* stands endangering the interiors, utilities and buildings of cities. Pollen monitoring provides a basis for proposals and plans for measures to control the invasive tree species and mitigate the damage caused by it.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

[1] G. Hegi, Illustrierte Flora von Mittel-Europa. VII. München, (1924). [Illustrated flora of Central Europe.] (in German)

[2] S.Y. Hu, *Ailanthus*. Arnoldia, 39(2) (1979), pp. 29-50.

[3] L. Udvardy, Bálványfa (*Ailanthus altissima* [Mill.] swingle). In: Mihály B. – Botta-Dukát Z. (szerk.): Biológiai inváziók Magyarországon. Özönnövények. – A KvVM Természetvédelmi Hivatalának Tanulmánykötetei 9., Természet BÚVÁR Alapítvány Kiadó, Budapest, (2004), pp. 143-160. [Tree of heaven.] (in Hungarian)

[4] J.J. Barkman, New system of plant growth forms and phenological plant types; In: Werger, M.J.A – Aart, P.J.M. – van der During, H.J. – Verhoeven, J.T.A. (eds.): Plant Form and Vegetation Structure. SPB Academic Publishing, The Hague, (1988), pp. 9-44.

[5] D. Bartha, Magyarország faóriásai és famatuzsálemei. Erdészettörténeti Közlemények, 15 (1994), p. 242. [Hungary's wooden giants and wooden Methuselahs.] (in Hungarian)

[6] T. Simon, A magyarországi edényes flóra határozója. Tankönyvkiadó, Budapest, (1992). [Definition of the vascular flora of Hungary.] (in Hungarian)

[7] J.S. Thompson, Pollination Biology of *Ailanthus altissima* (Mill.) Swingle (Tree-of-Heaven) in the Mid-Atlantic United States. MSc thesis, Virginia Polytechnic Institute and State University, Blacksburg, Virginia, (2008).

[8] B. Mihály, Z. Botta-Dukát, Biológiai inváziók Magyarországon - Özönnövények. Természet Búvár Alapítvány Kiadó, Budapest, (2004). [Biological invasions in Hungary - Invasive plants.] (in Hungarian)

[9] Á. Csiszár, Inváziós növényfajok Magyarországon. Nyugat-magyarországi Egyetem Kiadó, Sopron, (2012). [Invasive plant species in Hungary.] (in Hungarian)

[10] P. Ascherson, P. Graebner, Synopsis der Mitteleuropäischer Flora. Leipzig-Berlin, 5(1) (1914), pp. 220-370. [Synopsis of the Central European flora.] (in German)

[11] R. Good, The Geography of the Flowering Plants. Longman, London, (1974).

[12] R. Böcker, I. Kowarik, Der Götterbaum (*Ailanthus altissima*) in Berlin (West). Berlin, Naturschutzbl., 26 (1982), pp. 4-9. [The Tree of Heaven (Ailanthus altissima) in Berlin (West).] (in German)

[13] I. Kowarik, Zur Einbürgerung und zum pflanzengeographischen Verhalten des Götterbaumes [*Ailanthus altissima* (MILL.) SWINGLE] in französischen Mittelmeergebiet (Bas-Languedoc). Phytocoenologia, 11 (1983), pp. 389-405. [On the naturalization and phytogeographical behavior of the tree of heaven [Ailanthus altissima (MILL.) SWINGLE] in the French Mediterranean region (Bas-Languedoc).] (in German)

[14] I. Kowarik, R. Böcker, Zur Verbreitung, Vergesellschaftung und Einbürgerung des Götterbaumes [*Ailanthus altissima* (MILL.) SWINGLE] in Mitteleuropa. Tuexenia, 4 (1984), pp. 9-29. [On the distribution, socialization and naturalization of the

tree of heaven [Ailanthus altissima (MILL.) SWINGLE] in Central Europe.] (in German)

[15] J. Bartosságh, Beobachtungen und Erfahrungen über den Götterbaum (*Ailanthus glandulosa* L.) - Ofen, 3 (1841), p. 47. [Observations and experiences about the tree of heaven (Ailanthus glandulosa L.)] (in German)

[16] J. Bartosságh, Folytatólagos értesítés a bálványfa (*Ailanthus glandulosa*, Götterbaum) terjedése körül. Magyar Gazda, 3 (1843), pp. 298-300. [Continuous notification about the spread of the tree of heaven (Ailanthus glandulosa, Götterbaum).] (in Hungarian)

[17] R. Soó, S. Jávorka, A magyar növényvilág kézikönyve. I–II. Akadémiai Kiadó, Budapest, (1951). [Handbook of Hungarian flora. I–II.] (in Hungarian)

[18] M. Kovács, Sz. Priszter, A flóra és vegetáció változása Magyarországon az utolsó száz évben. Botanikai Közlemények, 61 (1974), pp. 185-196. [Changes in flora and vegetation in Hungary in the last hundred years.] (in Hungarian)

[19] R.E. Landenberger, N.L. Kota, J.B. McGraw, Seed dispersal of the non-native invasive tree *Ailanthus altissima* into contrasting environments. Plant Ecology, 192(1) (2007), pp. 55-70.

[20] F. Mousavi, A. Majd, Y. Shahali, F. Ghahremaninejad, R.S. Shoormasti, Z. Pourpak, Immunoproteomics of tree of heaven (*Ailanthus atltissima*) pollen allergens. Journal of proteomics, 154 (2017), pp. 94-101.

[21] L.H. Ziska, L. Makra, S.K. Harry, N. Bruffaerts, M. Hendrickx, F. Coates, A. Saarto, M. Thibaudon, G. Oliver, A. Damialis, A. Charalampopoulos, D. Vokou, S. Heiđmarsson, E. Guđjohnsen, M. Bonini, J.W. Oh, K. Sullivan, L. Ford, G.D. Brooks, D. Myszkowska, E. Severova, R. Gehrig, G.D. Ramón, P.J. Beggs, K. Knowlton, A.R. Crimmins, Temperature-related changes in airborne allergenic pollen abundance and seasonality across the northern hemisphere: a retrospective data analysis. The Lancet Planetary Health, 3(3) (2019), pp. e124-e131.

[22] M. Thibaudon, B. Šikoparija, G. Oliver, M. Smith, C.A. Skjøth, Ragweed pollen source inventory for France–The second largest centre of Ambrosia in Europe. Atmospheric Environment, 83 (2014), pp. 62-71.

[23] R.N. McInnes, D. Hemming, P. Burgess, D. Lyndsay, N.J. Osborne, C.A. Skjøth, S. Vardoulakis, Mapping allergenic pollen vegetation in UK to study environmental exposure and human health. Science of the Total Environment, 599 (2017), pp. 483-499.

[24] O. Udvardy, D. Kajtor-Apatini, D. Magyar, T. Szigeti, A magyarországi Aerobiológiai Hálózat tájékoztatója 2019. Nemzeti Népegészségügyi Központ, Budapest, (2020). [Information sheet of the Hungarian Aerobiological Network 2019.] (in Hungarian)

[25] D. Kajtor-Apatini, D. Magyar, O. Udvardy, E. Bócsi, V. Pál, T. Szigeti, A Magyar-országi Aerobiológiai Hálózat tájékoztatója 2020. Nemzeti Népegész-ségügyi Központ, Budapest, (2021). [Information sheet of the Hungarian Aerobiological Network 2020.] (in Hungarian)

[26] O. Udvardy, D. Kajtor-Apatini, D. Magyar, T. Szigeti, A magyarországi Aerobiológiai Hálózat tájékoztatója 2017. Országos Közegészségügyi Intézet, Budapest, (2018). [Information sheet of the Hungarian Aerobiological Network 2017.] (in Hungarian)

[27] O. Udvardy, D. Kajtor-Apatini, D., Magyar, T. Szigeti, A magyarországi Aero-biológiai Hálózat tájékoztatója 2018.

Nemzeti Népegészségügyi Központ, Budapest, (2019). [Information sheet of the Hungarian Aerobiological Network 2018.] (in Hungarian)

[28] K. Szabó, Közterületi Sorfák Jegyzéke. Magyar Díszkertészek Szövetsége, Budapest, (2019), pp. 1-41. [List of Row Trees in Public Areas.] (in Hungarian)

[29] P. Cariñanos, M. Casares-Porcel, J.M. Quesada-Rubio, Estimating the allergenic potential in urban green zones: a case study in Granada. Landscape and Urban Planning, 123 (2014), pp. 134-144.

[30] D. Magyar, A. Páldy, T. Szigeti, A. Szilágyi, L. Orlóci, A potenciális allergenitás felhasználási lehetősége a zöldterületek minősítésében és az allergén terhelés szabályozásában. Egészségtudomány 64(4) (2020), pp. 57-80. [The possibility of using potential allergenicity in the classification of green areas and the control of allergen load.] (in Hungarian)

[31] M. Peng, S.H. Chen, Comparison of counting methods for the study of air-borne pollen with special reference to Broussonetia pollen. Taiwania, 41 (1996), pp. 35-42.

Development of modern industries in European startup ecosystems

A. Arsic[a], D. Valentirovic[a], J. Borocki[a], N. Miric[a] and A. Vekic[a]

[a] University of Novi Sad, Faculty of Technical Science, Trg Dositeja Obradovica 6, 21000 Novi Sad, Serbia, andjelina175@gmail.com, deki.ncs@gmail.com, nenadmiric3@gmail.com, borocki@uns.ac.rs, vekic@uns.ac.rs

Abstract

Startup companies, together with other economic entities, make up the startup ecosystem of a city, region or country. Startup ecosystems, in addition to helping startup companies to develop and grow, also give a large contribute to the national economies of the countries in which they are located, primarily through the generation of innovative product and service solutions, but also through the creation of new jobs. That is the reason for analysis, by different subject of interest, primarily of the state and its institutions, but also numerous scientists and researchers. The research aims to determine the stage of development of individual European startup ecosystems and subsectors which are characterized as "strongest" in given startup ecosystems, through the method of comparative analysis. Also, this research shows comparison of countries where particular startup ecosystems are located, according to an Industrial production index in the period of 2019-2021. The result of the research is a comprehensive picture of the specifics of European startup ecosystems analyzed based on the previously mentioned parameters.

Keywords: Startup ecosystems, Europe, Strong subsectors, Development

1. INTRODUCTION

The global startup economy generates nearly $ 3 trillion in value, a number equal to the GDP of the G7 countries' economies. Seven of the ten largest companies in the world are in technology, and in 2019, close to $ 300 billion in venture capital investments were recorded worldwide [1].

Considering the above, it can be said that the mentioned figures justify the rapid growth of startup companies around the world. The impact of the COVID crisis on startup ecosystems and companies around the world should be taken into account. Some companies have certainly been more successful, while others have stagnated and even shut down.

Startup companies are a special form of entrepreneurial ventures that are mainly engaged in creating their products or services for the global market [2]. Today, many large and well-known corporations, are startup companies that arise from the ideas of young people in old garages, apartments, or cheap, rented business premises. Startup companies, along with other organizations and people make up one startup ecosystem.

The startup ecosystem should be an environment that supports the generation of ideas and the implementation of innovative activities, bringing together universities and organizations that support startups in the form of finance, expertise, training, services, physical resources, and other forms of government support through events and activities focused on the development of the startup community as well as many other entities that interact with each other to create new or improve existing startup companies. These activities and results consequently lead to the development of the

local and national economy, but also the creation of new jobs.

Through this paper, the results obtained by research and analysis of European startup ecosystems are presented.

2. METHODS AND MATERIALS USED FOR RESEARCH

Within the research work, the phases of development of the mentioned startup ecosystems were analyzed based on the Startup Genome report for three years of observation (2019, 2020, and 2021) [3][1][4]. Also, the Industrial Production Index according to the observed countries was analyzed based on data from the Ycharts website. In addition, subsectors that were rated as “strongest” in startup ecosystems were analyzed.

The methodology used to prepare this paper includes Startup Genome reports for 3 years, 2019 – 2021. The research that was conducted, but also the discussion that was conducted in this paper, was realized based on data on the phases of the life cycle of startup ecosystems and the strongest industries by given ecosystems. The Ycharts tool was also used to determine the Industrial Production Index for each country taken into consideration.

3. LITERATURE REVIEW

Entrepreneurship and innovation have huge importance for the development and growth of the economy of each country. Schumpeter made a key contribution to the understanding of entrepreneurship, defining entrepreneurship as “creating a new combination of already existing materials and forces, consisting of making innovations, as opposed to inventions, and that no one is forever an entrepreneur but only when he is actually engaged in innovative activities” [5]. “Entrepreneurship, in its narrowest sense, involves generating ideas, turning them into products and/or services, and then creating an endeavor to place the product on the market” [6]. The main role in the entrepreneurial process has an entrepreneur. That is a person gifted with business spirit and creative abilities, always "awake" and ready to recognize and use new business opportunities by the appropriate combination of factors of production and decisively take the risk of managing the organization based on innovation and permanent development, to create new value [7]. An entrepreneur is a person who has self-confidence and is oriented toward action and achievement where he has skills such as negotiation, persuasion, the ability to express their views, and the ability to socialize [8].

“Innovation is the creation of new knowledge and ideas to enable new business results, aimed at improving internal business processes and structures and creating market-driven products and services. Innovation encompasses radical and incremental innovation [9]. Innovations in entrepreneurship could be characterized as something that appears on the market as new and for the first time and enables the entrepreneur to make a profit.

A newer form of entrepreneurial venture based on innovation is called startup. That is a human institution designed to create a new product or service in conditions of extreme uncertainty [10].

A startup can also be described as an organization with limited experience, that works with inadequate resources, and is influenced by several factors such as investors, customers, competitors, and the use of dynamic product technologies [11]. A startup is a business venture that is not older than 10 years and the realization of which was made possible by the development of technology [12]. Blank.

Entrepreneurial ecosystems represent a diverse set of interdependent actors in a geographic region that influences the formation and direction of an entire group of actors and potentially the economy as a whole. They develop through a set of interdependent components that interact to create new ventures

over time [13]. The Startup Ecosystem is a shared fund of resources, which typically includes resources such as policymakers, accelerators, incubators, co-working spaces, educational institutions, and funding groups [1].

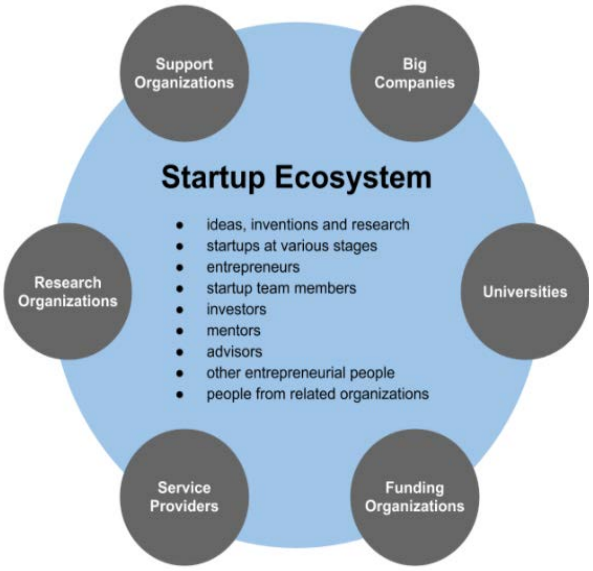

Fig. 1. Overview of the elements of the Startup Ecosystem [14]

Fig. 1. shown that startup ecosystems are determined by a network of interactions between people, organizations, and their environment [14]. They can occur in various forms but are most often viewed as startup ecosystems of certain cities or online communities. These participants in the startup ecosystem and their actions, determine the success of this ecosystem [15].

It is necessary to mention skills, time, and money as important factors of the startup ecosystem. The interaction between organizations and people who are part of the startup ecosystem allows resources to move through the ecosystem, thus encouraging the creation of new startups and strengthening existing ones. Even the failure of individual startups frees up people with experience and skills who can further create new startups or join existing ones.

Startup ecosystems are subject to the influences of both internal and external factors.

Financial climate, market disruptions, transitions of large companies, and other external factors can affect the functioning of the ecosystem and its structure. Even if ecosystems are located in a similar environment, other parts of the world may differ significantly in terms of functioning, precisely because of a different entrepreneurial culture and available resources. Also, some of the most important factors of the startup ecosystem that influence the achievement of success within it, are [16]: talent, density, culture, capital, and regional environment.

Managing with talent includes:

- Investing in human capital
- Creation of flexible labor market
- Supporting new learning experiences for the competitive workforce
- Promotion of workplace diversity

Creation of startup ecosystem density includes:

- Fostering startup density
- Supporting cluster growth
- Creation of physical hubs
- Driving awareness through media
- Building networks and mentors
- Linking academic and research networks and business

Encouraging culture in the startup ecosystem includes:

- Opening and risk-taking culture
- Highlighting entrepreneurs as role models
- Accepting failure as a part of the learning process
- Promoting jobs at startups
- Fostering public-private communications

Obtaining capital and financing includes:

- Funding/ smart capital
- Providing access to capital
- Creating incentives for new and experienced investors

The importance of the regulatory environment is reflected in:

- Stable and supportive regulatory environment
- Increasing the ease of doing business
- Focusing on tax policy
- Creating intermediary responsibility and safe harbors
- Enabling a free and global open web
- Creating flexible limitations to copyrights
- Providing patent protection that supports innovation
- Formalizing alternative funding mechanisms
- Supporting research and development

4. PHASES OF STARTUP ECOSYSTEM

The growing number of startups globally has encouraged governments around the world to invest in the faster development of their startup ecosystems. An ecosystem life cycle model is a model that helps governments determine where their ecosystem is located, identify gaps and priorities among them, and also define action plans that maximize impact - rather than squandering limited resources. Startup ecosystems evolve through four phases and each is characterized by a different set of characteristics [1].

Activation phase

Features:

a) Limited startup experience - this includes the founder's know-how, experienced investors, advisors, and mentors, as well as community behavior that is oriented towards supporting the success of the startup.
b) Low Startup Output of about 1,000 startups or less
c) Challenges that hinder development are reflected in the lack of startup experience and outflow of resources into ecosystems that are in later stages of the life cycle

Globalization phase

Features:

a) “Trigger” for this phase: Increased Startup experience leads to the creation of a series of regionally impressive “triggers” (companies) worth usually over $ 100 million (in developed countries and above)
b) Startup output of between 800 and 1,200 startups (depending on the population)

Attraction phase

Features:

a) Output usually consists of more than 2,000 startups (depending on the population)
b) A series of globally impressive "Triggers" (companies), usually unicorns or "exits" of over 1 billion dollars (in developed countries and more)
c) $ 1 billion triggers are the cause of global "resource attraction"
d) There are only a few holes left in terms of performance factors

Integration phase

Features:

a) More than 3,000 startups
b) Global “Resource Attraction” produces a higher and self-sustaining degree of global connectivity and knowledge flow into an ecosystem that sustainably keeps startups integrated into the global knowledge thread and can produce the leading business models and skills needed to achieve high global market reach.

5. RESEARCH RESULTS

The first part of the research refers to the comparison of European startup ecosystem countries for the period 2019–2020, according to the development phases of startup ecosystems and strong subsectors within the observed startup ecosystems. These results are shown in *Table 1*. It should be noted that the “/” mark is left in the tabular fields for those countries for which there is no data within the available literature, and which concern strong sub-sectors of the countries shown. These countries are Austria, the Czech Republic, Iceland, Italy, Luxembourg, Norway, Poland, Portugal, Romania, Slovenia, and Switzerland.

Table 1. European startup ecosystem overview (Source: Startup Genome Reports 2019-2021)

Country	Name of ecosystem (city or area)	Startup ecosystem phase	The strongest sub-sectors in the startup ecosystem
Austria	Vienna	/	/
Belgium	Brussels	Early globalization phase	Life Sciences and Smart Cities
	Antwerp		
Czech Republic	Prague	/	/
Denmark	Western Denmark	Early globalization phase	Advanced Manufacturing & Robotics and Life Sciences, Edtech and Fintech
	Copenhagen		
Estonia	Estonia	Activation Phase	Cybersecurity and Fintech
Finland	Wider areas of Helsinki	Early globalization phase	AI, Big Data, & Analytics, Gaming and Health and Life Sciences and Digital Health
France	Marseille	Attraction phase	Healthtech, Edtech, and Fintech
	Lion		
	Paris		
Netherlands	Amsterdam – Delta	Attraction phase	Agtech & New Food, Health and Life Sciences, and Fintech
Ireland	Dublin	Activation Phase	Agtech & New Food
	Middle - Eastern region		
Iceland	Reykjavik	/	/
Italy	Milan	/	/
	Rome		
Lithuania	Lithuania	Activation Phase	Fintech and Mobility
Luxembourg	Luxembourg	/	/
Hungary	Budapest	Activation Phase	Artificial Intelligence
Malta	Malta	/	Fintech, Blockchain, and Gaming
Moldova	Moldova	Activation Phase	E-commerce
Germany	Berlin	Early globalization phase	IoT and Health and Life Sciences, Advanced Manufacturing & Robotics and B2B, Enterprise Solutions, Cybersecurity, AI, Big Data & Analytics and Fintech, Healthcare, and Mobility
	Hamburg		
	Rhineland		
	Frankfurt		
	Stuttgart		
	Munich		
Norway	Oslo	/	/
Poland	Warsaw	/	/
Portugal	Lisbon	/	/
Romania	Bucharest	/	/
Slovenia	Ljubljana	/	/
Serbia	Belgrade and Novi Sad	Activation Phase	Blockchain and Gaming
Spain	Madrid	Early globalization phase	Gaming, Health and Life Sciences and Smart City, and Fintech
	Valencia		
	Barcelona		
Switzerland	Bern – Geneva	/	
	Zurich		
Sweden	Malmo	Attraction phase	Gaming, Fintech and Cleantech, and Life sciences
	Stockholm		
	Gothenburg		
United Kingdom	Edinburgh–Glasgow	Integration phase	Fintech, Blockchain and Adtech, Edtech
	Manchester–Liverpool		
	Durham		
	Birmingham		
	Bristol		
	London		

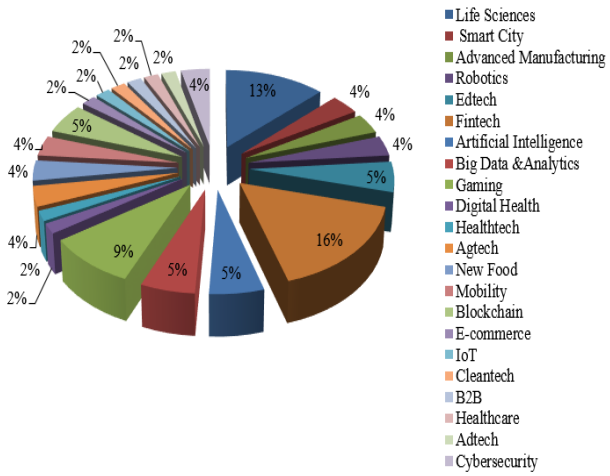

Fig. 2. Strongest sub-sectors of the European startup ecosystem (Source: Startup Genome Reports 2019-2021

According to Fig. 2. the most developed sub-sectors in the European startup ecosystem are Fintech, Life Sciences, and AdTech.

Fintech: Fintech aims to improve existing processes, products, and services in the financial services industry (including insurance) through software and modern technologies.

Life Sciences: The natural sciences subsector is focused on diagnosing, treating, and managing diseases. This includes startups in the field of Biotech, Pharma, and Medtech.

Advertising Tech (Adtech): This subsector includes various types of analytical and digital tools used for promotion and marketing purposes.

The next segment of this research is a review of the Industrial Production Index for observed countries in the period 2019-2021. The end of the table shows the average Industrial production Index per year of all observed countries. Data was collected through the interactive YChart tool [17], and shown in Table 2.

Table 2. Overview of the Industrial Production Index by observed countries in the period 2019-2021 (Source: Ycharts data)

Name of the country	Industrial Production Index according to the observed years		
	2019	2020	2021
Austria	111,10	110	125,30
Belgium	117.9	113	128,30
Czech Republic	110.4	113.5	110,50
Denmark	119.9	108.3	119,10
Estonia	117.5	118.5	130,50
Finland	112.4	110	11sni9,70
France	101.3	98.1	108,63
Netherlands	100.1	99.8	105,90
Ireland	92.1	123.9	139,10
Iceland	/	/	/
Italy	102	101	105,70
Lithuania	117	119.7	155,90
Luxembourg	93.3	91.4	97
Hungary	113	114.7	120,50
Malta	109.9	104.4	98,50
Moldova	/	/	/
Germany	99.6	100.7	97,70
Norway	100.6	102.3	103,90
Poland	120.6	128	147,20
Portugal	106.5	101.7	92,20
Romania	111	112.8	105,40
Slovenia	124.3	123.5	135,80
Serbia	113.8	117.4	121,30
Spain	104.2	102.6	105,30
Switzerland	/	/	/
Sweden	110.3	112.2	115,40
United Kingdom	97.2	95	97
Average:	103,96	113,82	120,63

The growth of the Industrial Production Index in 2021 compared to 2020 is noticeable in all countries, except the Czech Republic, Malta, Germany, Portugal, and Romania, where a decline in the value of this index was recorded. The average Industrial Production Index in observed countries was growth by 9,48 % in 2020 compared to 2019, and 5,98 % in 2021 compared to 2020. The total growth of the average Industrial Production Index for observed countries in the period 2019-2021 is 16,30 %. Data of the Industrial Production Index for Iceland, Moldova, and Switzerland are not available through this tool.

It should be emphasized that startup companies are mainly related to modern and tech industries, primarily the IT sector, so that is a reason why there is no significant relationship between the development of a particular startup ecosystem and the Industrial Production Index, which is a still mainly based on traditional industries.

6. CONCLUSIONS

Risk has always been associated with starting a new entrepreneurial venture. As startup companies create innovative products and service solutions, their risk compared to existing business models is far higher. In recent years, startup companies are gaining accumulative media space, popularizing the idea of starting this type of company primarily among IT professionals and people interested in new technologies.

Additional support for the startup world is provided by university programs that provide not only knowledge in relevant areas for creating innovative products and service solutions, but also programs designed to study startup companies and ecosystems from the business side, creating experts who will professionally lead such companies and increase its chances of success. Considering the importance of startup companies for national economies around the world, state governments and other organizations have additionally provided various forms of support to startup companies, to create mutual benefit and satisfaction.

Most of the startup ecosystems in European countries that have been analyzed for the period 2019-2021, are in the Activation phase, and the Early Globalization phase. Fintech stands out as the strongest and most dominant sub-sector, followed by the life science and AdTech sub-sectors.

The pandemic of Covid-19 affected the development of the startup ecosystem in particular countries and a whole European startup ecosystem to a large extent because countries had strict restrictions that affected all areas of business. The impact of this crisis can also be seen in the slowdown of industrial production growth, especially in some observed countries, which this research has clearly shown.

During the research, certain limitations were encountered in terms of the data used. Namely, the data are not fully available for all years and all observed countries.

Research and analysis of the startup ecosystem with all its characteristics is very important and gives both, theoretical and practical implications. In the literature is noticeable a lack of studies in this area that are based on a theoretical basis, but also quantitative indicators. This kind of research contributes to a better understanding of this area from the academic point of view, but also provides important guidelines to all participants and related entities in the startup ecosystems of the observed countries, as well as the European startup ecosystem as a whole.

As the presented research refers only to startup ecosystems of European countries, in the future, if based on the same methodology, using the mentioned reports, research of American, Asian, or other ecosystems is performed, it is possible to compare these ecosystems and see their differences, advantages, and disadvantages. It is possible to further investigate the causes of progression, decline, or stagnation of startup ecosystems by country, based on which it is possible to report conclusions and further steps to improve local policies and strategies, looking at examples of successful countries and avoiding negative consequences in times of crisis.

7. REFERENCES

[1] The Global Startup Ecosystem Report 2020 (GSER 2020), Startup Genome, https://startupgenome.com/report/gser2020, last access 14.04. 2022.

[2] What is a startup?, Investopedia, https://www.investopedia.com/terms/s/startup.asp , last access 17.04.2022.

[3] The Global Startup Ecosystem Report 2019 (GSER 2019), Startup Genome, https://startupgenome.com/reports/global-startup-ecosystem-report-2019, last access 15.04.2022.

[4] The Global Startup Ecosystem Report 2021 (GSER 2021), Startup Genome, https://startupgenome.com/report/gser2021, last access 27.04.2022.

[5] J.A. Schumpeter, Economic Theory and Entrepreneurial History. In: Aitken HG (ed) Explorations in enterprise. Harvard University Press, Cambridge, MA (1965).

[6] D. Johnson, What is innovation and entrepreneurship? Lessons for larger organisations", Industrial and Commercial Training, (2001), Vol. 33 No. 4, pp. 135-140.

[7] N. Penezić, Entreprenuership, Modern Approach, (In Serbian Preduzetništvo – savremeni pristup), Sremska Kamenica: Univerzitet Educons (2009).

[8] J. Borocki, Entreprenuership, Innovation and company development, (In Serbian Preduzetništvo, inovacije i razvoj preduzeća), Novi Sad: FTN., (2014).

[9] M. D. Plessis, The role of knowledge management in innovation", Journal of Knowledge Management, (2007) Vol. 11 No. 4, pp. 20-29.

[10] E. Ries E. The Lean Startup, New York: Crown Business (2011).

[11] M. Crowne, M. Why software product startups fail and what to do about it. In: In: Proceedings International Engineering Management Conference (IEMC), (2002), pp. 338–343.

[12] S. Blank, B. Dorf, The Startup Owner's Manual:The Step-by-step guide for building a great company ISBN: 978-0-9849993-7-8 Pescadero, California, Library of Congress Cataloging-in-Publication Data (2012).

[13] B. Cohen, Sustainable valley entrepreneurial ecosystems. Business strategy and the Environment, (2006), Vol.15, No. 1, pp. 1-14.

[14] What Is Startup Ecosystem? Startup Commons,https://www.startupcommons.org/what-is-startup-ecosystem.html, last access 12.05.2022.

[15] C. Ziakis, M. Vlachopoulou, K. Petridis, Start-Up Ecosystem (StUpEco): A Conceptual Framework and Empirical Research. Journal of Open Innovation: Technology, Market, and Complexity, (2022), Vol. 8, No. 1, pp. 35.

[16] D. Agnihotri, Startup Ecosystem. Srujan, (2018).

[17] Industrial Production Index, YChart, https://ycharts.com/dashboard_beta/#/?activeTabDashboardId=-1, last access 15.06. 2022.

Employee participation in education and training programs

V. Bartolovic [a], D. Policic [b], V. Vucemilovic [c]

[a] University of Slavonski Brod, Trg Ivan Brlic Mazuranic 2,35,000 Slavonski Brod, Croatia, vbartolovic@unisb.hr

[B] Osimpex d.o.o., Osijek, Eugene Kumicic 103, 35,000 Slavonski Brod, Croatia, davorp10@gmail.com

[C] Croatian Parliament, Sv. Mark 6, Zagreb, Croatia, Vesna. Vucemilovic @yahoo. com

Abstract

According to Eurostat data, indicators of adult participation in education and training programs at the level of the European Union rank the Republic of Croatia in the last place for many years without significant improvements. The digitalization of business, the need to strengthen the competitive position of companies leads to the need to enable employees to participate in education, learning and training programs in the workplace. According to available research from other scientists, employers will have to invest more money in the knowledge of employees with secondary education than in employees with higher education. It is estimated that workers with a higher level of education will find it easier to adapt to future job needs. The aim of this paper is to determine and interpret the results of the state and perspectives of education and training in companies through variables: age, gender, level of education of respondents, years of service, participation in educational programs, employee attitudes and career development. The survey was conducted on a sample of three companies in the Brod-Posavina County in the period from April 9, 2021 to April 30, 2021 and 102 complete answers were collected from respondents.

The results of the research point to the positive attitudes of the respondents towards training and education in the workplace and indicate the need for companies to invest more resources in the education and training of their employees. The results of the research can motivate employers in designing education and training programs.

Keywords: Employee, education, training, Workplace, on-the-job learning

1. INTRODUCTION

The effectiveness and relevance of on-the-job learning and training ensures employees with the necessary knowledge and skills to work in the workplace. Learning contributes to the improvement of employee performance and also contributes to the feeling of self-confidence. Employee who learn on workplace improve their performance standards, measured by self-assessment [1]. Therefore, the design of training for employees and providing of continuous learning through employee education and training is an important topic in the field of human resources management in the enterprise. Each enterprise should examine its employees on satisfaction with training, measure performance, hold quarterly, semi-annual or annual discussions on the performance of its employees, and set goals for the development of employees that can be achieved through education and training. Each education and training are based on the aforementioned employee performance assessments. Therefore, the assessment of performance at work is related to the elaboration of the education and training plan in the forthcoming period, and the measurement of the effects of employees and employee satisfaction by training is necessary.

1.1. Review literature

Nafukho et al. in online research (n = 251) finds that effective and relevant training is essential in transmitting learning among

participants. The training enabled respondents to acquire knowledge and skills for application in the workplace. The working environment and the motivation of respondents to participate also had a positive impact on education and knowledge transfer [1].

Learning in the workplace requires a strategic approach because it becomes part of the workers' daily routine. In this respect, the organisational maturity of the enterprise to design a learning system in the workplace is important [2].

The relevance of training and the scope of courses related to the participants' job and the professional development of employees have a positive impact on the success of training. Enabling knowledge and skills to be acquired also has a positive effect on knowledge transfer. Motivation of workers to participate in learning and learning related courses are factors that have a positive impact on the transfer knowledge to employees. [3]

In the investigation of the connection between education and training and motivation of employees, a positive and significant influence on the performance is observed. [4] This finding also suggests the growing importance of investing in employee potential in achieving the expected results.

In the research of the role of education and training on employee loyalty, a positive relationship between education and training, employee motivation, internal communication, organizational culture and loyalty was identified [5].

Knowledge sharing, education and training are part of an organisation's learning indicator. Organizations should transform themselves into learning organizations through focus on learning, but also on awards, recognitions, information flow, construction of vision, strategy [6].

Beaver, G., & Hutchings [7], Hurtado et al. [8] in their findings suggest that SMEs developing a strategic approach in human resources management through employee education and training will ensure themselves a competitive position on the market in which they operate and will be more easily adapted to external influences.

Education and training of employees is part of the theoretical model Total quality management and are associated with statistically significant acquisition of competitive advantages of the company, among other elements of the model: “top management commitment/leader SHIP, teams, Culture, training/education, and process Efficiency”, as shown in Figure 1. [9]

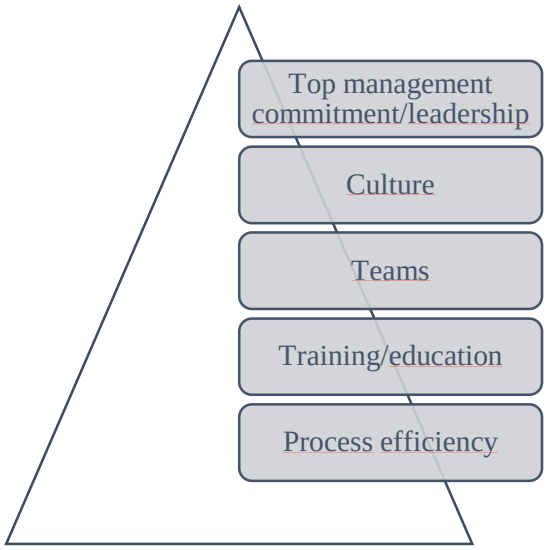

Fig. 1. TQM components affecting the company's competitive edge [authors according to 9]

Transformation of existing organisations into an organisation that learns includes rewarding employees and developing a learning system in the enterprise and sharing knowledge among employees [10].

1.2. Hypotheses and statistics procedures

Table 1 presents research issues, goals, hypotheses and statistical procedures for testing hypotheses.

Table 1. Hypotheses and procedures

Research question	Research goal	Hypothesis	Statistical procedure for testing hypotheses
RQ1. Do the examinees who consider education important for them to successfully perform their work tasks think that the enterprise motivates them by investing in them through education and training?	RG1. Determine whether the respondents to whom education is important for successful performance of tasks also consider that the enterprise motivates them by investing in them through education and training	H1. A statistically significant link between the variable "I think that education is important to me for successful performance of work tasks" and the variable "I think it personally motivates me if the enterprise invests in me through education and training" has been identified.	1. Procedures for testing the normality of distribution of both variables 2. Descriptive statistics, correlations
RQ2. Do the respondents who consider that learning along with the work of the employees has a positive impact on the development of the enterprise also consider education important for the successful performance of the work tasks?	RG2. Determine whether employees for whom education is important for successful performance of work tasks also consider that learning along with the work of employees has a positive impact on the development of enterprises.	H2. A statistically significant link between the variable "I think that education is important to me for successful performance of work tasks" and the variable "I think that learning along with the work of employees has a positive impact on the development of enterprises" has been identified.	1. Procedures for testing the normality of distribution 2. Descriptive statistics, correlations

Sorce: authors

2. METHODS AND MATERIALS USED FOR RESEARCH

Phase 1: Research questions, goals and hypotheses	Phase 2: Review literature	Phase 3: Selection of variables for the questionnaire
Phase 4: Create a survey with a measuring scale	Phase 5: Data collection	Phase 6: Reliability and factor analysis

Phase 7:	Phase 8:	Phase 9:
Testing hypotheses	Interpretation of research results and links with other investigations	Limitations in research and recommendations for future research

Fig. 2. Research methodology [authors]

The research was conducted among the employees of three production companies in Slavonski Brod. The questionnaire was distributed online using the Google forms form. It is important to emphasize that respondents are ensured anonymity when filling in the Survey and are given the possibility to give up the Survey at any time. A total of 102 subjects making up the sample gave a complete response.

The respondents were not able to influence each other or the investigators on the respondents, thus ensuring the independence of the observations. Responses were collected between 9.04.2021. and 30.04.2021.

3. RESULTS AND ACHIEVEMENTS

3.1. Reliability analysis

A reliability analysis was carried out based on the data collected from the survey. The attitudes of employees towards education and training were measured. A total of nine variables were measured by the Likert scale, with the option of neutrality of response integrated (3 - "I disagree or disagree"), which satisfied the semi-interval assumption of the scale, and statistical methods for the interval scale were used. Table 2 shows indicators of the measuring instrument.

The measuring instrument has very good internal reliability (Cronbach's Alpha > 0,8), inter-item correlations 0,452 [11]. On the basis of the data presented in Table 2, the measuring instrument "employees' attitudes towards education and training" is considered reliable.

After reliability analysis, further procedure includes: testing of data normality, factor analysis, correlation for testing hypotheses at the statistical significance level p <, 05. The assumptions for conducting hierarchical regression are also tested (Enter method: dependent variable: I believe that education is important to me for successful performance of work tasks).

Table 2. Characteristics of the measuring instrument "employee attitudes towards education and training

Indicators of the measuring instrument	Attitudes of employees towards education and training
Number of items	9
Cronbach's Alpha	0,865
Cronbach's Alpha Based on standardized items	0,881
Item means	3,956
Inter-Edit correlations	0,452

Source: authors

3.2. Testing of data normality

Data processing is performed using the IBM SPSS 25 statistical package. The verification of data normality shall include the following statistical procedures: numerical tests are taken into analysis (the asymmetry and curvature measures), as well as Kolmogorov-Smirnov and Shapiro Wilk test. Histogram, tree and leaf diagram, Q-Q diagram and Q-Q diagram of the detrended data were used for visual tests.

Assumptions for testing data normality are set:

H0 … distribution has normal form

H1 … data distribution is not normal

a) Numerical tests: the results of the K-S test calculation and the Shapiro Wilk test for N = 102 subjects indicate p <, 05, which includes the rejection of the null hypothesis on the normal distribution. The values ratios of the asymmetry and rounding indicator with the corresponding standard asymmetry and rounding errors point to the conclusion that the data are not normally distributed.
b) Visual tests: the variables' histograms indicate a different distribution from normal. However, the tree and leaf diagram, the normal Q-Q Plot and the Detrended normal Q-Q Plot point to the conclusion about normally distributed data. Normal Q-Q Plot suggests that data by individual variables are positioned on a straight line or around a straight line indicating normal distribution. Detrended normal Q-Q Plot shows that the data are normally distributed because they are within +/- 2 interval (the criterion meets the general rule for normally distributed data). This finding suggests that 95% of the response distribution is in normal distribution interval [11].

According to the nature of variables, the independence of observations, sample size (n = 102) and the positioning of data in visual charts (normal Q-Q Plot and Detrended normal Q-Q Plot), it was decided to use parametric statistics methods in the hypothesis test section.

3.3. Factor analysis

Nine variables from the questionnaire were tested. The data follows below.

Table 3. KMO and Bartlett's test of Sphericity

KMO and Bartlett's test		
Kaiser-Meyer-Olkin measure of Sampling Adequacy.		0,845
Bartlett's test of Sphericity	Approx. Chi-Square	615,193
	df	36
	Sig.	0,000

Source: authors

Kaiser-Meyer-Olkin measure of Sampling Adequacy shows satisfactory values: KMO > 0.6 criterion is met. Bartlett spherical test χ 2 (36) = 615,193, p < .05.

Factor analysis (employee attitudes towards education and training) represent two factors (67.57% of variance explained):

a) the first factor explains the development of personal performance that an individual has in the workplace that he currently performs if he is educated on workplace and includes six dimensions: success in performing work tasks, progress in the profession, taking on greater responsibility, positive influence of the employees learning on the development of companies, improvement of employee motivation, positive attitude towards learning and development of their skills.
b) The second factor explains the employee's views about the enterprise towards investing in employee education and includes three dimensions: Employee assessment of whether the company invests enough funds in employee education, whether the company is advancing towards educating its employees and developing its own career. The results of factor analysis are presented in Table 4 and Table 5.

Table 4. Factor analysis

Total variance of explained

Factor	Initial Eigenvalues			Extract Sums of squared Loadings			Rotation Sums of squared Loadings		
	Total	% of variance	Cumulative%	Total	% of variance	Cumulative%	Total	% of variance	Cumulative%
1	4,709	52,318	52,318	4,386	48,728	48,728	3,788	42,086	42,086
2	1,908	21,197	73,514	1,696	18,842	67,570	2,294	25,484	67,570
3	0,602	6,686	80,200						
4	0,485	5,387	85,587						
5	0,410	4,555	90,142						
6	0,334	3,713	93,856						
7	0,266	2,950	96,806						
8	0,188	2,092	98,899						
9	0,099	1,101	100,000						
Expression method: Principal Axis factoring.									

Source: authors

Table 5. Rotated Factor Matrix

Rotated Factor Matrix [a]		
	Factor	
	1	2
I think learning on workplace (education, training) allows me to take on greater responsibility in the workplace	0,910	
Workplace learning allows me to make progress in the profession	0,835	
I think education is important to me for the successful performance of my work tasks	0,813	
I find it personally motivating if a company invests in me through education and training	0,742	
I like to learn on my workplace and develop my skills	0,736	
I think learning of employees on workplace has a positive impact on the development of companies	0,640	
I think my current company is advancing in terms of educating its employees		0,958

I think that my current company I work in is investing enough in employee education		0,907
I think the company allows me to develop my own career		0,635
Expression method: Principal Axis factoring. Rotation method: Varimax with Kaiser Normalization.		
a. Rotation converged in 3 iterations.		

Source: authors

3.4. Results of hypothesis processing

a) hypothesis H1

Research goal 1 is to determine whether the respondents to whom education is important for successful performance of work tasks also consider that the enterprise motivates them by investing in their education and training.

Table 6. Descriptive Statistics

	Mean	St. Deviation	N
I think education is important to me for the successful performance of my work tasks	4,48	0,805	102
I find it personally motivating if a company invests in me through education and training	4,34	0,970	102

Source: author

The prerequisites for the Pearson correlation, two-way test, are satisfied. The H1 hypothesis contains two variables measured by the questionnaire, and the condition for accepting hypothesis is set at p <, 05

Table 7. Testing the correlations of variables

Correlations			
		I think education is important to me for the successful performance of my work tasks	I find it personally motivating if a company invests in me through education and training
I think education is important to me for the successful performance of my work tasks	Pearson Correlation	1	, 636 **
	Sig. (2-tailed)		0,000
	N		102
* *. Correlation is significant at the 0.01 level (2-tailed).			

Source: author

A statistically significant link between the variable “I think that education is important for me to successfully perform my work tasks” and the variable “I think that it personally motivates me if the enterprise invests in me through education and training” (r =, 636, n = 102, p =, 000) has been identified. Thus, the H1 hypothesis has been accepted.

B) hypothesis H2

Research goal 2 is to determine whether employees whose education is important for successful performance of work tasks also consider that learning on workplace has a positive impact on the development of enterprises. The prerequisites for the Pearson correlation, two-way test, are satisfied. The H2 hypothesis contains two variables measured by the questionnaire, and the condition for accepting hypothesis is set at p <, 05.

Table 8. Descriptive Statistics

	Mean	St. Deviation	N
I think education is important to me for the successful performance of my work tasks	4,48	0,805	102
I think learning along with the work of employees has a positive impact on the development of companies	4,52	0,671	102

Source: authors

Table 9. Testing the correlations of variables

Correlations			
		I think that education is important to me for the successful performance of my work tasks	I think that learning along with the work of employees has a positive impact on the development of companies
I think education is important to me for the successful performance of my work tasks	Pearson Correlation	1	, 541 * *
	Sig. (2-tailed)		0,000
	N	102	102
* *. Correlation is significant at the 0.01 level (2-tailed).			

Source: authors

A statistically significant correlation between the variable “I believe that education is important to me for successful performance of work tasks” and the variable “I believe that learning with the work of employees has a positive impact on the development of enterprises” (r =, 541, n = 102, p =, 000) was identified. Thus, the H2 hypothesis has been accepted.

Table 10. Overview of research results and links with other studies

Number of hypotheses	Hypothesis name	Processing result	Link to other research
H1	Hypothesis 1: A statistically significant link between the variable “I think that education is important to me for successful performance of work tasks” and the variable “I think it personally motivates me if the enterprise invests in me through	Confirmed (r =, 636, n = 102, p =, 000)	Nafukho, et al. (2017) Renta-David et al. (2014) Iqbal et al. (2020)

	education and training" has been identified.		Hope & Naibaho, L. (2020)
H2	Hypothesis 2: A statistically significant link between the variable "I think that education is important to me for successful performance of work tasks" and the variable "I think that learning along with the work of employees has a positive impact on the development of enterprises" has been identified.	Confirmed (r =, 541, n = 102, p =, 000)	Beaver, G., & Hutchings, K. (2005), Iqbal et al. (2020)

Source: authors

3.5. Hierarchical regression analysis (Enter method)

Main assumptions for regression analysis are met: independence of observations, normality of distribution, linearity and homosquedasticity (the following examinations were used: regression standardized residual, normal P-P Plot of regression standardized residual, Scatterplot (regression standardized Predicted value vs. regression standardized residual).

Hierarchical regression analysis (Enter method) was carried out in two steps: in the first step, a dependent variable was set: I think that education is important to me for the successful performance of work tasks, and as a predictor variable a sex of respondents has been included. This characteristic was not shown significantly in the prediction of criteria. The second step included a set of predictors that proved significant. The variables influence predictors that influence the dependent variable (dependent variable: I think that education is important to me for successful performance of work tasks):

a) I think that work-related learning (education, training) enables me to take on greater responsibility at the workplace (β =, 393, t = 3.891, p =, 000),

B) I think that I am personally motivated if the company is progressing in terms of educating its employees (β =, 154, t = 2,082, p =, 040).

The proposed Enter method predicts 66.1% of the variance of criteria (R^2 =, 661, F (8.93) = 22,700, p =, 000), R^2 Adjusted =, 632 indicating that this model significantly predicts 63.2% of the variance of criteria.

4. CONCLUSION

In total 102 employees from production companies in Brod-Posavina County participated in the survey. Very good internal reliability of the measuring instrument (Cronbach's Alpha > 0.8), inter-item correlations 0.452, was established. The factor analysis (attitudes of employees towards education and training, 9 variables) explains two factors (67,57% of variance). The first factor refers to the dimensions explaining the development of performance that an individual has in the workplace that he currently performs if he is educated on workplace: success in performing work tasks, progress in the profession, taking on greater responsibility, positive influence of the employees learning about the development of companies, improvement of employee motivation, positive attitude towards learning and development of own skills. The second factor refers to the dimensions of enterprise's behaviour towards investment in employee education: Employee assessment whether the company invests enough funds in employee education, in the development of employees' own career, whether the company is advancing towards educating its employees.

This research provides answers to the questions of research. The H1 hypothesis based on research issue 1 has been confirmed: respondents who believe that education is important to them for successful performance of work tasks also believe that they are personally motivated if the enterprise invests funds in employee education and training (r =, 636, n = 102, p =, 000) which is in line with the previous findings of Nafukho, Fredrick Muyia, et al., (2017), Renta-David et al. (2014), Iqbal et al. al. (2020), Nadeak & Naibaho, L. (2020). The hypothesis related to research issue 2 was also confirmed: respondents who believe that learning along with the work of employees has a positive impact on the development of enterprises also believe that education is important for successful performance of work tasks (r =, 541, n = 102, p =, 000). This finding is on the trail of previous research conducted by Beaver, G., & Hutchings, K. (2005), Iqbal et al. (2020).

Hierarchical regression analysis (Enter method, dependent variable: I believe that education is important to me for successful performance of work tasks) found that Enter method predicts 66.1% of criteria variance (R^2 =, 661, F (8.93) = 22.700, p =, 000), R^2 Adjusted =, 632 indicating argument that this model significantly predicts 63.2% of criteria variance. There are two variables that measure employee attitudes towards education and training (p <, 05): "I think that working learning (education, training) allows me to take on greater responsibility in the workplace" (β =, 393, t = 3.891, p =, 000) and "I think that I am personally motivated if the company is progressing in terms of educating its employees" (β =, 154, t = 2.082, p =, 040).

When considering the presented results obtained in this study and comparing them with the results of previous studies, similarity in findings and practical usability of research results is observed.

These findings can serve the management of the company as a basis for making decisions on investing in education and training of own employees, because employees are motivated to take on greater responsibility in the workplace and are personally motivated when the company advances in terms of educating its employees. Learning in the workplace and investing in employee education and training is also one of the components of Total quality Management and learning Organization (Griego et al.). According to the findings of Beaver, G., & Hutchings, Hurtado et al. companies that develop a strategic approach in human resources management through employee education and training provide their competitive position on the market and adapt more easily to external influences from the business environment. The results of this research should therefore be considered in the context of industry 4.0 and IoT. The results of this research with its positive findings can also be used as arguments in this direction.

4.1. Recommendations for further research and limitations of this research

It is necessary to repeat the survey with a geographically broader scope of the research area because the research was conducted in production companies in Brod-Posavina County. It would also be desirable to include data subjects not only manufacturing companies but also service companies in order to ensure the greatest possible diversity of the sampled respondents. Through the sample collected in this way, the conclusions could refer to the geographically and economically wider population, and not only to the employees of production companies of the narrower local area. Despite the mentioned limitations of this research, statistically significant findings were obtained in all segments of the conducted analysis, which have a practical application for enterprises in the production sector. The findings of this research confirm the results of previous research.

5. REFERENCES

[1] Nafukho, Fredrick Muyia, et al. Predicting Workplace transfer of learning: A study of adult learners enrolled in a consulting professional

education training program. *European Journal of training and Development* (2017)

[2] Egginton, Bill. Realising the Benefits of investment in Project Management training: evidence Supporting the need for a more strategic approach. *International Journal of Managing projects in business*, 2012.

[3] Renta-David, A. I., Jiménez-González, J. M., Fandos-Garrido, M., & González-Soto, Á. P. Transfer of learning: motivation, training design and learning-conducive work effects. *European Journal of tracing and Development*. (2014).

[4] Iqbal, N., Khan, M., Mohmand, Y. T., & Mujtaba, B. G. The impact of in-service training and motivation on job performance of technical & Vocational education Teachers: role of person-job fit. *Public Organization review*, *20* (3), 529-548. (2020)

[5] Nadeak, B., & Naibaho, L. Motivation and HRM factors relation this Employee loyalty. *Polish Journal of Management studies*, *22*. (2020).

[6] Griego, O. V., Geroy, G. D., & Wright, P. C. Predictors of learning Organizations: a Human resource development practitioner's perspective. *The learning Organization*. (2000)

[7] Beaver, G., & Hutchings, K. Trading and developing an age diverse workforce in SMEs: the need for a Strategic approach. *Education + training*. (2005).

[8] Hurtado, M. J. R., Guasch, M. D. M., Rodríguez, F. C., Gámez, A. N., & Herrero, P. Training in Spanish organizations: trends and future Perspectives. *Intangible Capital*, *7* (2), 236-260. (2011).

[9] El Shenawy, E., Baker, T., & Lemak, D. J. A meta-analysis of the effect of TQM on Competitiveness perspective. *International Journal of quality & reliability Management*. (2007).

[10] Griego, O. V., Geroy, G. D., & Wright, P. C. Predictors of learning Organizations: a Human resource development practitioner's perspective. *The learning Organization*. (2000).

[11] Horvat, J., & Mijoč, J. *Istraživački SpaSS*. Naklada Ljevak. (2019).

Student satisfaction with the digitalization of teaching in higher education

S. Knežević Kušljić [a]

[a] University of Slavonski Brod, Trg Ivane Brlić Mažuranić 2, 35000 Slavonski Brod, Croatia, sknezevic@unisb.hr

Abstract

The purpose of this paper is to analyse the level of student satisfaction with the digitalization of teaching in higher education and its consequences. The aim is to identify and explain the differences in the student profile with regard to the area, level and year of study with the satisfaction of online teaching (lectures, seminars /exercises and exams) and a sense of belonging to the student community. For the purposes of this paper, an empirical study was conducted involving students of the University of Slavonski Brod (UNISB). A survey questionnaire was used to collect data. Methods of data processing included the calculation of descriptive statistics parameters. One-way ANOVA was used in order to identify statistically significant differences between the groups.

Research results and variance analysis showed significant differences in all profile of students. Students from 1st year show the greatest satisfaction on online study and sense of belonging to the student community, students from undergraduate study show the greatest satisfaction in sense of belonging to the student community and students from social and humanistic study show the greatest satisfaction in online study and in sense of belonging to the student community.

Keywords: Knowledge management; Student; Digitization; Online study; Student community

1. INTRODUCTION

Pandemic has impacted most of the sectors globally. Among other things, the academic world, especially higher education. Higher educational institutions have to protect students from viral exposures by conducting online classes. According to UNESCO (2020) as of March 23, 2020, around some 1.3 billion learners around the world were not able to attend school or university for face-to-face classes in the physical infrastructure. [1] As of March 16, 2020, due to the coronavirus in Croatia, regular classes were interrupted and online classes were launched for the first time. [2] The pandemic inevitably led to great difficulties in study but these disruptions also provided opportunities for innovation. Youth organizations are also felt the consequences of the pandemic itself (e.g. Erasmus). All the activities were over, and the students used technology and social networks more. It became a meeting place for students. As a result, students did not have the opportunity to meet new people as before, socialize, and interact face to face. This led to a lack of social contact among students and a sense of belonging to the student community.

Ouma (2021.) conducted a systematic review of the perception of online learning among college students during the COVID-19 pandemic around the World. The results indicated that students reported lack of prior experience with online learning, technical difficulties accessing materials online, high volume of assignments, poor communication between learners and educators, distractions from home environment, and lack of practical and clinical experience for students in medical schools. [11]

Chakraborty et al (2020) investigate opinion of students on online education during the COVID-19 pandemic in India. The students considered online education a viable alternative under the current circumstances, they felt that the professors have improved their online teaching skills since the beginning of the pandemic (68.1%) and online education is useful right now (77.9%). However, the students felt that online education is stressful and affecting their health and social life. [5]

Mahat (2021.) analyses students' perception towards online-class during COVID-19 pandemic in Nepal. Findings show that majority of students had adopted online class first time in their learning career but they were enjoying in online class. [9]

Egielewa et al (2022.) investigate student perception of Nigerian institutions of higher learning using the new digital culture induced by the COVID-19 pandemic, namely, online learning. Results found that students are not satisfied with virtual learning and would not want the online learning to continue after the pandemic. [10]

Meşe & Sevilen (2021.) analyses factors influencing students' motivation in online learning in Turkey. Results demonstrated that students overall have negative perceptions towards online teaching which they believe has a negative impact on their motivation due to lack of social interaction, a mismatch between expectations and content, organizational problems and the organization of learning environments. [12]

According to Peimani & Kamalipour (2021) in research in UK the pandemic can also be considered as an opportunity to deliberate over its impacts and associated changes in a way that contribute to the pedagogical reinventions as well as the evolution of online education. [4]

Kovačević et al (2021.) presented the effects of online teaching on higher education institutions during the covid-19 pandemic in Serbia. [7] The results of the research suggest that the effects of online teaching are mostly positive (economy in time and financial resources) while the biggest drawback is the lack of direct contact and practical exercises.

According to AZVO (2022) and research conducted at the national level students (almost 4,300) expressed satisfaction with certain segments of the organization of online teaching and exams. [3] Results showed that the transition to online forms of teaching had a significant impact on the mental health of students, their social inclusion, the study experience and the quality of student life.

Bačić & Krstinić (2020) examine the satisfaction with the conduct of online classes among the students of Zagreb University of Applied Sciences. [8] Results expressed satisfaction with the teaching, materials available and implementation tools online teaching.

Kostović-Vranješ et al (2021.) examine attitudes of teacher and students of teacher education in Split about distance learning. [6] Research has shown that teachers perceive the transition from regular to distance learning as statistically significantly more difficult than students, and both spend the same amount of time preparing for online classes as they did before in regular classes. The biggest disadvantages of online study are the lack of direct contact.

Precisely because of all the above, this paper analyses the student satisfaction with the digitalization of teaching. The aim of this paper is to determine whether there are differences between student area, level and year of study with satisfaction of online study and a sense of belonging to the student community. In accordance with the aim of the research therefore the following hypotheses were defined:

H1: Area of study affects the satisfaction on online study.
H2: Level of study affects the satisfaction on online study.
H3: Year of study affects the satisfaction on online study.
H4: Area of study affects the satisfaction on sense of belonging to the student community.
H5: Level of study affects the satisfaction on sense of belonging to the student community.
H6: Year of study affects the satisfaction on sense of belonging to the student community.

The results of this study can be used to understand the student's satisfaction on online study and sense of belonging to the student community.

2. METHODS AND MATERIALS USED FOR RESEARCH

The sample consists of 201 entities (63 male and 138 female) a representative sample of respondents, i.e. students from UNISB: technical area - study of Mechanical engineering, biotechnical area – study of Herbology, social area - study of Management and humanistic area - study of Education. Except the student status and university of study, there were no other restrictions on entity selection.

Independent variables are: gender, year of study, level of study, area of study. Dependent variables are: Online lectures, online exams, online seminars/exercises, and sense of belonging to the student community due to online teaching. Three variables of satisfaction on online teaching are condensed by arithmetic mean in the variable “online study” (online lectures, exams and seminars/exercises).

A survey in the form of an online survey was used to collect data. The link to the online survey was sent via e-mail to students. Along with the link provided to the online survey, there were several sentences of explanations related to the research and its purpose. The survey was conducted from 01.01.2022. to 01.02.2022. The survey was conducted voluntarily and a total of 201 responses were collected.

The questionnaire consists of 8 questions and two parts: in the first part, respondents were asked to fill in basic information about themselves. This was followed by a second part that include their level of satisfaction on online study and on sense of belonging to the student community. Questions were: To what extent are you satisfied with the organization of online lectures/seminars/exercises and online exams and to what extent are you satisfied with the feeling of belonging to the student community due to online classes?

For these questions’ respondents evaluate level of satisfaction on online study and sense of belonging to the student community with an interval of 1 to 5: 1 - not at all satisfied; 2 - slightly satisfied; 3 - moderately satisfied; 4 - very satisfied; 5 - completely satisfied.

Statistical analysis of results is performed in the statistical program SPSS and STATISTICA. Descriptive statistical parameters were calculated for all variables and tested by the Kolmogorov-Smirnov test. The Kolmogorov-Smirnov test determines whether a distribution deviates significantly from normal (either in terms of skewness or kurtosis). One-way ANOVA with Tukey's post hoc test was used in order to identify statistically significant differences between the groups.

3. RESULTS AND ACHIEVEMENTS

The results of the research are based on the survey “Student's perception of online study”.

Table 1. Socio-demographic characteristics of the survey participants [author]

Characteristics		Total (N)	%
Gender	Male	63	31,34
	Female	138	68,66
Year of study	1.year	37	18,40
	2. year	39	19,40
	3.year	51	25,37
	4.year	32	15,92
	5.year	37	18,40
	Postgraduate	5	2,48
Level of study	Undergraduate	121	60,20
	Graduate	75	37,31
	Postgraduate	5	2,48
Area of study	Social	101	50,25
	Humanistic	39	19,40
	Technical	42	20,89
	Biotechnical	19	9,45

Table 1. shows that the total number of respondents is 201, of which 31,34% are male and 68,66% are female respondents. The largest share 60,20% are undergraduate students, 37,31% are graduate and only 2,48% are postgraduate students. The largest share 50,25% are from social study, slightly more respondents 20,89% from technical than those from humanistic study 19,40%, and the smallest share 9,45% from biotechnical study.

Table 2. Descriptive indicators measuring variables for online lectures/exams/seminars/sense of belonging to the student community [author]

Variable	M	Median	Mode	Min	Max	SD	Skew	KURT	STD. ERR

Online lectures	3,71	4,00	4,00	1,00	5,00	1,12	-0,71	-0,13	0,08
Online exams	3,67	4,00	4,00	1,00	5,00	1,18	-0,68	-0,33	0,08
Online seminars	3,73	4,00	4,00	1,00	5,00	1,16	-0,74	-0,19	0,08
Sense of belonging to the student community	3,18	3,00	5,00	1,00	5,00	1,47	-0,15	-1,38	0,10

Table 2 shows that students equally value the online lectures, exams and seminars. However, results show that students are the least satisfied with the sense of belonging to the student community (M = 3.18). Since the scale of each variable varies from 1 to 5, it can be observed that averages ranging from 3.18 to 3.73 are average, i.e. that students are moderately satisfied with variables. Three variables (online lectures, online exams, and online seminars) were condensed by the arithmetic mean into the Online study variable. The following Table 3. shows the basic statistical parameters of the obtained variable.

Table 3. Descriptive indicators measuring variable "online study" [author]

Variable	M	Median	Mode	Min	Max	SD	Skew	KURT	STD. ERR
Online study	3,70	4.00	4,00	1,00	5,00	1,01	0,61	0,08	0,07

The obtained value of the Cronbach's alpha coefficient is .841 and confirms the consistency in the answers of the respondents through different scales, which indicates that the reliability can be considered very acceptable. The normality of the distribution was tested by the Kolmogorov-Smirnov and Lilliefors test, and the distribution of results by variables significantly and significantly deviates from the normal distribution, with an error of less than 1% ($p<0.01$).

In educational research, there is a limit theorem that enables the application of parametric tests when the sample is larger than 100, even though the distribution is not normally distributed. [13] One-way ANOVA, analysis of variance was conducted to determine if there was a difference in level of satisfaction of the variables online study and sense of belonging to the student community with respect to year, level and area of study.

Table 4. One-way ANOVA for independent samples as opposed to variable year of study [author]

Variable	Year of study	M	SD	F	df	p value ($p \leq 0,05$)
Online study	1.year	4,02	0,89	4,080	195,00	0,001
	2. year	3,44	1,12			
	3.year	3,86	0,93			
	4.year	3,28	0,99			
	5.year	3,94	0,95			
	Postgraduate	2,80	1,01			
Sense of belonging to the student community	1.year	3,78	1,33	3,424	195,00	0,005
	2. year	2,74	1,44			
	3.year	3,33	1,47			
	4.year	3,06	1,34			
	5.year	3,16	1,57			
	Postgraduate	1,60	0,54			

Table 5. shows that there is a statistically significant difference in level of satisfaction of online study considering to year of study. Tukey's post hoc test indicated that there are significant differences between groups, 1st year (M = 4,02, SD = 0,89) differs significantly from 4th year (M=3,28, SD = 0,99). Furthermore, there is a statistically significant difference in sense of belonging to the student community considering to the year of study. Tukey's post hoc test indicated that there are significant differences between groups, 1st year (M = 3,78, SD = 1,33) differs significantly from 2nd year (M = 2,74, SD = 1,44) and 1st year differs significantly from postgraduate (M = 2,80, SD = 1,01).

Table 5. One-way ANOVA for independent samples as opposed to variable level of study [author]

Variable	Level of study	M	SD	F	df	p value (p ≤ 0,05)
Online study	Undergraduate	3,77	0,99	2,454	198	0,088
	Graduate	3,64	1,03			
	Postgraduate	2,80	1,01			
Sense of belonging to the student community	Undergraduate	3,28	1,46	3,268	198,00	0,040
	Graduate	3,13	0,54			
	Postgraduate	1,60	1,48			

Table 5. shows that there is no statistically significant difference in level of satisfaction of online study considering to level of study. Furthermore, there is a statistically significant difference in sense of belonging to the student community considering the level of study. Tukey's post hoc test indicated that there are significant differences between groups, undergraduate (M=3,28, SD=1,46) differs significantly from postgraduate (M=1,60, SD=1,48).

Table 6. One-way ANOVA for independent samples as opposed to variable area of study [author]

Variable	Area of study	M	SD	F	df	p value (p ≤ 0,05)
Online study	Technical	3,41	1,20	2,736	197, 00	0,044
	Social	3,90	0,93			
	Humanistic	3,62	0,85			
	Biotechnical	3,50	1,19			
Sense of belonging to the student community	Technical	2,71	1,44	3,563	197, 00	0,015
	Social	3,44	1,44			
	Humanistic	3,28	1,36			
	Biotechnical	2,63	1,70			

Table 6. shows that there is a statistically significant difference in level of satisfaction of online study considering to the area of study. (F (3, 197) = 2,736, P = 0,044). Tukey's post hoc test indicated that there are significant differences between groups, technical area of study (M = 3,41, SD =1,20). differs significantly from social (M = 3,90, SD = 0,93). The reason for this may be that students in the technical field have more material to learn that is easier to pass physically (mathematical tasks) while students of social sciences have material that does not require mathematical tasks. Furthermore, there is a statistically significant difference in sense of belonging to the student community considering to the area of study. Tukey's post hoc test indicated that there are significant differences between groups, technical area of study (M=2,71, SD=1,44). differs significantly from social (M=3,44, SD=1,44).

4. CONCLUSIONS

The shock of online study that many students experienced was a great challenge for students who suddenly had to switch to digital classrooms and lost a very important part of the student experience - socializing. In March 2020, classes took place completely online for the first time in history so that was the reason to examine and analyse student's satisfaction about online study and sense of belonging to the student community. Students from 1st year show the greatest satisfaction on online study and sense of belonging to the student community, students from undergraduate study show the greatest satisfaction in sense of belonging to the student community and students from social and humanistic study show the greatest satisfaction in online study and in sense of belonging to the student community. As much as online study may sound like the study of the future, the fact is that nothing will ever be able to replace live lecture.

This paper represents a contribution to the discussion of the connection between the COVID-19 pandemic and changes in the quality of student life. Considering the set hypotheses

and goals the analysis show there are statistically significant differences between student area, level and year of study with satisfaction of online study and a sense of belonging to the student community so hypothesis H1, H3, H4 and H5 are accepted. There is no statistically significant difference in level of satisfaction of online study considering to level of study. Consequently, the hypothesis H2 is rejected.

The limitation of this research is the focus on a particular UNISB. The conclusion would therefore be better if the research included several universities from the entire territory of the Republic of Croatia. The instrument used to assess student satisfaction with online teaching was not detailed enough, and this is the main limitation of the study. This research can be a starting point for more detailed research about student's satisfaction with digitalization in teaching - to include all students in Croatia.

5. REFERENCES

[1] UNESCO, COVID-19 Educational Disruption and Response 2020, https://en.unesco.org/themes/education-emergencies/coronavirus-school-closures, last accessed 10/04/2022

[2] Ministry of Science and Education https://mzo.gov.hr/UserDocsImages/dokumenti/Vijesti/2020/Dodatne%20upute%20vezano%20uz%20obustavu%20nastave%20na%20visokim%20ucilistima%20-%2013.%203.%202020.pdf, last accessed 15/05/2022

[3] Agency for Science and Higher Education, Students and the pandemic: How did we (over)live? (Studenti i pandemija: Kako smo (pre)živjeli?) https://www.azvo.hr/hr/azvo-vijesti/2616-predstavljeni-rezultati-istrazivanja-studenti-i-pandemija-kako-smo-prezivjeli, last accessed 20/05/2022

[4] N. Peimani; H. Kamalipour, Online Education and the COVID-19 Outbreak: A Case Study of Online Teaching during Lockdown. Education Science 11 (2021) pp. 72.

[5] P. Chakraborty; P. Mittal; M.S. Gupta; S. Yadav; A. Arora, Opinion of students on online education during the COVID-19 pandemic 3 (2020), pp. 357-365,

[6] V. Kostović-Vranješ; M. Bulić; V. Periša V., Attitudes of teacher study students and classroom teachers about distance learning, Školski vjesnik: časopis za pedagogijsku teoriju i praksu 70 (2021)

[7] J. Kovačević; V. Radovanović; T. Radojević; J. Kovačević, Effects of online classes at higher education institutions during the covid-19 pandemic (Efekti online nastave na visokoškolskim ustanovama za vreme pandemije covid-19), XXVII Skup Trendovi razvoja: "Online nastava na univerzitetima", Novi Sad, 15 - 18. 02. (2021)

[8] L. Bačić; M. Krstinić, Satisfaction with the conduct of online classes among the students of Zagreb University of Applied Sciences (Zadovoljstvo izvođenjem online nastave među studentima Tehničkog Veleučilišta u Zagrebu) Obrazovanje za poduzetništvo- E4E: znanstveno stručni časopis o obrazovanju za poduzetništvo, 10 (2020), pp. 34-42

[9] D. Mahat, Students' Perception Towards Online - Class during COVID-19 Pandemic, International Research Journal of MMC (IRJMMC), 2 (2021)

[10] P. Egielewa; P.O. Idogho, FO. Iyalomhe; GT. Cirella, COVID-19 and digitized education: Analysis of online learning in Nigerian higher education. E-Learning and Digital Media, 19 (2022), pp. 19-35.

[11] C. Ouma, Online Learning Perception among College Students during COVID-19 Pandemic around the World: Review, African Educational Research Journal 9 (2021) pp. 790-799

[12] E. Meşe; C. Sevilen, Factors influencing EFL students' motivation in online learning: A qualitative case study. Journal of Educational Technology and Online Learning, 4 (2021) pp.11-22 .

[13] D. De Vaus, Analysing social science data, London, (2004).

Communication in a business environment with special references to empathy

A. Kulaš Mirosavljević [a], M. Bogdanić [b], M. Stanić Šulentić[c]

[a] University of Slavonski Brod, Ivana Brlić Mažuranić Square 2, Slavonski Brod, 35000, Croatia, akmirosavljevic@unisb.hr

[b] Primary school "Dragutin Tadijanović", Andrija Hebrang 12/1, Slavonski Brod, 35000, Croatia, mbogdanic22@gmail.com

[c] Agency Stanić, Matije Gupca 28, Slavonski Brod, 35000, Croatia, marina.stanic.sulentic@gmail.com

Abstract

The success of any organization depends on the quality of communication within the individual organization. Although the quality of communication is affected by all employees, the most important thing is that the management of the organization has pronounced communication skills, which are an important factor in the organization of business. This paper is focused on managerial communication as a means of motivating employees in order to plan and organize work or achieve common organizational goals. It is also focused on communication within employees. The study aims are to emphasize the importance of communication in the business environment with special references to empathy and to examine the participants' perception of some of the characteristics of internal communication (with co-workers and with supervisors) present in their organizations that indicate empathic behaviour. In order to determine the respondents' perceptions of the above, a survey was conducted, by surveying employees in for-profit and non-profit organizations. Based on the results of the research, it can be concluded that the respondents consider empathy in the communication of both organizations to be very important.

Keywords: Communication, business communication, business environment, emotional intelligence, empathy

1. INTRODUCTION

Every human activity, in a way, represents some form of communication. Communication is especially important in the functioning of the organization. Effective communication is extremely important for the development of the organization and the functioning of the organization as a whole. Communication in an organization is a system of exchanging information and receiving and issuing orders from each other. The way of communicating is essentially a skill that can be learned, practiced and continuously improved. The uninterrupted flow of information, where one party is the transmitter of a message or information, and the other party is the recipient of the same message or information, is important in communication. The feedback from the recipient of the information is an indication of the degree of its understanding.

Communication in organization depending on the direction is divided into: vertical, horizontal and diagonal communication. Vertical communication is the communication between organizational levels. It can be bottom-up communication and communication from top to bottom. Bottom-up communication involves sending messages from subordinates to superiors

(suggestions, ideas, inquiries, requests, complaints, and various information). Top-down communication involves sending messages from superiors to subordinates (instructions, information, procedures, practices, goals, strategies, etc.). Horizontal communication is communication between colleagues and associates at the same organizational level. It includes supporting and informing others about one's own work. Diagonal communication is communication between employees of different organizational levels and areas of work. Quickly and efficiently transfer of information between different levels is necessary form of communication.

Special attention in this paper is focused on manager communication as a means of motivating employees in order to plan and organize work or achieve common organizational goals.

The role of communications in an organization is not only to provide and exchange information within the organization, but to enable the exchange of information between the organization and its environment (customers, suppliers, shareholders, government).

In order for communication to be as efficient as possible, it is necessary to possess a certain level of emotional intelligence or empathy.

Emotional intelligence, according to Salovey and Mayer (1990), is a set of abilities that should contribute to a more accurate assessment and expression of one's emotions, as well as the assessment of other people's emotions and the use of feelings in motivating, planning and achieving life goals. [1]

Goleman (2000) presents five basic emotional and social competencies:

- self-awareness - knowing one's own feelings, being able to realistically assess one's own abilities
- self-control - emotion management, the ability to recover from emotional stress
- motivation - to use our deepest preferences to encourage and direct ourselves towards our goals, to take initiative and strive for improvement, to persevere when faced with failures and disappointments
- empathy - to feel what people feel, to be able to take their point of view and to cultivate personal relationships and harmony with different people
- adaptability in relationships or social skills - deal well with emotions in relationships and assess certain social situations, interact and use these skills to persuade and lead, negotiate and resolve conflicts, and achieve collaboration and teamwork [2]

Empathy is the ability to understand other people’s emotions. Having empathy for a person means understanding how he feels in a certain situation and thinking about how we would act to find ourselves in the same situation. Therefore, empathy can be defined in simple terms as "putting on someone else's shoes". Empathy creates realistic expectations, it creates value. It is especially important in communication processes within the organization, but also outside it (e.g. the relationship with customers and recognizing their needs and desires). Good communication is a necessary (but not sufficient) condition for success in work, especially when it comes to human resource management. [3]

Goleman (2002) believes that: "in the global economy, empathy is a critical skill both for getting along well with colleagues at work and for doing business with people from other cultures." [4]

Nothing can be more powerful than developing empathy skills during everyday job conversations. It all starts with self-awareness, and understanding your own feelings is key to understanding the feelings of others. It is crucial for effective communication and for leading others. Lack of empathy is a major cause of interpersonal difficulties. It leads to poor

performance, absence or inability to communicate, poor relationship with co-workers, and ultimately with clients. Without the inability to understand other people's views, some managers may not work well with the team and cannot influence them.

According to Goleman (2000), empathy is the basis for all social competencies important for work, especially:

- Understanding others: feeling other people's feelings and being actively involved in helping and caring
- service orientation: anticipating, recognizing and meeting user needs
- developing others: feeling for other people's developmental needs
- Using diversity: nurturing opportunities through the diversity of people
- political awareness: recognizing political and social currents in the organization. [2]

Leaders with empathy, Goleman (2000) believes, do more and use their knowledge to improve business results.

According to Tomulić and Grmuša (2017) in the organizational climate, empathy is a key management skill for a good relationship and interaction between associates. It is an ability that every manager should have. Furthermore, the same authors state: "leaders with developed empathy are able to understand the different views and emotions of others even when they do not express them and can successfully cooperate and interact with different people." [5]

Sikavica and Hernaus (2011) state that teamwork involves a high degree of interconnectedness of all participants in an organizational process, and therefore such communication requires the practice of empathy. [6]

Gutić and Peterschik (2018) believe that empathy encourages the creation of visions in a team, helps to build a work environment based on cooperation and trust. [7]

For the purposes of the paper, a survey was conducted on the perception of respondents of non-profit and for-profit organizations about the empathy in communication within employees and between managers and employees.

Before presenting the research results, it is necessary to briefly explain the difference between non-profit and for-profit organizations. The aforementioned goals were compared through surveys of respondents from these comparative organizations.

In non-profits, goals are not aimed at profit maximization, as is the case with for-profit organizations. The primary goal of non-profit organizations is considered by Rupčić (2018): "to maximize the quantity and quality of output within a certain and often limited budget." [8]

Furthermore, Rukavina (1994) states that in manufacturing and for-profit enterprises, managers make decisions in order to make a profit. The management of non-profit organizations makes decisions in order to achieve the best possible services in accordance with the available resources. The same author points out that non-profit organizations "do not measure business success through profit, but through their differentiated performance." [9]

Regardless of the limited type of decision-making, by setting a goal, as well as the management of for-profit organizations, the management of non-profit organizations applies identical rules and strives to achieve the set goals and justify the organizational purpose in the most efficient way. However, among other non-profit organizations, there are also those (eg hospitals, educational institutions) that operate according to "profit principles". In contrast to non-profit organizations, for-profit organizations always act in such a way that they always choose among the available options those that bring higher profits. Success is measured by the result of its business, and that is profit. This imposes the conclusion that managers of both organizations in their activities (depending on the primary activity of the organization) should have the same qualities, necessary knowledge

and skills, especially a certain degree of emotional intelligence - empathy.

The aim of the study is to examine the participants' perception of some of the characteristics of internal communication (with co-workers and with supervisors) present in their organizations that indicate empathic behaviour.

2. METHODS AND MATERIALS USED FOR RESEARCH

A total of 60 respondents took part in the survey. Respondents were segmented into two groups, respondents employed by non-profit organizations and employees employed in for-profit organizations, with equal shares of 50%.

In order to identify the importance of empathy in communication, an anonymous questionnaire was conducted. The questionnaire was sent by e-mail via the Google Forms form or by sending the form directly, and the completed forms were collected in the same way as they were submitted. A questionnaire contained 12 questions. In the part of the questionnaire, the respondents expressed their degree of agreement with each statement on the Likert scale with 5 levels of assessment (1 = I do not agree at all, 2 - I partially disagree, 3 - I neither agree nor disagree, 4 - I partially agree, 5 = I completely agree). Data were submitted and collected in the period from March 15, 2020 to April 1, 2020.

The survey was formed based on research: Tomulić, A.M. et al. (2017). Empathy in the work environment, Zagreb: Zagreb Business School with the right of the public (with additional processing by the author).

3. RESULTS AND ACHIEVEMENTS

A total of 60 respondents took the survey. Respondents were segmented into two basic groups, respondents employed by non-profit and employees employed by for-profit organizations. The number of respondents in both groups is equal. Sociodemographic data of respondents are presented in Table 1.

Table 1. Sociodemographic data of respondents (in %)

Description	**Structure**
Gender	
Male	40.00%
Female	60.00%
Age	
26 – 35 years	11.67%
35 – 45 years	50.00%
45 – 55 years	26.66%
55 – 65 years	11.67%
Education	
Primary school education	3.33%
Secondary school education	20.00%
Higher education	76.66%
Length of service	
Less than 3 year	13.33%
3 – 7 years	8.33%
7 – 15 years	28.34%
Longer than 15 years	50.00%

Below are graphical representations of vertical and horizontal communication in the organization, mutual understanding of associates and superiors. The presence of empathy in the organization must be the basis for mutual cooperation of all stakeholders.

The statement that employees communicate with each other in order to achieve common goals in non-profit organizations is positively perceived by 57% of respondents. It is interesting to note that a higher percentage of positive comments on this statement is in for-profit organizations, as shown in Figure 1. As many as 87% of respondents belonging to the segment of for-profit organizations responded positively to this claim. The specificity of for-profit organizations is to encourage teamwork and mutual respect.

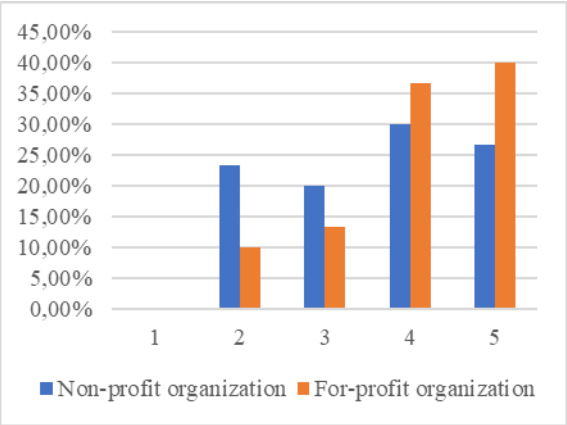

Fig. 1. Do employees communicate with each other in order to achieve common goals?

In the statement that employees help each other in order to achieve results (Figure 2), in non-profit organizations 20% of respondents fully agree with the statement while 33% of respondents partially agree with the same statement. In for-profit organizations, 37% of respondents fully agree with the statement, and 43% of respondents partially agree with the statement.

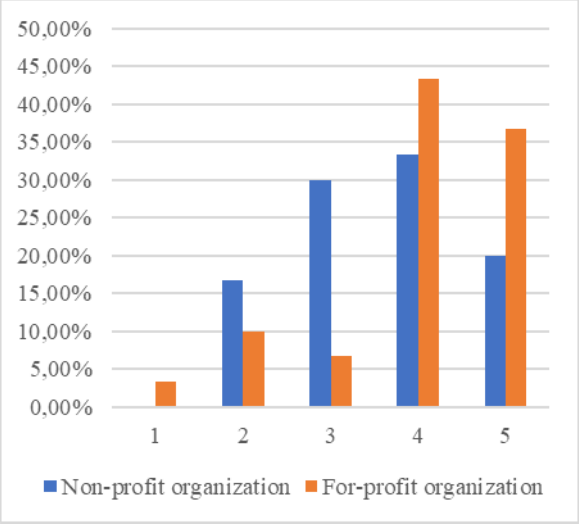

Fig. 2. Do employees help each other in order to achieve result?

The specificity of for-profit organizations is that employees help each other because of their common interest, and that is the achievement of the business goal of the organization, usually defined by a numerical equivalent on an annual basis (business year). This is precisely the difference compared to non-profit organizations, where a common goal or result is usually impossible or difficult to determine, even at the level of one business year.

In the statement that employees respect each other (Figure 3), in non-profit organizations 17% of respondents completely agree with it, while 33% of respondents partially agree with the same statement. In for-profit organizations, 23% of respondents fully agree with the statement that employees respect each other, and 44% partially agree with the statement.

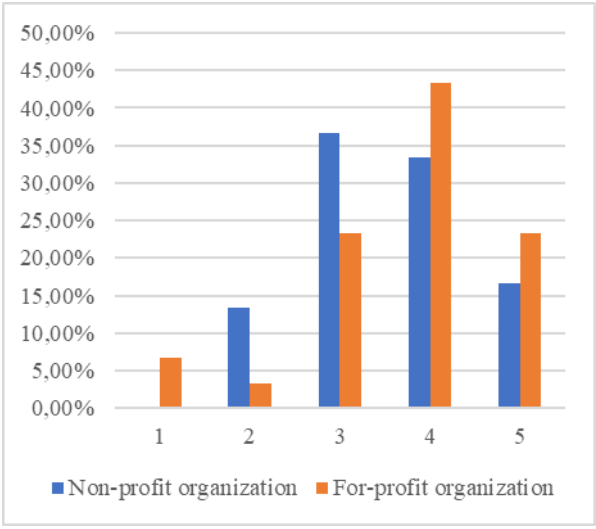

Fig. 3. Do employees respect each other?

As a rule, successful teams are recognized by a common identity and mutual cooperation, exchange of ideas and opinions. Each employee contributes to the team and through joint activity they create a complete whole and achieve joint business results. By presenting each other's ideas and attitudes, they find the best possible solution to a business problem or a given business task. Figure 4 shows that there is a smaller percentage of respondents from the segment of non-profit organizations who responded positively to the statement that they accept different views and opinions, ie 47%, while in the case of for-profit organizations, the percentage of respondents who responded positively to the aforementioned statement is higher, ie 63%.

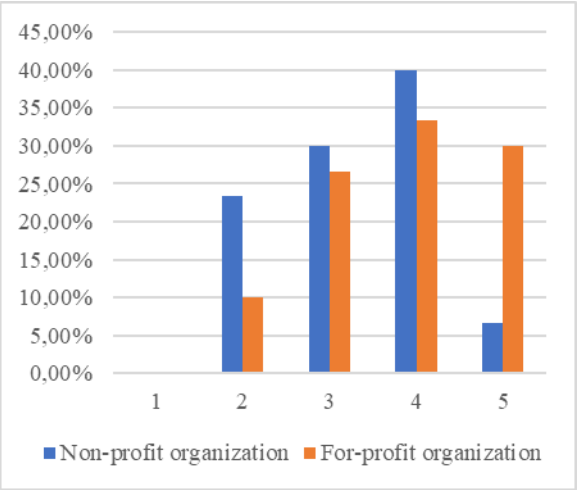

Fig. 4. Do employees accept different views and opinions regarding a possible solution?

Figure 5 shows the stronger influence of the organizational culture of for-profit versus non-profit organizations. This refers to internal communication within the organization, especially horizontal communication.

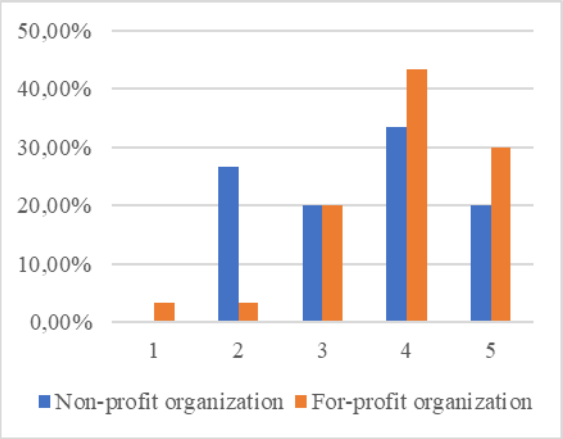

Fig. 5. Are employees always ready to help a co-worker in solving his problem task?

In the segment of non-profit organizations, 20% of respondents stated that they fully agree with the statement that they are always ready to help a co-worker in solving his problem task, while 33% of respondents said that they partially agree with the statement. In the segment of for-profit organizations, 30% of respondents stated that they fully agree with the statement, and 44% of respondents stated that they partially agree with the statement. Employees in their daily work are focused on each other and contribute to the quality of the work environment and personal satisfaction in doing the job.

However, from Figure 6, which shows the employee's perception of communication with a superior employee in order to solve work tasks, in non-profit and for-profit organizations, is evident that 70% of respondents fully agreed with the statement. This could be interpreted with a clear hierarchical relationship of subordinate and superior employees, control of the business process and ultimately work results.

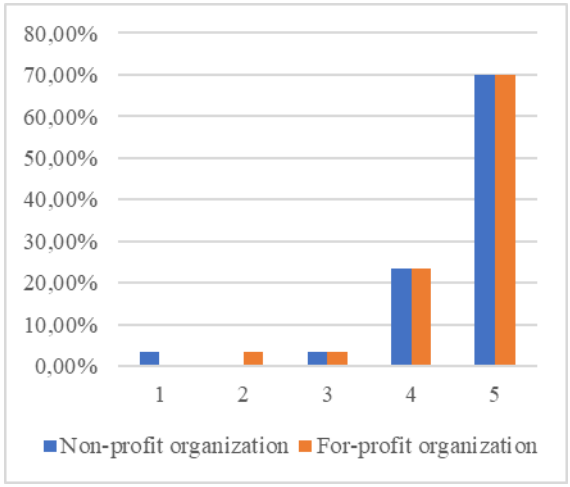

Fig. 6. Do employees, in order to solve work tasks, communicate with his superior employee?

The perception of the respondents of both comparative groups about the readiness of the superior employee to help solve a problem work task is visible in Figure 7. The perception of the employee is almost identical in both groups. 80% of non-profit respondents strongly agree or partially agree with this statement. In for-profit organizations, 81% of respondents are like that. The ability to listen and communicate is a key competence of the manager, as well as in cases of help in solving a problem task.

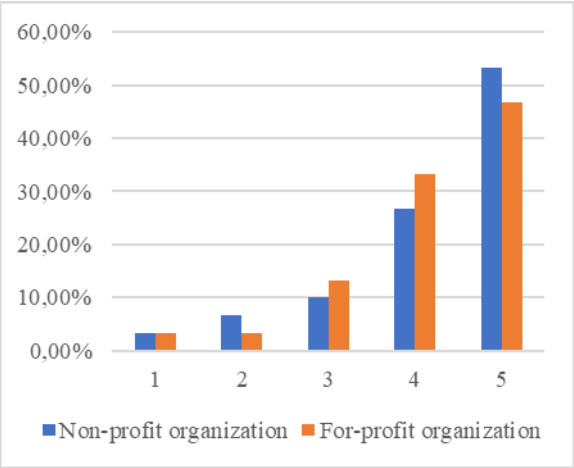

Fig. 7. Is the superior employee always ready to help if a problem arises at work?

Undesirable organizational behaviour refers to activities and behaviours that intentionally and knowingly harm employees and the organization. As a rule, these behaviours negatively affect the organization's operations. The incurred losses are stated in financial values. This is why certain internal rules of conduct are often prescribed in organizations. Figure 8 shows that the intolerance of superior employees to unethical behaviours among respondents in non-profit organizations is 74%, while among respondents in for-profit organizations it is 87%.

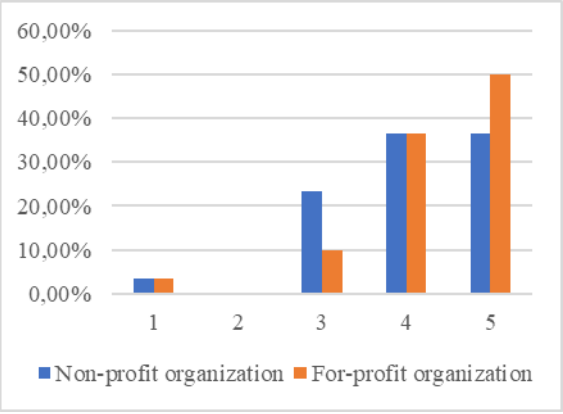

Fig. 8. Is a superior employee intolerant of unethical behaviour?

When claiming that the superior employee always knows the individual contribution of the employee to the work (Figure 9), 74% of respondents belonging to the segment of non-profit organizations responded positively to this statement. Among the respondents from for-profit organizations, 70% of them showed a positive opinion. Individual employee contribution is closely linked to motivation and reward.

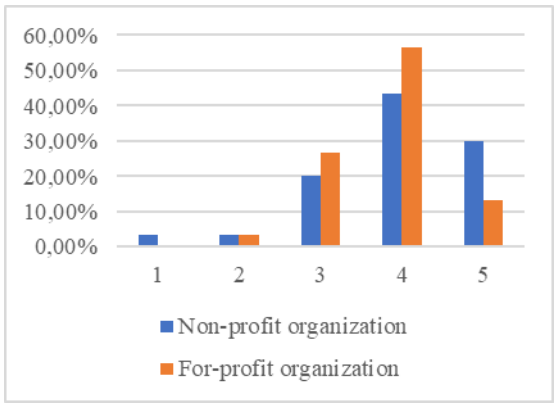

Fig. 9. Does a superior employee always know what the individual contribution of the employee to the work is?

In the statement that the superior employee always emphasizes the individual contribution of employees in the work (Figure 10), 67% of respondents belonging to the segment of non-profit organizations responded positively to this statement. Among the respondents from for-profit organizations, 50% of them showed a positive opinion.

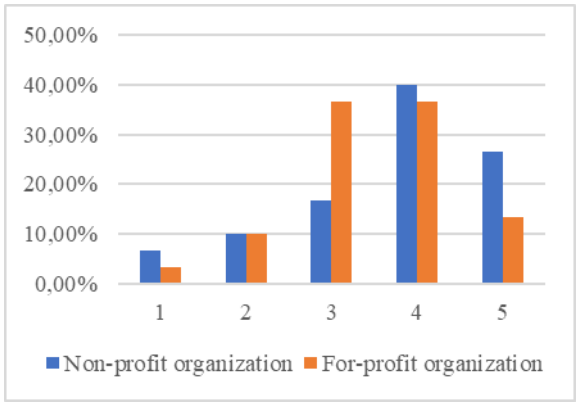

Fig. 10. Does a superior employee always emphasize the individual contribution of the employee?

When claiming that the superior employee respects the suggestions, proposals and opinions

of employees (Figure 11), in the segment of non-profit organizations 30% of respondents said they fully agree with the statement, and 37% of respondents said they partially agree with the statement. In the segment of for-profit organizations, 17% of respondents stated that they fully agree with the statement, and 63% of respondents stated that they partially agree with the statement.

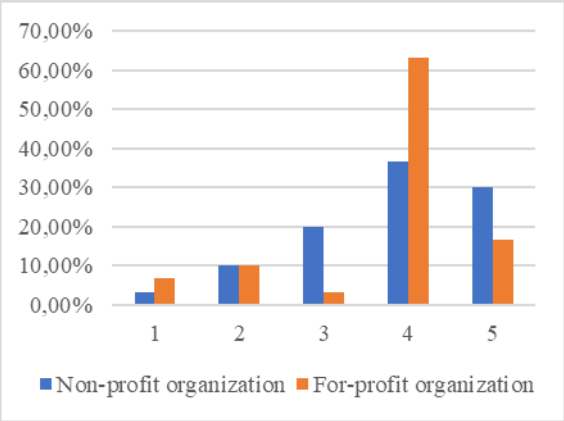

Fig. 11. Does a superior employee respect the suggestions, proposals and opinions of the employees?

When claiming that a superior employee is always ready to listen to personal problems of employees (Figure 12), as many as 70% of respondents belonging to the segment of non-profit organizations were positive, and 66% of respondents in for-profit organizations were positive about that statement.

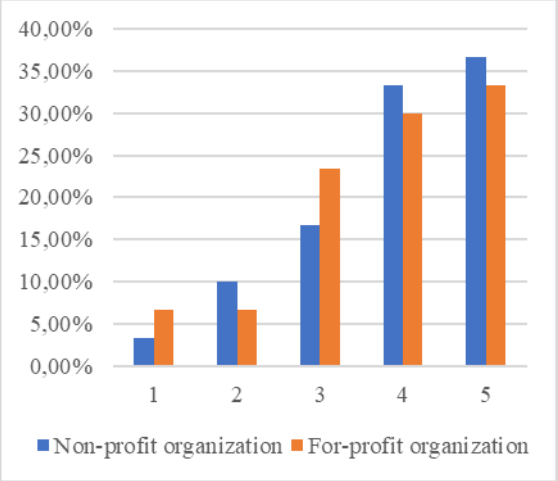

Fig. 12. Is a superior employee always willing to listen to regarding personal problems of employees?

An empathetic manager from time to time engages employees to talk about how they feel, whether they are burdened, what their current challenges are, future plans, and the goals they strive for. This will show that he cares about the employees, and such a relationship affects the quality of further business relationships.

4. CONCLUSIONS

Without good communication skills, it is difficult to achieve quality relationships with colleagues, interdependent hierarchical relationships and relationships with the environment (third parties, customers, etc.).

In order to achieve business results through associates, i.e. employees, the manager must have strong communication skills and has to find models of motivating employees in order to accomplish work tasks together. Managers must have well-developed listening and judgement skills. Only in such circumstances, where a harmonious mutual relationship prevails, a relationship of respect and a proactive focus on work, it is possible to achieve high work efficiency. Such success requires a distinct emotional intelligence of the manager.

Comparative results suggest that horizontal communication is more pronounced in for-profit organizations. In both groups, a high percentage of respondents who responded positively to claims of vertical communication within the organization can be observed.

Furthermore, according to the results in the part related to the claims that the superior employees recognize and emphasize the individual contributions of the employees in both comparative groups, a conclusion can be drawn on the predominant transactional management style.

However, a conclusion was also drawn on the readiness of superior employees to express empathy - empathic listening, which was positively expressed by more than 60% of employees of both comparative groups, even in

a slightly higher percentage in favour of non-profit respondents (70%).

These results showed the participants' perception of some of the characteristics of internal communication (with co-workers and with supervisors) present in their organizations that indicate empathic behaviour. Thus, from the analysis of the results, it could be concluded that the respondents consider empathy in the communication of both organizations to be very important.

The limitation of the present study was the available time for the completion of the questionnaire. As it was an on-line questionnaire, access to it was restricted by time. The result was that some of the participants were unable to complete it within the specified time. Finally, sample size and representativeness are an issue to be addressed.

In addition to the limitations of the study, it is necessary to highlight the importance of conducting further research in order to obtain more valid results such as a larger sample that should be used. Also, it would be interesting to study the extent to which organizational culture affects communication and emotional intelligence.

5. ACKNOWLEDGEMENTS

This paper was derived from the final thesis of a former student of the University of Slavonski Brod, Marina Bogdanić.

6. REFERENCES

[1] P. Salovey, J. D. Mayer, Emotional intelligence. Imagination, Cognition and Personality. (1990) Vol. 9 (3), pp. 185-211

[2] D. Goleman, Emotional intelligence in business (Emocionalna inteligencija u poslu). Mozaik knjiga, Zagreb, (2000).

[3] PSIHOportal - little school of psychology – Lesson 19. EMOTIONAL INTELLIGENCE AT WORK. http://www.psihoportal.com/index.php/hr/psihoportal-mala-skola-psihologije/1598-psihoportal-mala-skola-psihologije-lekcija-19-emocionalna-inteligencija-u-poslu, last access 9/4/2020

[4] D. Goleman, R. Boyatzis, A. Mckee, Primal Leadership: Realizing the Power of Emotional Intelligence. Harvard Business School Press, Boston, MA, (2002).

[5] A. M. Tomulić, T. Grmuša, Empathy in the work environment (Empatija u radnom okruženju). Media, Culture and Public Relations, Zagreb, (2017).

[6] P. Sikavica, T. Hernaus, Designing an organization: Structures, processes, jobs (Dizajniranje organizacije: Strukture, procesi, poslovi). Novi informator, Zagreb, (2011).

[7] D. Gutić, A. Peterschik, Emotional intelligence in management workshop (Praktikum emocionalne inteligencije u menadžmentu). Studio HS Internet, Osijek, (2018).

[8] N. Rupčić, Contemporary Management, Theory and Practice (Suvremeni menadžment, Teorija i praksa). Faculty of Economics University of Rijeka, Rijeka, (2018).

[9] K. Rukavina, Characteristics of non-profit organizations in relation to profitable organizations (Karakteristike neprofitnih i neprofitabilnih organizacija u odnosu na profitne i profitabilne organizacije). Ekonomski vjesnik: Review of Contemporary Entrepreneurship, Business, and Economic Issues, Vol. VII No. 1 (1994), pp. 85-90

Analysis of innovativeness: Case study - Croatian, Hungarian and Slovak companies

M. Martinović [a],

[a] University of Slavonski Brod, Trg Ivane Brlić Mažuranić 2, 35000, Croatia, mmartinovic@unisb.hr

Abstract

The paper analyzes the structure and relation between the innovation activities undertaken and the types of innovation outputs developed by Croatian, Hungarian and Slovak companies. The research was conducted using the *Community Innovation Survey* database for all three mentioned countries. *Spearman's rank* correlation analysis between innovation activities and degree of innovativeness was performed and *one-way ANOVA* analysis of variance was used to compare the means for the different levels of innovation activities. The results show positive and statistically significant correlation coefficients for all three samples with different levels of innovation performance among SMEs. These differences indicate the potential efficiency of each innovation activity in the above economies and point to possible directions for further research.

Keywords: Innovation, CIS, Croatia, Slovakia, Hungary

1. INTRODUCTION

One of the key components of economic growth that plays an important role in today's economy is innovation.

A large number of developed countries in the world have already recognized the important role that innovation plays and have integrated innovation into the core of their economic policies. The countries that are recognized as leaders in innovation are also the countries with the most developed economies.

Achieving a high level in the global innovation chain is a difficult journey. For a country to successfully position itself at a high level in the global innovation chain, it must constantly promote the development and progress of the innovation ecosystem. This can be achieved by setting the right and timely economic policies along with their activities.

The key role of national economies in developing and supporting innovation is to create all the conditions for the development of innovation and build an innovation ecosystem that serves, promotes and stimulates innovation. They also need to implement comprehensive structural reforms that enable commercially successful innovations to find a channel for their emergence.

One of the basic indicators of the innovation performance of an economy is the entrepreneurship's innovative capacity of the corresponding economy.

There is no single approach to determining the innovativeness of the economy. This paper refers to the metric of the European Innovation Success Scale (EIS) [1]. The scale divides countries into four groups: Innovation Leaders, Strong Innovators, Moderate Innovators, and Emerging Innovators. The main indicator of innovation performance is the corresponding index (*Summary Innovation Index*), which consists of, among others, innovation indicators for small and medium-sized enterprises. The indicators refer to the number of developed innovations, investments in research and development or similar.

These indicators at the micro level, i.e., the company level, are taken from the CIS (Community Innovation Survey) database [2], which serves as the basis for the reference research.

The research in this paper was conducted at the micro level, i.e., the firm level. The indicators that can be obtained from the CIS sample are the

percentage of innovative companies and the degree of innovativeness, which will be explained later.

1.2. Research question

The paper poses two research questions. The first one is related to the identification of the relationship between innovation activities and innovation output of companies, and the second one is related to the evidence of the difference in innovation performance between Croatian, Hungarian and Slovak SMEs.

H1: A greater number of innovation activities related to the promotion of innovation is associated with a higher degree of innovativeness.

H2: Croatia, Hungary and Slovakia have different innovation performance regarding to the degree of innovativeness.

1.2. Previous research

In previous analysis and research presented in numerous papers, the authors show that there is a clear relationship between innovation and R&D, marketing/design and many others activities [3][4][5].

Some of mentioned activities are part of this study. The aim of research is to identify whether relationship between innovation activities and innovation performance exist within the Croatian, Hungarian and Slovak SMEs and what are related correlation coefficients.

The result can be seen in the potential impact *(not only in the relationship*), because the activities were undertaken with the aim of creating new innovations.

Furthermore in the paper, an analysis of the performance of the EIS (*European Innovation Scoreboard*) index for Croatia, Hungary and Slovakia is made, sample is defined and the methodology is presented. Also, the basic model with input and output variables is presented. Then, an analysis of the structure of input and output variables was performed, i.e. the share of innovation activities and share of innovation types in sample, etc. The results of the model are shown and a comparison of performance for each country is made. Finally, conclusions are point out with a discussion of the results.

1.3. EIS innovation performance of Croatia, Hungary and Slovakia

Key indicators for the *European Innovation Scoreboard* are 12 innovation dimensions in which a country has to make progress in order to achieve a higher level in innovation (Human resources, Attractive research systems, Digitalisation, Firm investments, Finance and support, Use of information technologies, Innovators, Linkages, Intellectual assets, Employment impacts, Sales impact and Environmental sustainability) [7].

All this innovation dimensions are consisted of a few indicators that are measurable and data is assured. For example, innovation dimension Firm investment consists of expenditures on R&D, non-R&D innovation expenditures and innovation expenditure per employee, Finance and support consists of venture capital expenditures, R&D expenditures, government support for business R&D etc.

Each of this group is scored and a comparison with the EU average is given. Therefore, a country can benchmark itself with other countries and find out in which field has to make improvements to be more innovative.

On the scoreboard, all three countries are scored as Emerging Innovators (Croatia 78, Hungary 76 and Slovakia 71) but with different strengths and weaknesses. For example, Hungary has strengths in digitalisation, sales impacts and linkages, Slovakia has strengths in sales impact, use of information technologies and environmental sustainability and Croatia has strengths in linkages, use of information technologies and innovators[8].

If used wisely this can be a powerful tool for countries to assess some areas in which they would need to focus their time and money to improve innovation performance. It is also a good tool to benchmark itself against other countries (this scoreboard is for EU countries and non-EU countries as well).

2. METHODS AND MATERIALS USED FOR RESEARCH

2.1. Data

Analysed data for all three countries is from the *Community Innovation Survey* project. The CIS survey was first conducted in 1992 and it has been conducted regularly every two years since 1998 [2].

The data available for this research are from the *CIS2014* report, while the *CIS2016* and *CIS2018* databases were published afterwards.

The sample size is: Croatia 10,164, Hungary 13,648 and Slovakia 9,022 companies.

Within the sample there are weighted datasets of companies stratified by size and sector. Although CIS research is focused on innovative companies, there is also records for all other companies. The percentage of innovative companies in the sample is 35% for Croatia, 27% for Hungary and 29% for Slovakia.

2.2. Methods

Central hypothesis ***H1*** tests relationship between innovation input and model outputs. The input and output variables are of ordinal type. Because of that *Spearman's Rank* correlation analysis is used which is better fit than *Pearson* analysis.

Chi-square test was performed to determine if there are statistically significant differences between share of each innovation activity.

Finally, the comparison of means was performed by *One-way ANOVA* test. Differences in innovation performance between independent samples (countries) were tested.

Although the sample data have some limitations (the variance between samples is not completely uniform), the choice of using ANOVA test is preferable because it uses the averages instead of medians.

2.3. Model

The basic model is shown in *Figure 1*. The input variables of the model are different types of innovation activities that can take the value zero or one. In other words, they contain information about whether or not the firm has undertaken a particular activity.

Spearman's Rank correlation analysis was performed in two ways. First, an analysis of the correlation between the input variables was performed (each variable separately is compared with output) and then a correlation was made between their sum and the output. In that case, the input variable is called "*activities level"* and it can take a value from 1 to 8 - depending on the total number of activities which the company has undertaken.

The analysis was performed separately for each sample - for Croatia, Hungary and Slovakia.

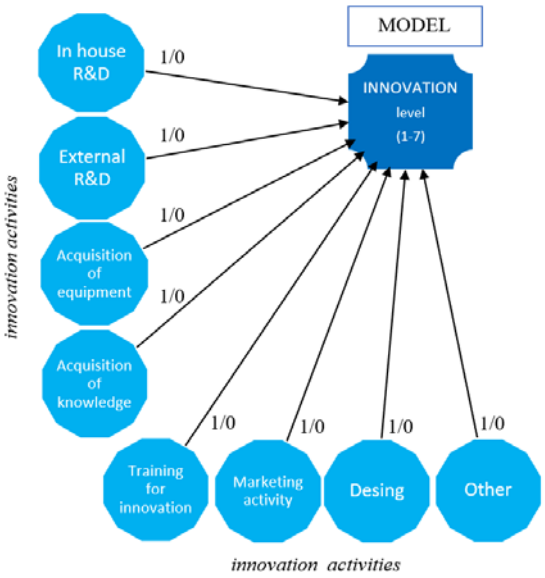

Fig. 1. Model

The structure of the output variable: *"degree of innovativeness*" is shown in *Figure 2.* The output of the model is a variable called *"degree of innovativeness"* and it indicates the total sum of all types of innovations developed by a company in the observed period.

A company is considered innovative if it has developed any of the mentioned innovations (either the innovation is still under development or it has been abandoned). The degree of innovativeness can take value between 1 (a company has developed one type of innovation) and 7 (a company has showed all seven forms of innovation).

Fig. 2. Innovation types

2.4. Analysis of innovation activities

Figure 3. shows the shares and structure of innovation activities for Croatian, Hungarian and Slovak SMEs.

The share indicates the presence of individual innovation activities within the subsample of innovative companies. The subsample includes those innovative companies that have undertaken at least one of the innovation activities.

The chart shows that the structure and distribution of the innovation activities is similar across the countries. With equipment/machinery acquisition activities dominating. Activities of external research and development (*external-R&D*) are the least represented in all three samples.

Greater deviations can be noticed in training activities (*Training for innovation*), where Croatia stands out, as well as for activities of equipment acquisition. Hungarian SMEs have strong component of in-house research and development activities (in-house R&D).

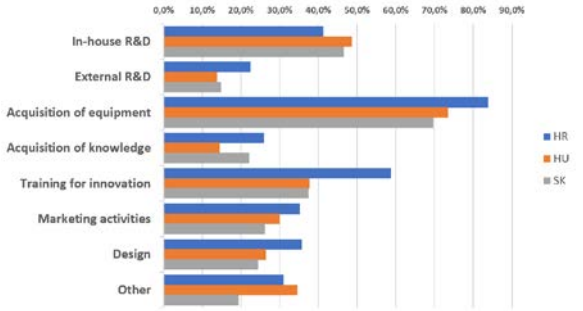

Fig. 3. Share of innovation activities

Although there are similarities in the structure of the innovation activity representation, all components are statistically significantly different. *Chi-square* test for independence is used and a statistically significant difference was found between all subsets:

HR ↔ HU, *Chi-Square = 33.41, df=7, p< 0.001*
HR ↔ SK, *Chi-Square = 35.13, df=7, p< 0.001*
HU ↔ HK, *Chi-Square = 15.70, df=7, p< 0.05*

2.5. Analysis of innovation types

A company may develop one or more forms of innovation. According to OECD [6], a company can be defined as innovative if it has developed one or more types of innovation (*product innovation, service innovation, process innovation, marketing innovation, organisational innovation*) in a given period of time.

In addition, a company is deemed innovative if it is currently developing an innovation but has not yet brought it to market (*ongoing innovation*). Even if the company has developed but at the end rejected the innovation it is still considered innovative (*abandoned innovation*).

Figure 4. shows an analysis of all defined types of innovation for Croatian, Hungarian and Slovak SMEs.

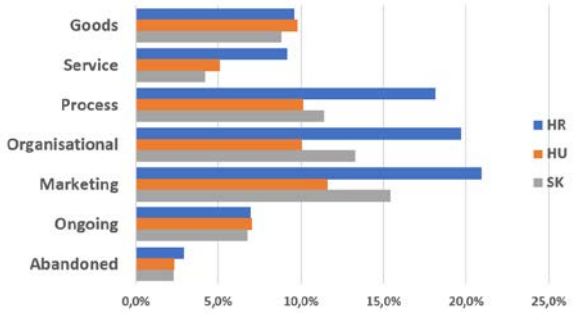

Fig. 4. Share of innovation types.

Figure 4. shows that, on average, Croatian companies have a slightly higher share of innovations with a notable deviation in process, organisational and marketing components.

Using the *Chi-square* test for independence, a statistically significant difference was found between the structure of Croatian and Hungarian innovation types and between Croatian and Slovak innovation types, while no statistically significant difference was found between Hungary and Slovakia.

HR ↔ HU, *Chi-Square = 26.28, df=6, p< 0.001*
HR ↔ SK, *Chi-Square = 15.05, df=6, p< 0.05*
HU ↔ HK, *Chi-Square = 2.17, df=6, p= 0.9*

3. RESULTS AND ACHIEVEMENTS

3.1. Correlation analysis

The input and output variables are defined according to the previously model (*Figure 1*). The input variables are binomial type, while the output (*degree of innovativeness*) of the model is presented as an ordinal variable. This output variable indicates the total number of different forms of innovation for a given company (the sum of the corresponding types of innovation).

Two types of correlation analyses were performed, the first between individual innovation activities and the degree of innovativeness, the second correlation analysis refers to the relationship between the sum of the

activities ("*activities level*") and the degree of innovativeness.

The results of the first correlation analysis for all three models (three samples) are shown in *Figure 5.*

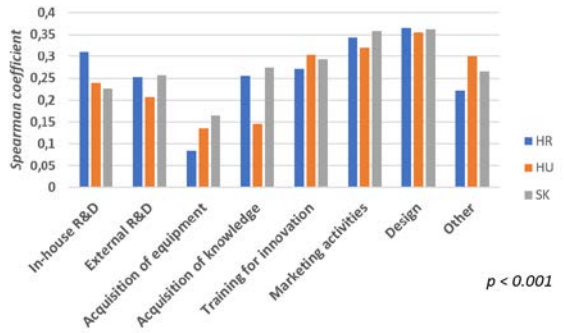

Fig 5. Spearman's Rank correlation - individual activities vs. degree of innovativeness

The figure shows the individual innovation activities and the corresponding correlation coefficients regard to innovation performance (*degree of innovativeness*). The correlation coefficients refer to innovative SME companies from Croatia, Hungary and Slovakia. All results are statistically significant.

It can be observed for all three submodels that innovation activities that are most strongly associated with output innovation are design activities, innovation marketing activities and training for innovation activities. On the other hand, activities of equipment and machinery acquisition have the lowest correlation values, regardless they are the most represented activities in the sample. In-house research and development activities also play an important role.

An alternative correlation analysis tests the relationship between the input variable "*activities level*" and the output variable "*degree of innovativeness*" Using *Spearman's Rank* correlation analysis, a statistically significant relationship ($p < 0.001$) was identified between the intensity of innovation activities and the degree of innovativeness for Croatian, Hungarian and Slovak SMEs. The values of the correlation coefficients are shown in *Table 1.*

The correlation coefficients are almost identical for all samples - around 0.5 - which represent moderate positive correlation. Thus, hypothesis *H1* has been accepted and relationship between entrepreneurial innovation activities and company's innovation output performance has been proven for SMEs of all three economies.

Table. 1. Spearman's Rank correlation

	HR		**HU**		**SK**	
level of activities (vs).	R	t	R	t	R	t
degree of innovativeness	**0.48**	26.0	**0.49**	27.9	**0.49**	22.7

3.2. Innovation performance

Hypothesis H2 addresses the question of whether there are differences in innovation performance among the reference countries by degree of innovativeness.

It has already been established that the share of innovative companies varies somewhat across the samples. For Croatia, this share is 35%, for Hungary 27% and for Slovakia 29%. However, the share of innovative companies indicates that companies have developed a certain form of innovation (or still developing it or have rejected it), but it does not tell us anything about the degree of innovativeness, i.e. how many different forms of innovation they have been created on average.

Univariate analysis of variance (*One-Way ANOVA)* for independent samples was used to test the differences in the degree of innovativeness for Croatian, Hungarian and Slovak SMEs and a statistically significant difference between them has been identified ($F = 126.74$, $p < 0.001$).

Additionally, *Scheffe post-hoc* statistical test is used for multiple comparisons and results are presented in *Table 2.*

Table 2. Scheffe post-hoc

	Scheffe Test; Variable: INO-BR (Spreadsheet61) Marked differences are significant at p < ,05000		
Country	{1} M=3,1625	{2} M=2,4877	{3} M=2,6745
HR {1}		0,0000	0,0000
HU {2}	0,0000		0,0004
SK {3}	0,0000	0,0004	

The *Scheffe* test identify a statistically significant difference between all the groups, although the difference in the degree of innovativeness between Hungary and Slovakia is slightly smaller in absolute terms than the difference between Croatia. Thus, the hypothesis *H2* has been confirmed.

From the results it can be concluded that Croatian companies in average have the highest

degree of innovativeness as well as highest share of innovative companies in the sample.

4. CONCLUSIONS

The research proves the importance and strength of innovation activities and their relation with the innovation output of the company. At the same time, the difference in innovation performance between Croatian, Hungarian and Slovak companies was identified and quantified.

The correlation analysis of input factors identified the most important innovation-related activities, such as marketing, design and internal R&D activities.

In addition, the structure of the representation of individual activities was pointed out, showing dominance of activities regard to equipment and machinery acquisition. Although, those actives are the least related (by models) to innovation performance.

A similar distribution of activities can be observed in other countries. For example, in the United Kingdom, where equipment acquisition activities are also very dominant, while R&D activities and training for innovation activities are moderately represented [9][10].

The study has also shown that the structure of input innovation activities as well as the output types of innovations are similar between SMEs among countries. However, statistically difference was found only between Slovakia and Hungary regard to innovation types representation.

Although, on average, Croatian SMEs have a slightly better innovation performance among the three observed economies, it is good to point out again that according to the *European Innovation Ranking* (EIS) report, all three countries are ranked in the lowest group of innovators (out of four possible) : "*emerging innovator*" [8].

Future research could go in the direction of identifying the strength of relations between innovation activities and a particular type of innovation. Rather than using information on the presence or absence of particular activities, perhaps models that include monetary expenditures on particular activities would be somewhat more accurate.

5. REFERENCES

[1] European Innovation Scoreboard: Innovation performance keeps improving in EU Member States and regions, Eurostat European Commission, https://ec.europa.eu/commission/presscorner/detail/en/IP_21_3048, last access 7/14/2022.

[2] Community Innovation Survey (CIS), Eurostat European Commission, https://ec.europa.eu/eurostat/web/microdata/community-innovation-survey, last access 7/14/2022

[3] R. Freeman, Quantitative methods in R&D management. California Management Review 2(4) (1960), pp.36-44

[4] T. Levitt, Growth and profits through planned marketing innovation. Journal of Marketing 24(4) (1960), pp.1-8

[5] N. Rosenberg; R. Nathan, Inside the black box: technology and economics. Cambridge University Press, New York, (1982).

[6] Oslo Manual - Guidelines for Collecting, Reporting and Using Data on Innovation, 4th Edition, Organisation for Economic, Co-operation and Development (OECD), https://www.oecd.org/science/oslo-manual-2018-9789264304604-en.htm, last access 7/14/2022

[7] European Innovation Scoreboard: Innovation performance keeps improving in EU Member States and regions, Eurostat European Commission, https://ec.europa.eu/commission/presscorner/api/files/document/print/en/ip_21_3048/IP_21_3048_EN.pdf, last access 7/14/2022

[8] European Innovation Scoreboard 2021, Eurostat European Commission, https://ec.europa.eu/info/research-and-innovation/statistics/performance-indicators/european-innovation-scoreboard_hr, last access 14/7/2022

[9] S. Robson, G. Haigh, First findings from the UK Innovation Survey 2007. Economic & Labour Market Review (2008), pp. 47-53

[10] S. Robson, M. Kenchatt, First findings from the UK Innovation Survey 2009. Economic & Labour Market Review (2010), pp. 28-35

Validation of segmentation spraying from UAV in Serbia

Arpad Pletikosić [a], Laslo Tarjan[b]

[a] Faculty of Technical Sciences, University of Novi Sad, Trg Dositeja Obradovića 6, 21000 Novi Sad, arpad.pletikosic@uns.ac.rs

[b] Faculty of Technical Sciences, University of Novi Sad, Trg Dositeja Obradovića 6, 21000 Novi Sad, laci@uns.ac.rs

Abstract

The era of 4th agricultural revolution gave a good spot for Machine Intelligence (MI) aided computing systems for implementation in the field agriculture. The users of these technologies are more and more interested and ready to invest in them. Nowadays counting plants, predicting yield, recognizing several diseases are common tasks for a UAV combined with MI, but they are exclusively retrospective methods. If a disease is recognized in advance, the spread of it can be reduced. This requires a satellite monitoring system, and also a drone fleet, with advanced controlling system. A good summary of a possible real life application will be described. With fast sampling cameras, onboard microcontrollers, and new algorithms, the spraying from a UAV can be further improved. With this new implementation, the problem of short weather windows of treatments can be solved. Also, the follow-up data processing can be skipped from the equation, which is very time-consuming. Emphasis will be on the interest of farmers for the new technology. To change the way we are thinking is a great challenge for the researchers. The current state of this change in Serbia will be described in the paper.

Keywords: UAV, real-time application, spraying, Serbia, questionnaire.

1. INTRODUCTION

One of the most significant trends of modern agriculture is the reduction of the negative environmental impacts. Today's research proves that the consumption of the total drinking water is most consumed for agricultural purposes [1]. Also, one of the largest pollutants also the agricultural industry, because the machinery that are working in this area are spending fuel, and thus pollute the environment. Modern machines seeking for methods for the tractor to be as little time on the field as possible to consume as little fuel as they can. It is without a doubt one of the best tendencies ever appeared in this area.

Unfortunately, every innovative idea that brings economic benefits to the farmers, comes with a price. And if some solutions are very good and makes a lot of savings economically speaking, often requires a lot of financial investment that agricultural farm could begin to use those solutions. Modern spraying machines are for example divided into several segments, which can be turned on and off depending on the need, but this also requires such a tractor, which has a computer that is able to manipulate these segments. So in very frequent situations is not enough to buy only tools, but the renewal of the existing machinery needed. Due to such financial difficulties, there is a need for new technologies that can bring such a change in agriculture, which will also be economically and environmentally cost-effective.

The quantity of pesticides, herbicides and fungicides is also very huge, so any solution that could reduce its usage would be welcomed in this filed, and in the meantime the quality and the quantity of the grown crops would stay the same, or increased. The collective protection of an area is a good option, but hard to implement because many fields are divided into smaller parcels, and hard to convince a farmer to cooperate with the others.

In the following of this paper a collective plant protection technic will be discussed, starting with the explanation some of the phrases the reader need to be familiar with to fully understand the aim of the paper.

2. SELECTIVE SPRAYING

The need for selective spraying is huge. There are several stages of the development of the precision agriculture, especially in spraying methods [2]. Several computer visions aided decision-making algorithms are helping to work in different crops [3]

In current farming in Serbia, chemicals are sprayed uniformly across the whole field. In most of the time, the treatments are executed on the basis of spraying calendar. The experts are less frequently connected to the direct decisions. That is the same appearance of the situation in viticulture and also in field agriculture.

Recognized that the unattended number of treatments play a major role in environmental pressure and production costs on the farms. No less important that these interventions have a direct impact on the quality of food produced via agriculture. The demand for a newer, and more precise spraying method is adequate. With a site specific spraying unit, diseases can be located, treated, and their spread can be stopped. By making that, enormous quantity of chemicals can be preserved [4].

2.1. Implementation on a UAV

By making the spraying from an unmanned aerial vehicle, several benefits can be achieved:

- less water usage
- with vortex effect, the coverage from the bottom of the leaf is increased
- increased yield thanks to deficit of the tramlines [5].

By mapping the area, several treatment maps are available for modern UAV's, such as Fig. 1. By applying these maps point-of-interests, different concentrations and site specific actions can be achieved. These maps are mainly post processed, so that the decision-making algorithm can take its time to decide the best [6].

After making a map, several new missions can be planned for more deep observations. We can conclude that mapping a big geographical area consists of more maps, with more level of detains in them. The first level of maps are mainly used to create an overall picture of the covered territory. They can be gathered from drone, or from satellite imagery. If an anomaly is detected, a new mission can be created to gather a more precise, and more detailed map from the problematic area. This second level of imagery can be further used for generating new maps to take actions on the site Fig 4 [7].

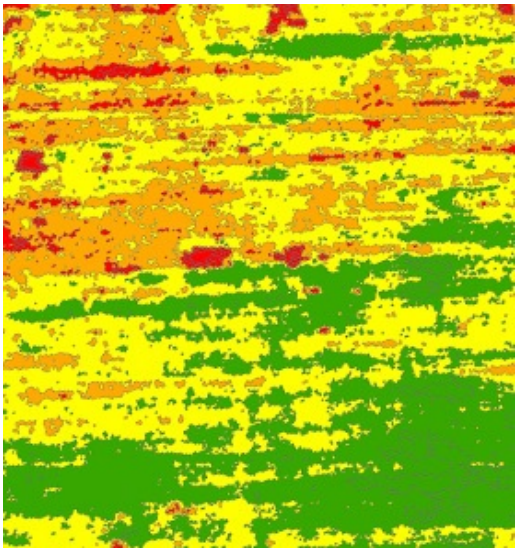

Fig. 1. Generated map for variable rate application. The dose of the active substance on the red zones are the highest and in proportion decreasing to a minimum recommended concentration which is represented with green color

The control of an active drone consists of two main elements, the ground unit and the drone itself. The drone and the ground unit are gathering data from satellites. The number of active connection depends on the weather conditions, on the interference from outer source, and from the geographical position. By adding

another ground station, the absolute positioning system can be further improved.

The number of active connections with the satellites, and the resolution of the positioning system, have a great impact on the final result of a variable rate application. If the actual position of the flying unit is adequately declared on the map, the data on the same spot can be read. That data can influence the flow across the nozzle of the drone.

The flow rate can be variated with several methods. One of the methods is if the variable map is compatible with the flight controller in the drone, the internal parameters can be set. This leads to an accurate flow control, but the number of drones which support such a map is very small. Maybe one of the main competitor is the DJI`s newest unit, the T30. It is a six winged unit with two or four nozzles on each wing. They are controlled from an internal valve system. The integrated map reading system automatically reads the data from a variable map. On the other hand, if any of the jobs before the spraying is not carried out from any also DJI unit, the map can not be imported.

The other method is more inaccurate, and a little more energy consuming, but has a much wider specter of applicability. If the flow rate control unit stays untouched, a separate valve system could be mounted on the drone. The solenoids can be placed between the pumps and the nozzles, so the whole applied liquid would flow across them. If the position is known, the data gathering would be the same, but a separate controlling unit could process the flow data. According to the processing unit, the valves can be partially open, close, or fully open or close. That system would require lesser level of autonomy from the drone, but required additional expertise.

3. SURVEY ON THE TERRITORY OF AUTONOMOUS PROVINCE OF VOJVODINA

After taking a short review of the technology, it is time to review the results of the survey made on the territory of Vojvodina.

By making a new technology able to survive, it needs to be verified via the needs of the market. This year we have held series of seminars for the farmers about innovative technologies. The main theme was precision agriculture.

The farmers were told to fill in a short survey after the seminars, so we could gather some information about the market. These presentations were held in several locations by name Senta, Bačka Topola and Bečej, Autonomous province of Vojvodina, Serbia. I distinguished three main categories depending on the size of their cultivated fields, Fig. 2. These farmland sizes are defined by the average field size in Vojvodina. About 70% of population'slife depends on some way from the agriculture. Also, Vojvodina has about 1.6 million hectare of field agriculture [8]. Statistic data shows that an average farmer has about 6,2 hectares. Because of that, I decided to separate the farmers in the following three categories

- farmers who have less than 20 hectares
- farmers who have between 20 and 50 hectares
- and farmers who have more than 50 hectare overall cultivated area.

After that, they were asked if they're already using GPS system. In the following, this question will be of higher interest.

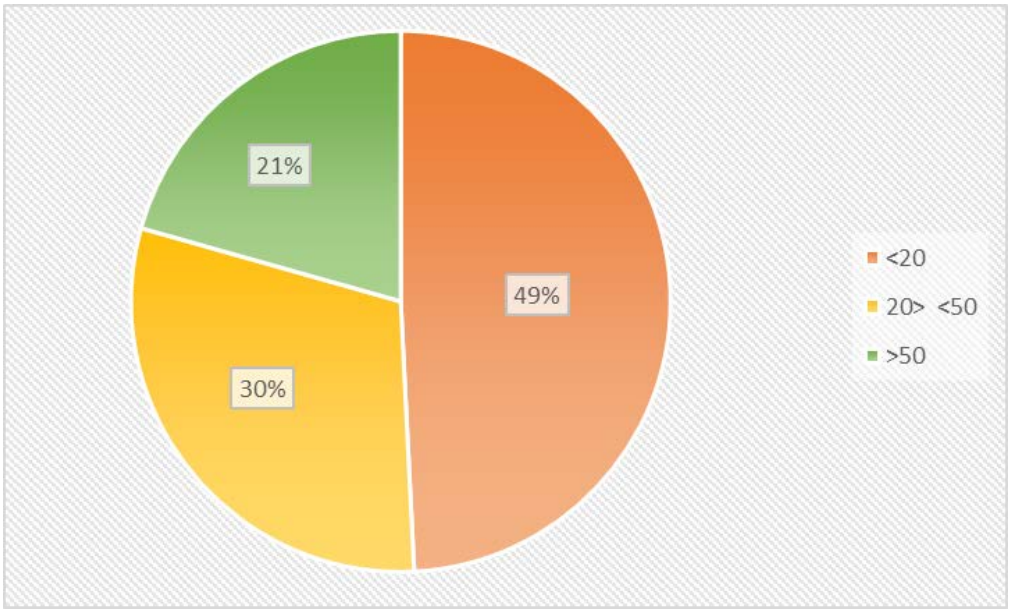

Fig. 2. Proportion of farmers depending on the size of cultivated area, expressed in hectares

From the Fig. 2 we can conclude that the small size farmers were present in overwhelming majority.

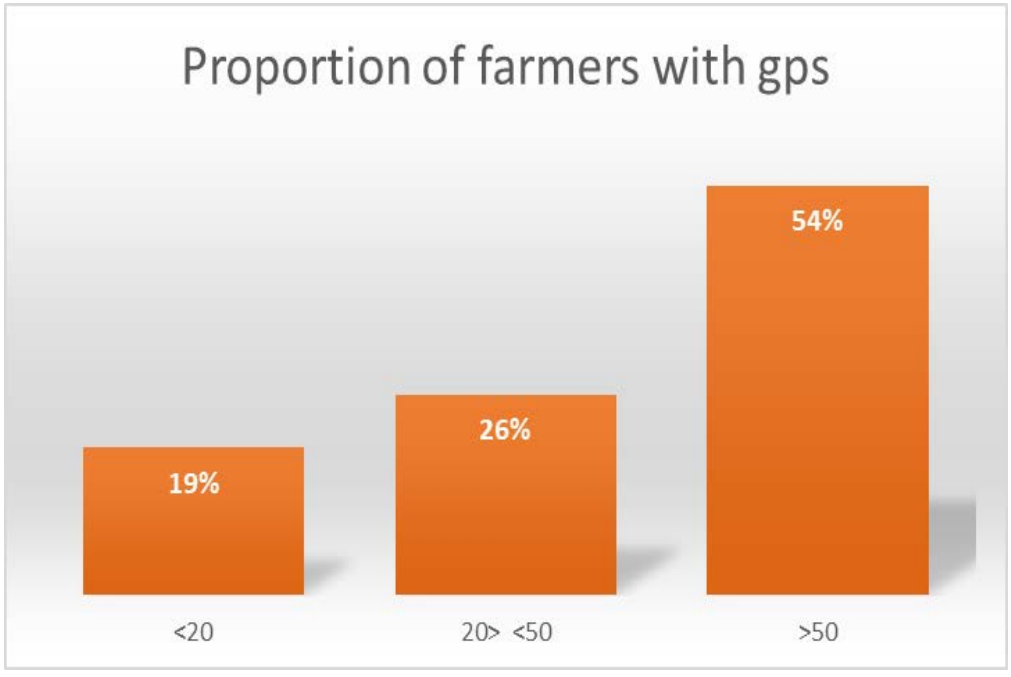

Fig. 3. Proportion of farmers according to their size, who owns a tractor equipped with GPS system

On the Fig. 3 some expected numbers can be noticed. If a farm is bigger, cultivates larger area, it can of course produce higher profit. Also with the growth of the cultivated area, the level of automation also increases. This is very clearly presented on this graph.

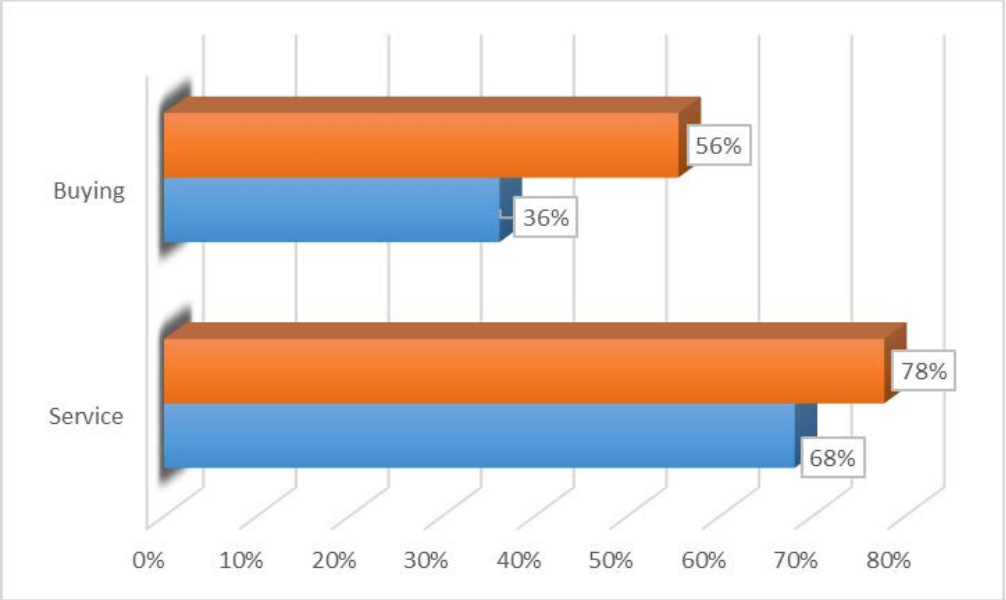

Fig. 4. Blue columns show the proportion of farmers who would like to buy or to use drone services from the whole group. Orange columns show the proportion of farmers who has GPS and interested in buying or in service

The last graph, Fig. 4 is the most vital part of the survey, and it requires a little more attention. First, the blue columns that show the overall interest in buying and use drone services. The question was asked if they are interested in multispectral drone analysis on their own field or in spraying with drones. We can conclude that most of the farmers are interested in drone services, and a smaller portion of them would possibly buy a unit for their own purposes. We know from the Fig 2 that a higher number of small sized farmers were present, so they would likely not to separate that amount of their profit for a new unit. But if we assume that the people that are already started to integrate innovative technology in their farm, like GPS which is definitely the base of all precision farming, it would be useful to analyze the correlation between the interests of these farmers towards the earlier mentioned categories. The orange columns give the correlation between the number of farmers already owning a GPS and the interest to buying or to use services. The numbers are much more impressive. More than 50% of the farmers would like to buy a spraying or a multispectral drone for their own farm, and almost 80% of them would like to use these services in real environments.

4. CONCLUSIONS

The initial aim of the precision agriculture is to reduce the expenses and to optimize the farming. By using enhanced GPS technologies, by gathering data from new specters and by taking actions depending on the previous the main goal of this segment of agriculture 4.0 can be achieved. If an adequate amount of input data is collected from the field, selective spraying can reduce the total amount of pesticide and herbicide consumption. Also by reduced fly time the carbon dioxide emission is also restrained.

On the territory of Autonomous province of Vojvodina the effect of these methods could be very warmly welcomed. The foundations for helping organic farms, the area-based support per hectare are so small, that an innovation that can live on here are boldly welcomed in any county worldwide. The survey shows that people are ready for new challenges, and for new machinery on their farmlands. Also, the survey's results show a good picture of the portion of farmers interested in types of integration of drone technologies. We can see that a big amount of respondents are much more likely to test them first. Also, that if someone started his way into

renew its machinery, it is most likely to invest in his own drones.

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5. REFERENCES

[1] R. Stefanie: Agricultural green and blue water consumption and its influence on the global water system, *Water resources research,* vol. 44, no. 9, (2008)

[2] N. Zhang, M. Wang, N. Wang.: Precision agriculture - A worldwide overview, Computers and Electronics in Agriculture, volume 36(2-3) pages 113-132 (November 2002)

[3] A. Tellaeche, X. P. BurgosArtizzu: A new vision-based approach to differential spraying in precision agriculture, Computers and electronics in agriculture, Volume 60, pages 144–155 (2008)

[4] R Oberti, M Marchi, P Tirelli, A Calcante: Selective spraying of grapevine's diseases by a modular agricultural robot, Journal of Agricultural Engineering, ; volume 44(s2):e29 (2013)

[5] M. Shahrooz, A. Takaeizedeh: Agricultural Spraying Drones: Advantages and Disadvantages, Virtual Symposium in Plant Omics Sciences (OMICAS), 23-27 Nov. 2020 (2020)

[6] A. Hafeez, M. A. Husain: Implementation of drone technology for farm monitoring & pesticide spraying: A review, Information Processing in Agriculture, volume 9, Issue 2 (2022)

[7] I. Suroso: Analysis of Mapping Area of Flood With Drone Type Multicopter in Girimulyo, Kulonprogo, IOP Conf. Series: Earth and Environmental Science. volume 271 (2019)

[8] Provincial assembly, http://demo.paragraf.rs/demo/combined/Old/t/t2015_01/t01_0116.htm, last accessed: 18.02.2022.

Visitor Risk Management in Medvednica Nature Park

M. Popijač [a], S. Wolf Kramarić [a], M. Jurjević Varga [a], S. Zec [b]

[a] Public Institution Nature Park Medvednica, Bliznec 70, 10000 Zagreb, Croatia,
marina.popijac@pp-medvednica.hr
sandra.wolf.kramaric@pp-medvednica.hr
martina.j.varga@pp-medvednica.hr
[b] Croatian Chamber of Forestry and Wood Technology Engineers, Prilaz Gjure Deželića 63, 10000 Zagreb, Croatia, silvija.zec@hkisdt.hr

Abstract

The most common forms of using Medvednica Nature Park (Medvednica NP) are sport and recreation and enjoying nature. Public Institution Nature Park Medvednica (PI NPM) manages a total of 17.938 ha and has over 1.000.000 visitors a year. Due to such a large number of visits and the diversity of visiting interests, PI NPM is faced with a number of issues related to visitor management, which includes maintaining high standards of visitors' safety. Visitation itself, and especially some forms of recreation, have their hidden dangers, moreover for most recreational activities risk and challenges are their feature and integral part. Besides recreational activities, a large risk for visitors presents natural disasters caused by climate change, but also different human diseases like COVID-19 diseases, and wildlife diseases that can consequently endanger human health (zoonoses). Most risks are inherent risks that cannot be prevented due to a number of uncontrolled factors. A new type of risk emerged with the opening of the central visitation point, Medvedgrad Visitor Center, given that a larger group of people gathers in one place, which opens up new risk opportunities. The majority of visitors are prone to use drones without authorization, because of their easy commercial availability and relatively low prices. In such conditions, there is a high danger of using drones over a large group of people outdoors, which could fall and injure the group, but neither can the possibility of their misuse for terrorist purposes cannot be excluded.

In order to adapt to the new conditions of protected area management, increased awareness of danger in Medvednic NP is being advanced, which indicates the need to manage visits and recreational activities by launching a modern concept of visitor risk management.

Keywords: management, visitors, danger, risk, diseases, nature park.

1. INTRODUCTION

The main potential of the Republic of Croatia is the beauty of the landscape and preserved nature and environment (PI MNP, 2020). More than 10% of the territory of our country is covered by national parks and nature parks. Sustainable tourism is encouraged and developed in protected areas at all levels. Medvednica NP , as a protected area, is extremely important for its surroundings due to its ecological, aesthetic, health and tourist values. It stands out as a separate mountain massif with a length of 42 km and extends over the territory of the City of Zagreb, Krapina-Zagorje and Zagreb counties, at an altitude of 120 to 1,035 meters being the highest peak named Sljeme (Figure 1). Medvednica is mostly covered by well-preserved forests with numerous important and endemic plant species and different fauna. Medvednica is also intertwined with numerous streams and springs. Medvednica NP is also part of the Natura 2000 ecological network.

Medvednica NP is managed by a Public institution based on the Founding Decree, (NN 118/98). In addition to collecting data for the purpose of monitoring the state of nature conservation, the activity of the Public Institution includes the protection, maintenance and promotion of the Park in order to protect and preserve the originality of nature, and to ensure the smooth development of natural processes and sustainable use of natural resources according to the Statute of PI NPM, (2014).

Fig. 1. Medvednica NP administrative location; Source:PI NPM

2. VISITOR MANAGEMENT OF MEDVEDNICA NATURE PARK

In order to ensure the long-term preservation of natural values, zoning is the basic tool in planning the management of the Park. Medvednica NP is divided into limited spatial units, or zones, in order to preserve certain values based on the degree of preservation, distribution of target species and habitat types. For each individual zone Ordinance on Protection and Conservation of Medvednica Nature Park (NN 17/21) defines the manner and conditions of use and defined activities.

For the past ten years, PI NPM has placed great emphasis on the visitor infrastructure, developing and applying a model of organized visits, aimed at education and interpretation of natural and cultural heritage, especially in the facilities that are manage by PI NPM (CEETO, 2019). Such an approach is a consequence of the increased number of tourist and recreational interests, the development and increase in the number of contents, programs and services for visitors, but also the appearance of negative tourist impacts, which requires knowledge about visitors' profiles.

Public institution has its headquarter near the main entrance to the Park, and manages three special sites: Veternica cave, a geomorphological monument of nature, and two cultural heritages, Zrinski mine and Medvedgrad.

Medvedgrad is one of the largest Croatian medieval towns built in 1254 on the top of Mali Plazur, a hill on the southern side of Medvednica, with the purpose of defending Kaptol and the bishop's estates. In its history, it has changed more than one hundred and fifty owners, and in 2010 it was assigned to the Public institution Nature Park Medvednica. With the reconstruction and interior decoration over the past three and a half years, Medvedgrad has become a unique example of the conversion of a medieval "burg" into a modern visitor center. At the same time, Medvedgrad Visitor Center now contains a system designed for the sustainable management and use of natural heritage, management of visitors within Medvednica Nature Park, as a tourist attraction, and a public place for educational and exhibition purposes that connects local attractions, natural and historical sights.

At the main entrance, right in front of the headquarter, is Bliznec Info Center, with an educational Natura 2000 labyrinth, and there is a whole network of different trails, and several thematic educational trails (Miroslavec, Bistra, Slani potok, Slap Sopot, Kameni svati, Gorsko zrcalo , Horvat's steps), 150 km of bicycle paths and one enduro path, a 50 km long pilgrimage path (Marian pilgrimage path), 70 hiking trails and the first educational trail adapted for people with disabilities, Bliznec Forest Trail. In Bistra and Bliznec, there are also two geological pillars for visitors (PI NPM, 2019, Sustainable Tourism Strategy).

2.1. Risk incidence in the Park area

Our modern world is facing new and ever-increasing, unforeseeable, challenges. The continuous threat to the balance of the ecological system by increasing greenhouse gas emissions and climate change, which is partly caused by human activities, is one of the biggest challenges. In Medvednica Nature Park, existing and expected risks and adverse events related to climate change and possibilities for adaptation and strengthening of resilience were identified. Information about risks and vulnerabilities is important for determining mutual, climate and other (socioeconomic) effects.

The following risks and adverse effects can be distinguished (PI MNP & IRMO, 2017):

- Temperature (refers to an increase in average annual temperatures, an increase in the frequency of occurrences and values of extreme summer temperatures)
- Precipitation and wind (includes uneven distribution of precipitation, the incidence of extremely abundant short-term heavy precipitation, reduction of snow cover, extremely strong storm winds, ice break)
- Hydrological impacts (the trend of reducing the flow of streams, the incidence of torrential flows as a result of extremely heavy rainfall, the activation of landslides as a result of periods with more heavy rainfall)
- Fires (in extremely dry periods, especially in combination with high temperatures and wind, can increase the risk of fire, its rapid spread and the extent of the affected area)
- Seismic impacts (faulting, short earthquakes, permanent deformation, induced movements, movement of materials)
- Biological (epidemics in humans, animals or plants and diseases transmissible between animals and humans, the appearance of pests, weeds or invasive alien species that spread rapidly)
- Increase in the number of visitors (dangers from new technologies (drone), conflicts due to too many visitors (Medvedgrad Visitor Center)
- Terrorism (concerts, organized social events, a large group of people gathering in one place).

Due to the uniqueness, the assessment of risk and sensitivity is significantly influenced by climate change, which in the last ten years resulted in the incidence of large storms named Teodor (2013) and Rea (2019), as well as a series of wind and snow avalanches that literally devastated the forest of Medvednica.

2.2. Impact of risks on visits

Disasters and other risks are not only affecting the value of the natural and cultural heritage but also visitors, residents and all stakeholders who live in the Park or in the surrounding area. They can also have negative consequences on the local economy due to the loss of income from tourism, as well as on the lives of the local population, whose income maybe depends on it. As a consequence of the impact, a change in attendance dynamics may occur due to reduced visitor safety. The negative impacts are not only limited to the short periods in which adverse events are present but will also have a long-term impact through negative publicity (UNESCO, ICCROM, ICOMOS, IUCN, 2021). Degradation of forest components that are the fundamental phenomenon of the Park due to storms, droughts, landslides, forest pests and phytopathogens can affect the positive image of the Park and cause negative publicity. Increased populations of small forest rodents that are carriers of the haemorrhagic fever virus may also contribute to creating a negative image of the Park.

2.3. Visiting facilities managed by the Public Institution

Medvednica NP is easily accessible and there is no entrance fee. There are fees only for Veternica cave, Zrinski mine and Medvedgrad Visitor Center. Sports, social or scientific events in the Park are announced and the Public Institution issues concession approvals for them.

In the previous two years, a smaller number of visitors to the facilities was recorded as a result of the Covid 19 pandemic. Table 1 shows a

reduced number of visits in 2020 and 2021 in Zrinski mine and Veternica cave, while Medvedgrad was closed from September 2018 to November 2021 due to reconstruction. Veternica cave is closed annually during the hibernation of bats (November to April), and Zrinski mine is also closed in the winter months due to weather conditions. The data for 2022 refer to the first five months (January - May).

Table 1. The number of visitors in the three facilities managed by PI NPM (2014-2022). Source: PI NPM (2022)

Name	2014	2015	2016	2017	2018	2019	2020	2021	2022
Zrinski mine	5.246	4.185	5.303	3.874	6.201	5.693	1.556	2.331	2.580
Veternica cave	3.265	4.015	5.761	4.892	4.546	4.923	1.933	2.606	823
Medvedgrad Visitor Centre	13.165	13.954	18.787	22.569	8.129	-	-	2.994	8.921

2.4. Prevention measures and mitigation of the risk of disasters and adverse events

Risks from disasters and other harmful events must be predicted and, in accordance with expectations, mitigated by preventive activities and continuous education of employees. Preventive and mitigating measures require coordination between stakeholders and the Public Institution, as well as communication with external institutions and experts. In order to prevent or reduce the impact of hazards in the Park, special protective equipment and modern technology are needed, for which it is necessary to evaluate the profitability based on various factors, such as the availability of funds and trained employees. The Public institution has created a series of documents related to a safe stay and expectations for the visitors and employees activities in the facilities it manages, but also outdoor. Available documents were prepared as basic acts included in the strategic document of the Public Institution – the Management Plan, which prescribes how to prevent an unwanted activities, how to act during a harmful events and how to deal with the consequences of a possible disaster.

Activities carried out before a disaster or adverse event include risk assessment, prevention measures and mitigating measures in case of special hazards (maintenance and expert technical inspections, as well as the creation and implementation of various procedures and management methods).

For an incidence caused by a disaster or a harmful event, emergency response procedures were developed for the facilities managed by the Public Institution, and for the Medvedgrad Visitor Center, with the aim of saving people and cultural heritage.

Activities after a potential disaster or adverse event include damage assessment, damage repair and reconstruction, and recommending improvements to prevent further negative consequences.

3. RESULTS AND ACHIEVEMENTS

3.1. Implementation activities at the time of Zagreb earthquake

Employees of the Public Institution, as well as numerous stakeholders, felt the consequences of the earthquake that occurred on March 22, 2020, at 6:26 a.m. in Zagreb with a magnitude of 5.5 on the Richter scale. That unwanted event was

followed by numerous earthquakes that had a negative impact on people and their property. During the earthquakes that followed in Zagreb and the surrounding area, all employees were already ready to leave the buildings, and material damage assessments were carried out by experts on the buildings as well as minor repairs. The experiences gained during the response to and recovery from the consequences of the earthquake opened the need to review the risk management plan in crisis situations for facilities managed by the Public Institution.

3.2. New challenges of managing Medvedgrad Visitor Center

With the opening of the new Medvedgrad Visitor Center (Figure 2), the Parkgained a central visitor area, offering a modern and attractive place for visiting, socializing, learning, having fun and relaxing. In Medvedgrad Visitor Center, three new museum exhibitions are dedicated to the natural and cultural heritage of Medvednica Nature Park, the history of Medvedgrad and Medvednica, and the Park's rich intangible cultural heritage, stories and legends, and the central location in the courtyard provides space for various social events. Thus, the Public Institution obtained new activities that include the development of tourist attractions (Oikon d.o.o. et al, 2020), as well as greater obligations related to the safety of visitors as one of the key items in the quality assurance in tourism. Therefore, in the short period immediately after the opening, the Public Institution recognized the need to engage external security guards in order to reduce the risks of burglary and damage to cultural property. Since the facility is located in an isolated area, outside the settlement, security cameras, an alarm system and a fire alarm system were installed in order to prevent or reduce many risks: from theft, vandalism, burglary, harassment of visitors. The Public Institution's priority is to prevent those security risks that endanger people's health and life, such as natural disasters, fires, storms and hurricane winds, landslides. Supervision and monitoring are carried out by the Public Institution's employees, rangers and technical staff.

A new form of technology development has simplified the availability of drones, with which visitors often try to record their presence in nature. Such a form of recording is extremely dangerous in the central location of Medvedgrad Visitor Center, where many visitors gather, most of whom are children. The possibility of a drone fall on the crowd is a potential risk. The unannounced use of drones is risky in any part of the Park, given the increasing presence of recreationists, athletes, mountaineers, and children. Likewise, potential espionage in the area of the Park should not be ignored, because there is a ski resort, a TV tower, as well as many catering and even military facilities.

State institutions have regulated the use of drones, and Public Institution issues concession permits for their use in the Park. Unauthorized use is monitored, but it is almost impossible to prevent every occurrence of drones.

Fig. 2. Medvedgrad Visitor Centre
Source:PI NPM

4. CONCLUSIONS

Medvednica Nature Park is a spacious natural and partly cultivated area with valuable ecological features, emphasized landscape and cultural-historical values. In Medvednica Nature Park, economic and other activities and actions are permitted if they do not endanger its essential features and roles. The manner of performing economic activities and the use of natural resources is determined in accordance with the conditions of nature protection.

In order to have a pleasant and safe stay in the Park and to preserve nature, it is necessary to

adhere to the prescribed rules of conduct, and the rangers have the authority to impose a penalty for a violation in cases of non-compliance with the rules established by the Ordinance on Protection and Conservation (NN 17/21) and the Nature Protection Act (NN 80/13, 15/18, 14/19, 127/19). There are different models of drones on the market. Professional use requires a permit, while smaller drones are also in use that does not require permits, but they also pose a potential danger. It is difficult to control the use of drones because of the large area we control, but the penalties should be significantly higher to deter people from breaking the rules.

5 REFERENCES

[1] Central Europe Eco-Tourism: tools for nature protection, (CEETO), (2019), https://www.interreg-central.eu/Content.Node/Handbook-Sustainable-Tourism-HR-CEETO-Interreg.pdf, 2 https://www.interreg-central.eu/Content.Node/CEETO.html, last access 15/06/2022

[2] Oikon d.o.o., Markiva projekt d.o.o, Public Institution Medvednica Nature Park, Visitor management study, (2020), https://www.pp-medvednica.hr/wp-content/uploads/2020/09/Studija_upravljanja_posjetitelji_Medvednica.pdf, last access 20/06/2022

[3] Public Institution Medvednica Nature Park (PI MNP), Sustainable tourism strategy 2020-2024, (2020) https://www.pp-medvednica.hr/wp-content/uploads/2020/10/Strategija-odrzivog-turizma_2020_2024.pdf, last access 20/06/2022

[4] Public Institution Medvednica Nature Park (PI MNP) & Institute for Development and International Relations (IRMO), Action plan for adapting to climate change, (2017), https://irmo.hr/wp-content/uploads/2017/11/Priru%C4%8Dnik-PP-Medvednica.pdf, last access 30/06/2022

[5] Statute of PI NPM, (2014)

[6] UNESCO, ICCROM, ICOMOS, IUCN, Managing Disaster Risks for World Heritage_hrvatsko izdanje.pdf (2021), https://min-kulture.gov.hr/UserDocsImages/dokumenti/kulturna%20ba%C5%A1tina/Upravljanje%20rizicima%20od%20katastrofa%20za%20svjetsku%20ba%C5%A1tinu/Managing%20Disaster%20Risks%20for%20World%20Heritage_hrvatsko%20izdanje.pdf, last access 20/06/2022

With the completion of the European project and the opening of the new Visitor Center, the Medvednica Nature Park public institution has included the implementation of sustainable tourism in its activities. Now in the Republic of Croatia, a dozen new visitor destinations with new contents have been opened within the protected areas, which will make a great contribution to the protection and preservation of cultural and natural values, and to the achievement of the well-being of local communities. In the new conditions, it is necessary to monitor all pressures on nature and the environment in order to create all prerequisites for safety in the environment for visitors. The new monitoring mechanisms, in addition to the supervision of nature guards, include the installation of cameras, traffic counters, safety ramps, and continuous communication with the public.

The influence of direct foreign investments and innovations on the competitiveness in Croatia

L. Sigurnjak [a], I. Samardžić [a], M. Samardžić [b]

[a] University of Slavonski Brod, Trg Ivane Brlić Mažuranić 2, 35000 Slavonski Brod, Croatia, lena.sigurnjak@unisb.hr

[a] University of Slavonski Brod, Trg Ivane Brlić Mažuranić 2, 35000 Slavonski Brod, Croatia, iva.samardzic@unisb.hr

[b] Đuro Đaković Termoenergetska postrojenja d.o.o., Ul. M. BUdaka 1, 35000 Slavonski Brod, Croatia, mijat.samardzic@ddtep.hr

Abstract

Investments are one of the most important components for the development of a company. Companies must constantly invest in their development; in new technologies, development of human resources, in tangible and intangible assets, to develop market position and image. But all that is not enough without innovation. Innovations and investments have a kind of correlation, because companies must invest financial resources in order to encourage innovative activities and the implementation of innovations in their operations. Both investments and innovations encourage and enable the development of competitive advantage. Competitiveness is one of the most commonly defined concepts in the modern economy.

The aim of this paper is to provide a theoretical overview of the meaning and impact of innovation in the modern economy, and its impact on the development of a company's competitive advantage. In addition to the theoretical overview, the work presents an overview of investments in the Republic of Croatia, with an emphasis on the total amount of investments, on investments by activity, on the source of foreign investments with regard to the investing country, business sector, and the distribution of investments with regard to the geographical distribution by counties in Republic of Croatia. The paper carries out secondary research and data analysis.

Keywords: innovation, foreign investment, competitiveness, strategy

1. INTRODUCTION

This paper presents an overview and analysis of innovations and investments in the Republic of Croatia. The Croatian market has become available to foreign investors through the transition process, which has not yet been fully completed. There is a great need for investments that enable higher production productivity and the improvement and development of infrastructure. Domestic capital is not enough, and there is a significant need for foreign capital that will enable faster and better development. Investments enable the development of the competitiveness of the economy in the Republic of Croatia. No sector can function without investment.

However, investment in itself is not enough if the investments are not directed towards innovation. Innovations are necessary in entrepreneurship, production, tourism, finance, agriculture and all other sectors that are key to the domestic economy. This paper provides a theoretical review of the literature in order to define and explain the concept of innovation, and provides an overview of the amount and

type of foreign investments in the Republic of Croatia.

2. INNOVATIONS – LITERATURE REVIEW

Innovations are creating and developing competitive advantage and successful strategies. Historical development has shown that innovation and new discoveries and knowledge lead to significant economic growth, which leads to a close connection between innovation and economic development. “Transition countries are experiencing an influx of foreign and private technologies, while upon entering the EU, various incentive models and assistance are available to these countries in order to achieve convergence with other EU countries as soon as possible. However, a clear question arises as to whether the mentioned transitions really left a mark in the building of competitiveness. The competitiveness of countries largely depends on the quality of innovations, which is recorded through the international recognition of innovations, but also by monitoring contemporary trends and directions of technological development.” [1]

For the success and development of the economy as well as the technological progress of an individual country, it is necessary to develop new technologies. [2] It is necessary to develop technologies because in the conditions of the global economy companies from the Republic of Croatia often cannot compete with the price of products. One of the possible ways of differentiation and competitiveness of domestic products is innovation. [3]

“The influence these assets and other externalities can have on firm competitiveness, such as the ability of regions to attract creative and innovative people or provide high-quality cultural facilities, are all important features of regional competitive advantage.” [4]

Also, competitiveness od country is determinate with competitiveness of enterprises. So, investments are crucial and represents a necessary ingredient for entrepreneurial survival and growth. [5] The use of innovation and technology completely changes the perspective and strongly influences the development of key elements of the economy. [6]

“The sources of competitiveness are increasingly moving away from the price categories for which quality management systems are primarily intended, towards differentiation categories whose goals are primarily met by innovation management systems.” [7] Traditionally price was main element for competitive position of enterprise, but nowadays quality, market position, buyers satisfaction, distribution, new technologies implementations, improvement of product characteristic and so on, are more important for competitiveness.

“Innovation development is a process that requires various resources, both financial resources and appropriate skills and knowledge.” [8] One of main problems of Croatian economy and enterprises is very low level od innovativeness, and that problem should be treated seriously. “Since the innovations of products and services are the driver of the company's growth and encourage its success, the question arises as to how market orientation affects the development of new products and services.” [9] In modern economy, enterprises depend on external market dynamics and are forced to invest and implement innovations in their strategy in order to be competitive on the domestic and foreign markets.

“Entrepreneurship and innovation have always been in a close relationship, however, in today's globalized world, the need for innovation takes on exceptional importance because the competition is getting stronger, the differences between companies are getting smaller and smaller as customers have become less sensitive and more loyal to a particular company. It is increasingly difficult for them to maintain interest in a product or service, and thus their interest in the company also decreases”. [10]

"In the recent economic crisis, and even today, innovation is considered a lifeline for companies that intend to survive, and necessary for companies with ambition." [11] Without implementation of innovation business: innovation of products, innovation of process, innovation of marketing and organisational innovation there is no success and development of organisation.

A single definition for innovation does not exist, but after reviewing the literature, innovation can be defined through the OECD explanation. According OECD "an innovation is the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organisational method in business practices, workplace organisation or external relations." [12]

3. INVESTMENT FUNDAMENTAL DETERMINANTS

Investing in new products, technology, assets is very important for transition countries like Croatia, where one of most important strategies are innovation strategies. "Innovativeness of the economy is one of the key factors stimulating economic growth. Many countries have an increased focus on developing the innovation policy and strategy for their countries. Improving innovativeness is especially important for developing countries, which are trying to improve their competitiveness and stimulate economic growth." [13]

Investments are any investment in goods with the aim of future earnings. Investments can be active (real investments) and passive (portfolio investments). The person who invests is called an investor, and the object in which the investment is made is called an investment object. Companies invest in real goods in order to create conditions for permanent business, and have permanent investments in means of production, i.e. in permanent working and fixed assets. The purpose of the investment is to maintain business continuity and the development of economic entities. Safe investment today for uncertain future results.

According to the purpose of investment: new investments, investments in expansion, investments in reconstructions and modernizations, investments in environmental protection. According to the impact on the organizational structure: simple investments that cause minor changes in production and complex investments that significantly affect changes in production.

When investing, one of the most important elements of the investment decision is the payback period. Payback period (depreciation period, repayment period): is part of the period of use of the investment after which it is expected that the invested capital will be returned from the realized difference between receipts and expenses, as well as from annual depreciation, the number of years after which the amount of invested capital and the sum of accumulated net receipts become equal

Innovation is crucial for every company and every organization. Innovations in production and service provision are the main features for the development of the company. innovations are of particular importance for manufacturing companies. the reason is that Croatia is a small market compared to the world leaders, and cannot compete with large global producers, and that is precisely why it is necessary to focus on a market niche, and create innovative products on the basis of which domestic production can be competitive. Innovations are needed as domestic production would be maintained and domestic producers would remain the main leaders in the region.

4. RESEARCH OF FOREIGN INVESTMENTS IN REPUBLIC OF CROATIA

Research is conducted according information about investments in Croatia from Ministry of

economy and sustainable development Republic of Croatia.

Foreign investments are desirable for every country. Goal of Croatian economy and politics is to attract foreign capital with the aim of increasing competitiveness. In this paper are presented data for investments from 1993 to the end of 2021 year. In that period Croatia received foreign direct investments in the amount of 38.8 billion €. Detail analysis is shown in tables that follows. Table 1 presents amount of foreign direct investments (FDI) in the Republic of Croatia by country of capital origin in period from 1993-2021.

Table 1. Foreign direct investments in the Republic of Croatia by Country from 1993-2021, made by authors according literature [14]

	Country	FDI in %
1.	Netherlands	17
2.	Austria	13
3.	Luxembourg	11
4.	Germany	10
5.	Italy	10
6.	Hungary	7
7.	Slovenia	5
8.	UK	3
9.	France	3
10.	Other Countries	21

According Table 1 most significant investments came from Netherlands, even 17%, next are Austria and Luxembourg. Table 2. presents FDI by activity.

Table 2. FDI by activity, made by authors according literature [14]

	Activity	
1.	financial services	28%
2.	manufacturing	19%
3.	trade	13%
4.	real estate	13%
5.	ICT	8%
6.	tourism	4%
7.	construction	3%
8.	other sectors	12%

According table 2, financial services are most attractive for foreign investments, then manufacturing and trade. Croatia should improve and develop not just in investments, but generally manufacturing. Croatian economy cannot be competitive without strong production. Competitive production can be realised through significant development and implementation of innovations.

In text below there is Table 3 presents analysis of business sectors (number of enterprises by sector, number of workers and average gross salary), and table 4 below in text presents level of investments by county in Republic of Croatia (by each of 20 counties that Republic of Croatia is consisted of and Zagreb city, totally 21 geographical area). By each county is analysed GDP, GDP per capita, area size, population and foreign direct investment.

Table3. Analysis of business sectors, made by authors according literature [14]

Sector	Companies (by CBS 2021)	Workers (by CBS 2021)	Average gross salary (by CBS 2021)
ICT	11,717	53,424	1,851 €
Manufacture of Machinery and Equipment	700	11,780	1,226 €
Automotive Industry	470	8,945	1,130
Food Industry	3,260	58.733	1,037 – food 1,445- beverage
Pharmaceutical Industry	51	5,654	2,137
Logistics	12,868	89,927	1,200
Creative and Cultural Industry	9,843	26,228	1,093
Toursim Sector	20,767	99,580	968

Table 4. Investments by county in Republic of Croatia, made by authors according literature [14]

County	GDP 2019 EUR	GDP per capita 2019 EUR	Area size km^2	Population 2021	Foreign Direct Investments million EUR (1993.-2021.)
Brod-Posavina	1.129.939.000	8.211,00		130.782	154
Vukovar-Sirmium	1.299.445.000	8.606,00	2.454	144.438	148
Osijek-Baranja	2.793.014.000	10.232,00	4.155	259.481	368
Virovitica-Podravina	5.797.878.000	7.869,00	2.024	70.660	23
Požega-Slavonia	544.980.000	8.217,00	1.823	64.420	67
Bjelovar-Bilogora	971.350.000	9.132,00	2.640	102.295	98
Koprivnica - Krizevac	1.076.472.000	10.110,00	1.748	101.661	127
Međimurje County	1.254.707.000	11.476,00	729	105.863	184
Varazdin	2.013.939.000	12.112,00	1.262	160.264	476
Krapina-Zagorje	1.115.679.000	8.954,00	1.229	120.942	324
Zagreb	3.332.527.000	10.769,00	3.060	301.206	1.963
City of Zagreb	19.178.253.000	23.742,00	641	769.944	23.669
Sisak-Moslavina	1.416.203.000	9.706,00	4.468	140.549	86
Karlovac	1.098.265.000	9.510,00	3.626	112.596	137
Primorsko Goranska	4.305.677.000	15.232,00	3.588	266.503	2.602
Istrian	3.343.405.000	15.960,00	2.813	195.794	2.702
Lika - Senj	478.217.000	10.725,00	5.353	42.893	341
Zadar	1.939.861.000	11.544,00	3.646	160.340	951
Sibenik - Knin	1.124.210.000	11.325,00	2.984	96.624	407
Split-Dalmatia	4.819.201.000	10.759,00	4.540	425.412	2.445
Dubrovnik-Neretva	1.789.168.000	14.673,00	1.781	115.862	789

According presented data in Table 3 most attractive business sector for workers is pharmaceutical industry with highest average gross salaries, and most of works and registry companies is in tourism sector. According table 4 the highest standard of living has region of north-west area and north Adriatic coast in Croatia. City Zagreb has a significantly highest GDP per capita. In comparison with level of investments, highest amount od foreign direct investments is in Zagreb City. Lowest amount of investments and least attractive for investors are Eastern Croatia and central area. All data form table 4 shows that Croatia is not widely developed, and the standard of living and the level of investments differ significantly by individual geographical units.

5. CONCLUSION

In accordance with the conducted research and theoretical analysis, the following conclusions can be drawn from this paper. Innovations are key to the development of companies and the economic system as a whole. This applies especially to a geographically small country such as Croatia, which has gone through a process of transition, which is not yet complete. in order for the economy to be competitive, it is necessary to constantly innovate both products and production processes. Innovations by themselves cannot be realized without financial resources, i.e. investments. Domestic capital is not sufficient for development and competitiveness; therefore, this paper presents an overview and analysis of

direct foreign investments in the Republic of Croatia. The results of this research show that Croatia should develop more evenly, that it should focus on the development of less developed areas and create and develop a desirable entrepreneurial and business climate that would attract not only domestic but also foreign investors. In addition to service activities such as ICT and tourism, it is necessary to develop production activities in order to achieve competitiveness. For such changes, it is necessary to create and implement both national development strategies and individual entrepreneurial strategies. a significant strategic turn of the economy is necessary, which would result in greater competitiveness of the economy through better macroeconomic indicators, but also a better and more financially prosperous standard of living of the population in all regions of the Republic of Croatia.

6. REFERENCES

[1] D. Vlajčić, M. Bošnjak, The impact of the transformation of the innovation system on the change in the quality of the technology sectors of CEE countries (Utjecaj transformacije inovacijskog sustava na promjenu kvalitete tehnoloških sektora CEE zemalja), Notitia - časopis za ekonomske, poslovne i društvene teme prosinac broj 7 (2021) pp. 19-32

[2] K. Ćosić, R. Fabac, Economic growth, technological development and modern education (Gospodarski rast, tehnološki razvitak i suvremeno obrazovanje), Ekonomski pregled, 52 (5-6) (2001), pp. 516-544

[3] V. Andrijević Matovac, Innovative activities of Croatian companies - differences by industry (Inovativne aktivnosti hrvatskih poduzeća - razlika po industrijama), Ekonomski pregled, 56 (3-4) (2005), pp. 204-220

[4] R. Huggins et al., Regional competitiveness, economic growth and stages, Zbornik. radova Ekonomskog fakulteta u Rijeci, vol. 32, sv. 2 (2014) pp. 255-283

[5] I. F. Lucian, R. Sergiu, The role of innovation and entrepreneurship in small and medium businesses, Lucrări ştiinţifice, seria i, Vol.XXI (1), Management Agricol (2019) pp. 122-127

[6] M. Anđelinović, A. Validžić, Perspectives on the development of technological innovations through the optimization of the sales function (Perspektive razvoja tehnoloških inovacija kroz optimizaciju funkcije prodaje), Hrvatski časopis za osiguranje, Vol. No. 2, (2019) pp. 21-35

[7] T. Baković, The impact of quality and innovation on the operations of companies in the Croatian manufacturing industry (Utjecaj kvalitete i inovacija na poslovanje poduzeća u hrvatskoj prerađivačkoj industriji), Ekonomski pregled, 62 (9-10) (2011) pp. 525-543

[8] LJ. Božić: Constraints to Innovation Activities in Croatian Enterprises 178 Ekonomski pregled, 62 (3-4) (2011) pp. 177-189

[9] H. Miloloža, The influence of market orientation of Croatian companies on product and service innovations (Utjecaj tržišne orijentacije hrvatskih poduzeća na inovacije proizvoda i usluga), Poslovna izvrsnost zagreb, god. X br. 2 (2016) pp. 89-106

[10] A. Vukučević, L. Živković, Aspects of the development of innovative entrepreneurship in the Republic of Croatia (Aspekti razvoja inovacijskog poduzetništva u Republici Hrvatskoj), Zbornik radova Veleučilišta u Šibeniku, Vol. No. 3-4/2019, (2019) pp. 41-51

[11] S. Srhoj, I. Batarelo Kokić, T. Krišto, In search of innovation: the mediating role of learning orientation in the relationship between the determinants of entrepreneurial climate and product-service innovations (U potrazi za inovacijama: medijacijska uloga

orijentacije učenju u odnosu odrednica poduzetničke klime i proizvodno-uslužnih inovacija), Poslovna izvrsnost Zagreb, god. XI, br. 1(2017) pp. 9-37

[12] Organisation for Economic Co-operation and Development (OECD) https://stats.oecd.org/glossary/detail.asp?ID=6865, last accesses: 10/07/2022

[13] P. Dobrzanski, Efficiency of investments in investments in the countries of Central and Eastern Europe (Efikasnost ulaganja u investicije u zemljama Srednje i Istočne Europe), Zbornik radova Ekonomskog fakulteta u Rijeci Vol. 36, No. 2, (2018), pp. 827-859

[14] Ministry of economy and sustainable development Republic of Croatia, https://investcroatia.gov.hr/en/ict/, last access 10/07/2022

State financial support to small and medium-sized enterprises in the Republic of Croatia during the COVID-19 pandemic

M. Vretenar Cobović [a], G. Prebeg [b], M. Jerković [c]

[a] University of Slavonski Brod, Trg Ivane Brlić Mažuranić, 35000, Croatia, mvcobovic@unisb.hr

[b] University of Slavonski Brod, Trg Ivane Brlić Mažuranić, 35000, Croatia, gprebeg@unisb.hr

[c] University of Slavonski Brod, Trg Ivane Brlić Mažuranić, 35000, Croatia, mjerkovic@unisb.hr

Abstract

COVID-19 pandemic was, and still is, one of the biggest crises in history due to the fact that it's impact on economy was global, instant and drastic. Croatian government like governments all around the world needed to support entrepreneurs and SMEs in order to soften the economic shock as much as possible. The paper describes policy responses of Croatian government that were adopted with an aim to lower the negative impact of COVID-19 on entrepreneurs and SMEs. Specifically, it represents undertaken activities of Croatian government aimed at preservation of jobs in sectors affected by the COVID-19 pandemic. It is based on in-depth research of the impact of government support for SMEs on microlevel by collecting data from SMEs that had received support during three-month period of lock-down in 2020. Research is based on testing weather data collected from supported SMEs are corelating with data on national level. Paper should, therefore, give insight into direct impact of government support during COVID-19 pandemic on supported SMEs and answer weather the undertaken government activities helped them to preserve jobs and activities, at least in the very beginning of crisis. Although the overall effects of the crisis will only be possible to measure when the crisis is over, it is currently possible to measure the effects of undertaken government support at the very beginning of the crisis.

Keywords: Financial support, small and medium-enterprises, COVID-19 pandemic, Republic of Croatia

1. INTRODUCTION

The COVID-19 pandemic had a significant negative impact on economy and business activities all over the world. Lockdown period in around the world, as well as in Croatia (March-May 2020th) had mayor and instant impact on economy, while long-term impact of COVID-19 pandemic will be subject of researches in the future.

This paper focuses on analyses of impact of government support for small and medium businesses (SMEs) during COVID-19 pandemic, and based on data collected by the Croatian Ministry of Labour, Pension System, Family and Social Policy [1] as provider of government SMEs supports popularly called ORM (in further text ORM).

The aim of aforementioned government ORM supports was to preserve jobs [2]. Therefore, this paper provides insight into 5 local SMEs, based on internal data from local accounting office Count IT Ltd., [3] in order to determine whether the ORM supports have really helped in job preservation in a post-period of one year after SMEs have received a government support.

Since the COVID pandemic has impact on national, EU and global economy, authors provide data related to unemployment rate based on data from Croatian Employment Service [4]. GDP as an indicator of general state of economy is presented in a relevant period, based on EUROSTAT data [5].

2. METHODS OF RESEARCH AND DATA ANALISIES

Global pandemic as phenomena in modern history will surely be a subject of many researches, but in order to study its impact on the economy, there should be more researches on micro level.

2.1. Background of the research

The effect of crisis was devastating in many sectors, especially in those whose activity had to stop completely, but the small and medium-sized enterprises suffered the most due to the large share of SMEs in economy and in employment. In OECD countries, in sectors mostly affected by corona crisis, the share of SMEs in employment is average 75%, while globally, the share of SMEs in employment is around 60% [6]

According to CEPOR data small and medium-sized enterprises make up 99.7% of all registered enterprises in Croatia, employ three quarters of all employees in business entities, participate in the total realized exports with a share of 52.9% and generate 60.3% of the total income realized at the level of Croatia [7].

SMEs are more vulnerable during crisis, then big entrepreneurs are, because they do not have sufficient funds to ensure liquidity during period without business activities. Therefore, it was expected that the first response of SMEs on the crisis would be to reduce number of employees. In order to prevent problems with liquid funds, as well as to prevent jobs one of the first and the most important support for SMEs adopted by Croatian government was wage ORM support, provided by Croatian Ministry of Labour, Pension System, Family and Social Policy.[1]

The other related support was tax release on income from ORM government support (wage expenses were included in EBIT, and government support was used as tax release in EBITDA).

The aforementioned ORM was criticized by the public and SMEs representatives because they were not aimed at supporting business activities of SMEs as employers but mainly at preserving jobs. Later analyses should show whether or not ORM really saved jobs, and whether the it helped entrepreneurs to have positive profit-loss sheet in 2020 and in the following years, despite the reduction of business activities. Ministry of

New paper prepared by International Monetary Fund staff concludes that the widespread use of job retention schemes meant that the euro area’s unemployment rate was 2.5 percentage points lower than it would have been without any intervention. This kept around 4 million workers from EU in their jobs. [8]

Governments collect statistical data that do not provide in-depth researches. So, it is necessary to research whether or not are general data in consistency with data collected from each SME.

2.2. Objectives of the research

The objectives of the research are determined by the subject of the paper. The initial goal is to describe the adopted and undertaken support activities in the Republic of Croatia with an aim to reduce the impact of the COVID-19 pandemic on the economy and unemployment. The goal of the research is to analyse the impact of the government supports of SMEs, by in depth analyses of 5 SMEs from different sectors, which received subsidies to preserve jobs, and to determine whether the received subsidies achieved their goals. The research also tries to shed light on the role of various forms of incentives and state support in mitigating the effects of the pandemic on business. Although governments around the world, including Croatian one, have tried to maintain business operations of SMEs in pandemic conditions, the effects of such activities have not yet been sufficiently investigated, i.e. their effect is measured by overall unemployment rates at the level of the Republic of Croatia, or by monitoring general economic indicators (economic growth by sectors, GDP, etc.).

The question that arises is did the support received by the employers helped in preserving jobs and the stability of the business for a long period, i.e. how many companies that received the support have preserve jobs in long time period and did they achieved positive business results at the end of 2020. The other question is what happened to them in 2021, that also was impacted by the covid crisis.

Aim of the research is to have insight into fluctuation of the number of employees in SMEs through period 2020-2022 and EBIT in 2020 and 2021 as those data are comparable to unemployment rate and GDP data on national level.

2.3. Data on local SMEs

Since the beginning of pandemic COVID-19 authors of the article are in contact with local SMEs through local accounting office. Authors had collected different data on how pandemic affects decision-making processes of entrepreneurs, and are continuously following phenomenon of covid crisis and its impact on economy. The idea was to prepare detailed research on wider range of SMEs based on in-depth data provided by SMEs that has received ORM support. But since there is no public database on SMEs who received ORM support there was no possibility to make survey among relevant number of SMEs. Therefore, for the purpose of this paper authors have used data collected during pandemic in cooperation with local accounting office. Therefore, the data used for this paper are collected from local accounting office with 68 SME clients, and data from 5 SMEs were used as a case study, to check the hypothesis that ORM support helps SMEs to prevent jobs. Five SMEs that are analysed are from different sectors, and are different sizes, regarding their income, and therefore should provide sufficient quality insight in how does ORM support has impacted different size of SMEs.

Public institutions such as Tax office or Croatian Employment Office should provide data or research all or major SMEs who received ORM support, but for the purpose of the paper, data collected on the micro-level from 5 SMEs from different sector should provide sufficient answer on how the ORM support impacted SMEs.

3. ANALISIS OF IMPACT OF ORM ON JOB PRESERVATION AND SME

In further this paper will explain an impact of ORM supports on SMEs in the EU, Croatia and 5 local SMEs.

3.1. Data on ORM support for SMEs in Croatia

Supports for preservation of jobs - ORM were provided at the very beginning of the crisis (few weeks after the lockdown) to all the SMEs that had income decrease of at least 20% during lockdown in compare with the same month in 2019 [2]. Criteria for support were later on changed depending on the development of crisis

and situation in health care. As it is indicated in Table 1. [1] the biggest number of supports were during lockdown period, while later that number has decreased, and has changed regarding situation with pandemic.

Table 1. Amounts of ORM supports during 2020

Month	Number of employers	Total amount in HRK	Number of employees
03/2020	86.648	1.648.059.652,61	528.641
04/2020	100.835	2.325.789.009,66	595.090
05/2020	100.789	1.997.805.502,00	513.001
06/2020	18.603	331.415.279,36	84.942
07/2020	18.982	241.156.786,01	73.758
08/2020	14.439	175.383.815,06	51.853
09/2020	15.144	139.450.548,49	44.317
10/2020	26.859	321.975.354,70	97.639
11/2020	39.828	442.973.902,76	144.361
12/2020	42.921	558.767.598,40	156.869
TOTAL		**8.182.777.449,05**	

Amount of support was no more than 3.250,00 HRK for March 2020 per full-time worker, and no more than HRK 4,000.00 per month per full-time worker for April and May 2020. The support has also covered the contribution for pension insurance based on individual capitalized savings. Later on, it was decided that the wage taxes and insurance contribution will not be charged to SMEs i.e., total support was not more 3.250,00 or 4.000,00 HRK net salary plus all taxes and contribution.

3.2. Data on unemployment rate

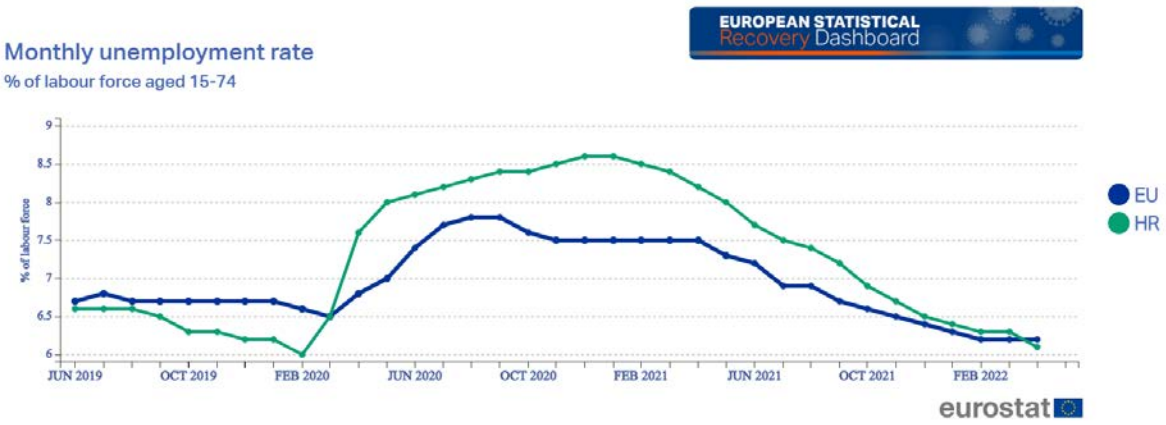
Data of unemployment rate is the main indicator of undertaken activities.

There was an instant increase of the unemployment rate in labour force in March of 1,7 percentage points compared to February 2020 and in continues in April for further 0,5 percentage points, while in the EU that trend is visible in April and May for 1%. According to data from the Croatian Employment Service in the Republic of Croatia, the number of unemployed in April 2020, is higher by 15,773 than the previous month and by 28,144 than in April 2019. Thus, in April 2020, unemployment increased by 11.0% compared to the previous month, and by 21.5% compared to the same month in 2019. [4] Croatian Employment Service (CES) collects data of registered unemployed people (not all unemployed people are registered at CES).

The other support for the SMEs was shortening working time. Therefore, all the further statistic data doesn't count part-time workers as an unemployed. While the unemployment rate in EU-27 peaked at 7.8 percent in August 2020, an augmented measure of unemployment for selected countries, suggests that unemployment rates in Europe at the peak of the crisis in 2020Q2 could have been significantly higher if sort-term participants would have been dismissed.

Unemployment rate is higher due to fact that the number of SMEs did not benefit from the ORM supports whether because they didn't meet the criteria for the support or they decided that it is more efficient to solve problem of liquidity by closing the business.

Figure 1. Monthly unemployment rate [5]



3.3. Data on employers and ORM supports of local SMEs

Five local SMEs that will be used as a sort of control group of the national data have applied for ORM support. All five SMEs were supported only during lockdown (March-May 2020). The amount of received support is shown in Table 2. [3]

Table 2. Amounts of ORM supports at local SMEs

	Amount of support HRK	Number of employees
SME 1	10.557,82	1
SME 2	81.172,69	6
SME 3	118.844,80	9
SME 4	164.105,59	12
SME 5	397.813,88	31

SME1 is in sector of car repair, SME2 is in sector of Construction of residential and non-residential buildings, SME3 is in IT sector, SME4 is in sector maintenance and cleaning of buildings and facilities and SME5 is in sector of electrical installation service.

It is also important to have insight in what extent has the received support affected the final financial result (EBIT).

As it is shown in Table 3. a share of ORM in total income for 2020 varies from 1,76 % to 10,57%. [3]

Table 3. Financial data of local SMEs

2020	SME 1	SME 2	SME 3	SME 4	SME 5
Income	126.483,32	4.610.999,64	1.123.970,33	3.800.319,18	10.113.422,11
Outcome	110.444,11	3.475.337,22	983.873,55	2.712.673,41	8.927.340,29
EBIT	**16.039,21**	**1.135.662,42**	**140.096,78**	**1.087.645,77**	**1.186.081,82**
COVID tax release	1.055,78	8.117,27	14.261,38	19.692,67	71.606,50
ORM + Tax release	**11.613,60**	**89.289,96**	**133.106,18**	**183.798,26**	**469.420,38**
EBIT - COVID support	4.425,61	1.046.372,46	6.990,60	903.847,51	716.661,44
% of support in total income	8,35	1,76	10,57	4,32	3,93

2021	SME 1	SME 2	SME 3	SME 4	SME 5
Income	114.565,00	9.504.979,61	1.079.473,74	4.181.144,12	11.320.439,60
Outcome	109.562,98	7.364.109,43	1.059.659,62	3.117.225,91	10.843.514,36
EBIT	5.002,02	2.140.870,18	19.814,12	1.063.918,21	476.925,24

Data also shows that all five SMEs would have positive financial result (EBIT – COVID support) at the end of the 2020. Therefore, it is to conclude that ORM support mainly helped them to overcome the crisis regarding liquidity. But, ORM supports has impacted decision making processes on level that is hard to measure since it is subjective perception of the representatives of SMEs. In conversation with representatives of all five SMEs they were asked about an impact ORM support in the decision-making processes. All five SMEs have stated that the anxiety regarding lockdown was very high at the beginning of the crisis, and the support trough ORM have helped to reduce anxiety. The entrepreneurs were faced with the situation of really high uncertainty regarding future of their business as well as global situation. In a time of such crisis, it is really hard for entrepreneurs to make rational decisions. Most of them didn't want to reduce number of employees, but were at the same time considering cutting costs. For all of them reducing costs would result in cutting wages or even number of employees. After the government of Croatia have presented first package of supports for SMEs in a second week of lockdown, the situation among entrepreneurs was a bit more positive. The entrepreneurs have said that ORM support helped them to delay decisions on reducing the number of employees until they see how the situation will further develop.

Therefore, ORM support have helped them to ensure liquidity in a very uncertain situation,

and to get some more time to reconsider what are future options for their business. All of them stated that that ORM support have helped them to overcome the first shock regarding lower or zero business activity during lockdown and have encouraged them to put an effort in preserving their business and jobs.

Financial data in Table 3. shows that all five the SMEs have achieved similar or higher income in 2021. EBIT in 2021 was higher than the EBIT-COVID support in 2020 (EBIT from business activities) for three SMEs. The other two SMEs had higher investments and costs, and therefore lower EBIT in 2021. None of the researched SMEs were start-ups and therefore were probably more resistant on crisis.

Further data analysis presented in Table 4. has shown that the received ORM support has helped local SMEs to preserve jobs during lockdown, but also in a long-term future period. [3].

Table 4. Number of employees at local SMEs

Month	SME1	SME2	SME3	SME4	SME5
3/2020	1	6	9	12	31
3/2021	1	28	9	12	47
3/2022	1	23	9	12	58

3.4. Data on GDP growth

Since the lockdown was at the end of first quarter of 2020 the fell of GDP was instant and evident in the second quarter of 2020. As the Figure 2. shows Croatian economy was highly impacted by pandemic COVID-19 crisis.

Figure 2. Quarterly GDP growth [5]

The fell of GDP for 14% was a result of highly reduced business activity and it corelates with higher unemployment rate.

It is evident that the GDP has recover in the third quartal due to the end of lockdown in May 2020. Government ORM has helped SMEs to ensure liquidity, and to preserve business activities. The data on GDP are consistent with data collected from 5 local SMEs.

There were some indicators that a number of SMEs had non-transparent financial data during first months of COVID supports. Since one of the criteria for support was at least 20% of income increase, some SMEs have provided false data, i.e. they reported income increase during lockdown months, and then reported those income in post lockdown period. It is not clear in what extend if any has such unfair reporting has on overall economic data.

Data on all COVID supports in period from March 2020 till May 2022 are presented in Table 5.

Table 5. Total COVID supports

Type of support	Amount in HRK
ORM supports	11.397.834.304,36
Micro entrepreneurs support	128.486.896,12
Disabled people support	1.742.007,90
Shorted-working time	379.088.299,88
Contribution and taxes	615.674.177,06
Refund of utility costs	486.359.046,37
Returns	-318.480.132,68
TOTAL COVID SUPPORTS	**12.690.704.599,01**

As the data in Table 5 shows 2,45% of all supports were returned due to some kind of irregularities.

The other measure that should ensure long-term liquidity is income tax release. The income tax for 2020 had to be paid due to 30th June 2021. The income tax release was between 12% and 18% on the amount of received ORM support. Therefore, ORM support received in period from March till May 2020 has not only increased liquidity in 2020 but also in 2021 through additional tax releases.

4. CONCLUSIONS

Global pandemic COVID-19 as phenomena and its impact on the economy will surely be a subject of many future researches. Governments all around the world had provided different types of support in order to ensure stability and economic growth. Through massive data analysis decision makers get insight into general state of economy and different aspect of society. But, for further insight there should be more in-depth researches on micro level. Authors of the paper have actively monitored the situation regarding COVID-19 and an impact that it has on a local economy. Therefore, the aim of the paper was to provide insight into micro-level impact of ORM support on local SMEs through comparation of data collected on national and global level with case-study of data from 5 local SME that had received government support.

Case study on 5 local SMEs, has shown that all 5 SMEs have preserved employees and have positive financial result at the end of 2020 as well as 2021. Data collected on local SMEs are consistent with data on national and EU level.

Available national data regarding unemployment rate have shown that government manage to preserve jobs by undertaken activities and supports of employers. Unemployment rate in Croatia, as well as in the EU has increased to the pre-pandemic level by the end of 2021. Total amount of COVID-supports provided by the Croatian authorities is 12.690.704.599,01 HRK by the May 2022. Policies for recovery of economy, and financial support for entrepreneurs in Croatia are consistent with activities undertaken on the EU level.

5. REFERENCES

[1] Croatian Ministry of Labour, Pension System, Family and Social Policy, data collected on 30/06/2022, available on request on https://mrosp.gov.hr/kontakt-4124/4124

[2] https://mjera-zrm.hzz.hr/potpora-ocuvanje-radnih-mjesta-ozujak-svibanj/ , last access 15/06/2022

[3] Count IT Ltd Slavonski Brod, financial data from financial reports of SMEs, available on request

[4] Croatian Employment Service, Monthly statistics April 2020 and May, https://publikacije.hzz.hr/statisticke-publikacije/#1572_2020 , last access 15/06/2022

[5]https://ec.europa.eu/eurostat/cache/recovery-dashboard/ , last access 15/06/2022

[6] OECD (2021): One year of SME and entrepreneurship policy responses to COVID-19: Lessons learned to “build back better”, OECD SME and Entrepreneurship Papers, forthcoming, OECD Publishing, Paris, pg. 3-4: https://www.oecd.org/coronavirus/policy-responses/one-year-of-sme-and-entrepreneurship-policy-responses-to-covid-19-lessons-learned-to-build-back-better-9a230220 , last access 15/06/2022

[7] CEPOR (2020): Report on SME, page 7-9: http://www.cepor.hr/wp-content/uploads/2021/01/Izvjesce-2020-HR-web.pdf , last access 15/06/2022

[8] International Monetary Fund, https://www.imf.org/en/Publications/Departmental-Papers-Policy-Papers/Issues/2022/03/02/European-Labor-Markets-and-the-COVID-19-Pandemic-Fallout-and-the-Path-Ahead-512327 , last access 15/06/2022

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