Hasan Talić[1*], Atif Hodžić[2]

Influence of Feed Speed and Cutting Depth During Planing on Surface Roughness of Fir, Poplar and Beech Wood

Utjecaj posmične brzine i dodatka za obradu drva na hrapavost površine jelovine, topolovine i bukovine obrađenih blanjanjem

ORIGINAL SCIENTIFIC PAPER
Izvorni znanstveni rad
Received – prispjelo: 31. 5. 2023.
Accepted – prihvaćeno: 3. 1. 2024.
UDK: 674.056; 620.179.118
https://doi.org/10.5552/drvind.2024.0119

ABSTRACT • *The roughness of the machined surface is a crucial factor in the woodworking process because it influences the quality of future operations like gluing, sanding, pressing, surface treatment and protection, and assembly. The quality of the machined surface is determined by a number of machining process parameters as well as material properties, and their proper selection and optimization will yield the best results. The purpose of this article is to demonstrate how specific parameters and wood species affect surface roughness. In the experiment, three species of wood: beech (Fagus sylvatica), fir (Abies alba), and poplar (Populus alba) with the same moisture content were used, and combinations of feed speed (5 and 8 m/min) and cutting depth (2 and 4 mm) were created. The processing was done on a wood planer (thickener) machine of the SD-B-510 series manufactured by Robland Machines Belgium. Following that, roughness measurements of Ra, Rz, Rt, and Rq were taken with a focus on the mean deviation of the profile Ra, and an analysis of the results was presented, revealing that different roughness values are obtained with the same processing parameters depending on the wood species. The difference between the greatest (5.36 µm) and lowest (2.41µm) roughness values (Ra) for beech is 2.95 µm, 1.25 µm for poplar, and 1.34 µm for fir.*

KEYWORDS: *surface roughness; planing; feed speed; depth of cut; quality*

SAŽETAK • *Hrapavost obrađene površine ključni je čimbenik u procesu obrade drva jer utječe na kvalitetu naknadnih postupaka poput lijepljenja, brušenja, prešanja, površinske obrade, zaštite i montaže. Kvaliteta obrađene površine određena je brojnim parametrima obrade i svojstvima materijala, a njihovim pravilnim odabirom i optimizacijom postižu se najbolji rezultati. Svrha ovog članka jest pokazati kako specifični parametri i vrsta drva utječu na hrapavost površine obrađene blanjanjem. Istraživanje je provedeno na uzorcima od bukovine (Fagus sylvatica), jelovine (Abies alba) i topolovine (Populus alba) te uz kombinaciju dviju posmičnih brzina (5 i 8 m/min) te dvaju dodataka za obradu blanjanjem (2 i 4 mm). Obrada je provedena na blanjalici (debljači) proizvođača Robland Machines (serija*

[*] Corresponding author
[1] Author is senior assistant at University of Bihać, Faculty of Technical Engineering, Department of wood industry, Bihać, Bosnia and Herzegovina. https://orcid.org/0009-0009-5272-8291
[2] Author is full professor at University of Bihać, Faculty of Technical Engineering, Department of wood industry, Bihać, Bosnia and Herzegovina.

SD-B-510) iz Belgije. Nakon toga izmjereni su parametri hrapavosti Ra, Rz, Rt i Rq, s fokusom na srednjem odstupanju profila Ra. Analiza rezultata pokazala je da se različite vrijednosti hrapavosti dobivaju pri jednakim parametrima obrade za različite vrste drva. Razlika između najveće (5,36 µm) i najmanje (2,42 µm) vrijednosti hrapavosti (Ra) za bukovinu je iznosila 2,95 µm, za topolovinu 1,95 µm, a za jelovinu 1,34 µm.

KLJUČNE RIJEČI: *hrapavost površine; blanjanje; posmična brzina; veličina dodatka za obradu blanjanjem; kvaliteta*

1 INTRODUCTION
1. UVOD

The roughness of the machined surface is one of the parameters by which the quality of the processing itself is evaluated. In order for the product to be economical and competitive on the market, one of the important factors is the quality of the processing, which includes the precision of the processing and the roughness of the processed surface. The roughness of the machined surface directly and indirectly affects the quality of the product itself because further treatments such as surface treatment and gluing depend on the roughness of the machined surface.

In the final processing of wood, roughness represents defects on the surface of the wood that, among others, occur due to the action of the tool on the workpiece. Controlling the surface roughness of the workpiece is crucial in maintaining the quality of the product, and it is essential to constantly implement the flow of the entire production. This depends on the type of processing (sawing, planing, milling, etc.), but with each processing, even with the same processing parameters, a change in roughness can occur on the same sample of wood. This can be affected by the dullness of the tool, a change in moisture content in the wood, or the occurrence of certain defects in the wood (Karahasanović, 1988; Bjelić, 2022).

It is known that the quality of processing is influenced by the anatomical, physical, and mechanical properties of wood. They differ not only depending on the species of wood but also within the same species. In addition, the quality is affected by factors such as blade geometry, cutting direction, cutting depth, feed rate, cutting speed, etc. (Škaljić *et al*., 2009).

Roughness is a microcosmic geometric shape on the surface of a measuring piece composed of depressions and peaks with a small space between them. There are a number of parameters that describe the roughness of the surface; the basic problem is the correct choice of parameters that correctly describe the surface being measured. Roughness parameters (according to ISO 4289/11) can be divided into sizes related to: height characteristics of irregularities (amplitude parameters), characteristics of irregularities in the length direction (distance parameters), and profile deviation form (hybrid parameters) (Sofuoğlu and Kurtoğlu, 2015; Bojović and Janjić, 2013).

Due to the effort to provide the most precise roughness values, two different measuring systems have appeared: M (Medium) system and E (Envelope) system. System M is a system of the middle line, while system E is a system of a separate line, and they differ only in the rate of occurrence of the roughness problem.

The basic difference between these two systems is in the way roughness is separated from other types of deviation. The basic parameters of roughness are determined by the standard BAS EN ISO 4287:2000, which refers to terms, definitions, and parameters of roughness that are currently in use (Bjelić, 2022).

The mean deviation of the profile (*Ra*) is the arithmetic mean value of the deviation of the profile within the sampling length, approximately determined according to Eq. 1:

$$R_a = \frac{\sum_1^n |Y_i|}{n} \tag{1}$$

Where:

Yi – distance of a single point of the effective profile from the middle line in absolute value,

n – total number of measured points of the effective profile. (Sofuoğlu and Kurtoğlu, 2015)

The medium deviation of the profile (*Ra*) shown in Figure 1 is the generally recognized and most widely used international parameter for roughness. In addition to *Ra* (the arithmetic mean value of profile deviation within the length of sampling), Figure 1 also shows the parameters *Rz* (maximum height of irregularity), *Rq* (root mean square profile deviation), and *Rt* (total height of peak and valley).

The aim of this study is to show how the type of wood, *i.e.* the anatomical structure of wood and various processing parameters, influence the surface quality of the processing and which are the optimum processing parameters to obtain the best surface quality.

2 MATERIALS AND METHODS
2. MATERIJALI I METODE

2.1 Samples preparation
2.1. Priprema uzoraka

Samples of solid beech (*Fagus sylvatica*), fir (*Abies alba*), and poplar (*Populus alba*) wood with dimensions of 35 mm × 15 mm × 500 mm were used for testing. The wood from which the samples were pre-

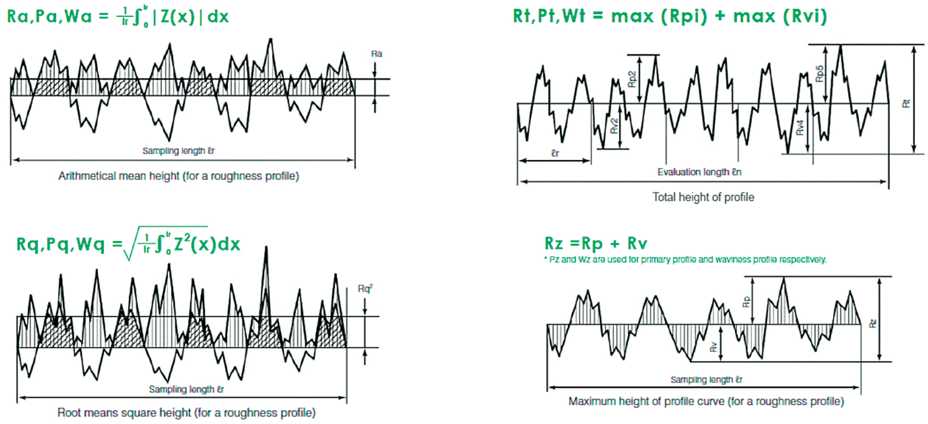

Figure 1 Graphics of roughness parameters evaluated included *Ra*, *Rq*, *Rt* , and *Rz* (Nicolas-Silvente *et al*., 2020)
Slika 1. Grafički prikaz istraživanih parametara hrapavosti *Ra*, *Rq*, *Rt* i *Rz* (Nicolas-Silvente *et al*., 2020.)

pared underwent a drying process where the moisture content of the wood was brought to (8±1) %. Wood samples were machined on a planer (thickener) SD-B-510-serie manufactured by Robland machines Belgium.

Figure 2 presents a machine for planing samples and their appearance. It has a knife holder with a diameter of 100 mm on which 3 knives are placed. The rotational frequency of the tool is 6000 min^{-1}, and the engine power is 5.5 kW. The specifications of the machine are automatic movement of the workpiece feed speed of 5, 8, 10 and 16 m/min and adjustable cutting depth.

The planing of samples for each wood species (beech, fir, and poplar) was done at a feed speed of 5 and 8 m/min, and cutting depth of 2 and 4 mm. Thus, two samples were planed for each of the mentioned combinations.

Table 1 Processing parameters for tested samples
Tablica 1. Parametri obrade ispitivanih uzoraka

Test mark *Oznaka uzorka*	**Wood species** *Vrsta drva*	**Wood density, g/cm³** *Gustoća drva,* g/cm³	**Feed speed, m/min** *Posmična brzina,* m/min	**Cutting depth, mm** *Dodatak za obradu blanjanjem,* mm
1B-52	Beech	0.664	5	2
2B-54	Beech	0.664	5	4
3B-82	Beech	0.664	8	2
4B-84	Beech	0.664	8	4
5T-52	Poplar	0.495	5	2
6T-54	Poplar	0.495	5	4
7T-82	Poplar	0.495	8	2
8T-84	Poplar	0.495	8	4
9J-52	Fir	0.432	5	2
10J-54	Fir	0.432	5	4
11J-82	Fir	0.432	8	2
12J-84	Fir	0.432	8	4

Figure 2 Machine for planing samples and their appearance
Slika 2. Stroj za blanjanje uzoraka i izgled uzoraka

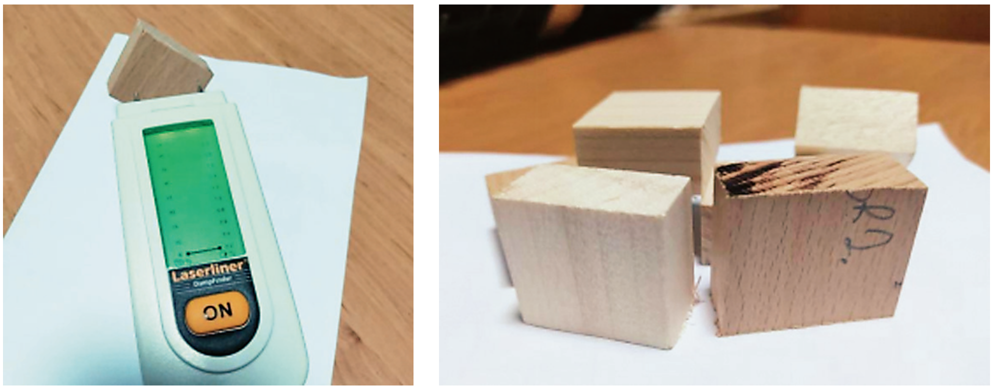

Figure 3 Measurement of moisture content and determination of density of samples
Slika 3. Mjerenje sadržaja vode i određivanje gustoće uzoraka

2.2 Measurement procedures
2.1. Postupci mjerenja

Before measuring the roughness, two tests were performed: measurement of wood density of the above samples and their moisture content. The moisture content of the samples was measured in accordance with the ASTM D4442 standard using the Laserliner 082.011A Damp Finder Plus wood moisture meter. The calibration of the equipment according to the manufacturer's instructions is part of the test method. The hygrometer probes are then pressed against the selected sample, and the moisture values for the given sample are displayed on the display. For every trial made, this method was repeated.

The ISO 3131 standard was used to calculate wood density. The test was performed using previously measured samples with dimensions of 30 mm × 30 mm × 15 mm and moisture content of (8±1) %. Six samples of each wood species were taken, and the arithmetic mean was determined following the measurements.

The measurement of the surface roughness of the machined samples was done using the TMR 120 TM Teck Instrument Co. roughness meter. Ltd. The basic characteristics of this device for measuring the roughness are the measurement parameters (μm): *Ra*, *Rz*, *Rt*, and *Rq*, stroke length of 6 mm, sampling length (*Lr*) values of 0.25, 0.8, and 2.5 mm, access length of 1.25 and 4.0 mm, and indication error ±15 %. This device complies with EN, ISO, DIN, ANSI, JIS, and ASME B46.1 national standards. The difference in the measurement parameters is reflected in the accuracy of the results and the reduction of errors. This measurement was made at a sampling length of 2.5 mm and an access length of 4.0 mm. The test was carried out in the direction of fibre stretching of processing at three arbitrarily determined points (Figure 4), where the results and the average value were recorded.

This test was done in the Wood Testing Laboratory at the Technical Faculty in Bihać, following all the recommendations for roughness testing according to the EN ISO 4287:2010 standard.

3 RESULTS AND DISCUSSION
3. REZULTATI I RASPRAVA

The results of the roughness measurement are shown in Table 2; more precisely, the mean value of the measurement for each sample is shown. In addition to *Ra*, data are given for *Rz*, *Rq*, and *Rt*.

The following diagram shows that the measurement parameters (*Ra*, *Rz*, *Rt*, and *Rq*) change depending on the processing parameters for feed speed 5 and 8 (m/min) and cutting depth 2 and 4 mm. It is also shown for all three examined wood species (beech, fir, and poplar).

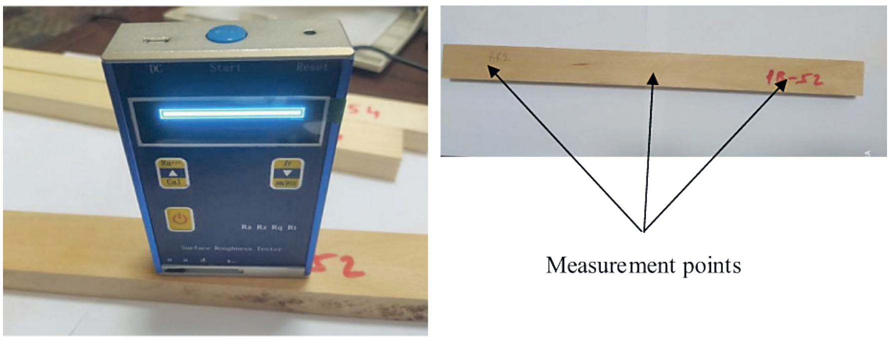

Figure 4 Measurement of roughness on samples
Slika 4. Mjerenje hrapavosti na uzorcima

Table 2 Mean values of measurement results
Tablica 2. Srednje vrijednosti rezultata mjerenja

Test mark *Oznaka uzorka*	**Number of measurements** *Broj mjerenja*	*Ra*, µm	*Rz*, µm	*Rq*, µm	*Rt*, µm
1B-52	9	2.41	10.42	3.01	15.48
2B-54	9	3.39	14.95	4.00	25.57
3B-82	9	3.82	13.30	4.45	22.77
4B-84	9	5.36	18.54	6.41	33.80
5T-52	9	1.61	7.37	1.96	10.79
6T-54	9	2.86	13.02	3.33	21.69
7T-82	9	2.08	9.20	2.80	15.77
8T-84	9	2.86	11.01	3.51	20.33
9J-52	9	2.53	12.13	3.20	19.27
10J-54	9	3.87	13.47	4.60	26.27
11J-82	9	3.20	13.17	3.93	19.47
12J-84	9	3.87	13.63	4.47	20.20

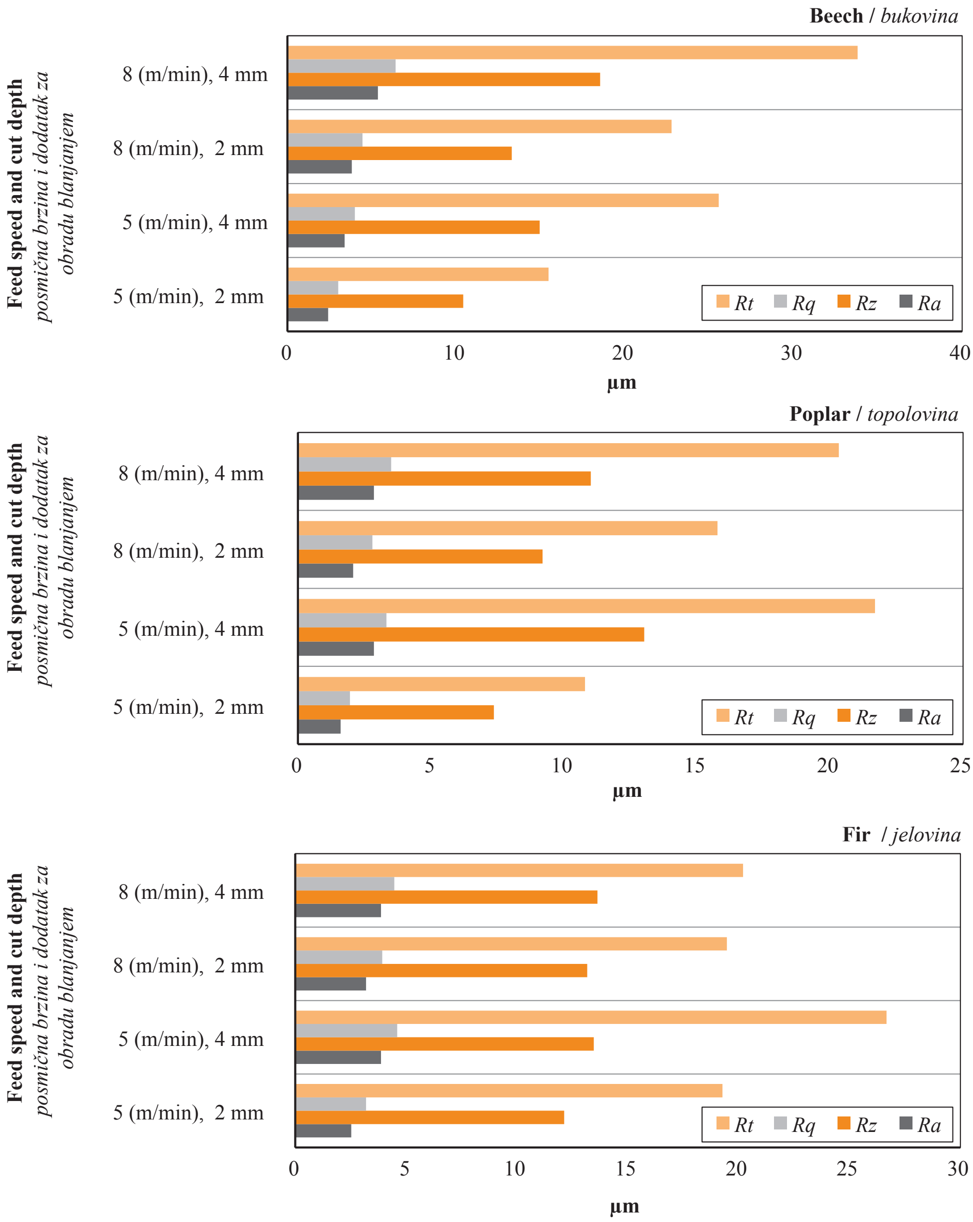

Figure 5 Graphic representation of results of measuring samples roughness according to processing parameters and wood species
Slika 5. Grafički prikaz rezultata mjerenja hrapavosti uzoraka prema parametrima obrade i vrsti drva

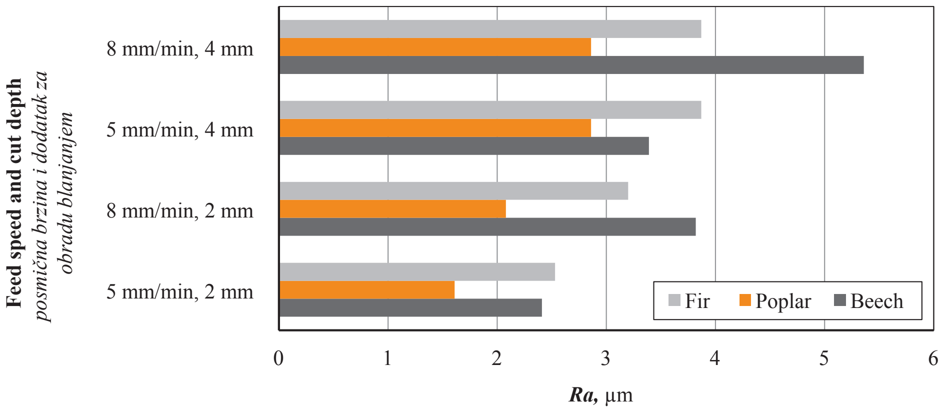

Figure 6 *Ra* – arithmetic mean value of profile deviation shown as comparison for fir, poplar and beech and given parameters
Slika 6. Usporedni prikaz aritmetičke srednje vrijednosti odstupanja profila (*Ra*) za jelovinu, topolovinu i bukovinu te za zadane parametre

The diagram shows the mean value of profile deviation (*Ra*) as an indicator of surface roughness on the measured samples. The dependence of the surface roughness on the processing parameters and the type of wood is visible, and the results showed that the lowest roughness is at feed speed of 5 m/min and cutting depth of 2 mm for all three wood species. Analogously, the highest surface roughness was obtained with increased feed speed and depth at 8 m/min and 4 mm.

The diagram and results show that the influence of feed speed on roughness also depends on the type of wood (that is, the density of the wood), so in the case of beech, the depth of cut had a greater influence on the change in roughness, while in fir and poplar, the opposite was the case as a greater change in roughness is caused by feed speed.

Changes in the mean value of the deviation of the *Ra* profile for the same processing parameters and different species of wood are obvious, with beech being the most pronounced. The difference between the highest and lowest roughness values is 2.95 µm (2.41–5.36); in poplar, this difference is 1.25 µm (1.61–2.86); and in fir, it is 1.34 µm (2.53–3.87). Likewise, the lowest roughness measured for samples made from poplar is 1.61 µm.

The quality of the machined wood surface depends on the processing parameters. The influence of the tool rotational frequency and feed speed results in varying levels of surface roughness; hence, increasing cutting speed while decreasing feed speed improves the processed surface quality in beech wood (Bojović and Janjić, 2013). The behaviour of wood during processing can also be seen in wood-based materials. According to Prakash and Palanikumar (2011), spindle rotation frequency and feed rate, tool shape, and tool diameter have the biggest effects on surface roughness. The study findings showed that the surface roughness values of wood-based panels increased with increasing cutting tool diameter while decreasing with increasing spindle rotation frequency and feed speed (Demir *et al.*, 2022). The porosity of the wood has an impact on the quality of the processed surface (Kudela *et al.*, 2018). This work also shows that the influence is present for the same parameters but different types of wood. For the process of managing wood milling machines or CNC woodworking machines using the milling method, design data is needed with the aim of achieving the highest productivity and lowest energy consumption, while ensuring the desired surface quality. As a result, optimal processing parameters for this type of wood are provided (Loc and Hung, 2021). Further to the above, it is important to know the influence of all processing factors on the quality of the processed surface in order to create the conditions for optimal processing with the desired quality.

4 CONCLUSIONS
4. ZAKLJUČAK

In this study, the surface roughness of beech, poplar, and fir was examined. The samples were processed at various feed speed rates - 5 and 8 m/min and cutting depths - 2 and 4 mm. After examining the surface roughness results on the above samples, the following can be concluded:

- The influence of the processing parameters on the roughness is visible, and the results show that the smallest roughness is at feed speed of 5 m/min and at cutting depth of 2 mm, for all three species. Analogously, the highest surface roughness was obtained with increased feed speed and depth at 8 m/min and 4 mm. The reason for this is that the increase in feed speed and depth directly affects the roughness of the processed surface; the higher these parameters are, the higher is the roughness in all three species.
- The density and anatomical structure of the different wood species provide variable results when the same processing conditions are used. The mean value of

profile deviation Ra for the parameters feed speed of 5 m/min and cutting depth of 2 mm shows that poplar has the lowest value while beech has the highest. This difference is also obvious when considering other factors - *Rz*, *Rt*, and *Rq*.

- The difference between the highest and lowest measured value of *Ra* is 2.95 µm for beech (Ra_{min} = 2.41, Ra_{max}= 5.36). It is 1.25 m for poplar (Ra_{min} =1.61, Ra_{max} =2.86) and 1.34 m for fir (2.53 - 3.87). Furthermore, the lowest value of *Ra* was observed for poplar samples and is 1.61 m. Such changes are also visible in other measured values of *Rz*, *Rt* and *Rq*.

This research shows the influence of the processing parameters on the surface roughness, that is, the influence of the feed speed and depth of cut, along with the effect of wood species on the roughness at the same processing parameters. Knowing this, but also considering other research, opens the possibility of improving the processing quality, such as the surface roughness, by changing the processing parameters of feed and cutting depth, but also by choosing the type of wood that can provide improved results.

5 REFERENCES
5. LITERATURA

1. Bjelić, A., 2022: Optimization of solid wood workability parameters in the process of planing on CNC machines. PhD Thesis, University of Bihac, Bihac, Bosnia and Herzegovina.
2. Bojović, I.; Janjić, M., 2013: The influence of the number of revolutions of the main spindle on the roughness of the processed surface of beech wood. In: Proceedings of 9th International Scientific Conference on Production Engineering RIM 2013, Budva, North Macedonia, pp. 173-178 (in Bosnian).
3. Demir, A.; Cakiroglu, E. O.; Aydin, I., 2022: Effects of CNC processing parameters on surface quality of wood-based panels used in furniture industry. Drvna industrija, 73 (4): 363-371. https://doi.org/10.5552/drvind.2022.2109
4. Karahasanović, A., 1988: Wood science. Sarajevo, Svjetlost Sarajevo. ISBN 86-01-00984-0 (in Bosnian).
5. Kúdela, J.; Mrenica, L.; Javorek, L., 2018: The influence of milling and sanding on wood surface morphology. Acta Facultatis Xylologiae Zvolen, 60 (1): 71-83. https://doi.org/10.17423/afx.2018.60.1.08
6. Loc, N. H.; Hung, T. O., 2021: Optimization of cutting parameters on surface roughness and productivity when milling wood materials. Journal of Machine Engineering, 21 (4): 72-89. https://doi.org/10.36897/jme/144426
7. Nicolas-Silvente, A. I.; Velasco-Ortega, E.; Ortiz-Garcia, I.; Monsalve-Guil, L.; Gil, J.; Jimenez-Guerra, A., 2020: Influence of the titanium implant surface treatment on the surface roughness and chemical composition. Materials, 13: 314-https://doi.org/10.3390/ma13020314
8. Prakash, S.; Palanikumar, K., 2011: Modeling for prediction of surface roughness in drilling MDF panels using response surface methodology. Journal of Composite Materials, 45 (16): 1639-1646. https://doi.org/10.1177/0021998310385O
9. Škaljić, N.; Beljo Lučić, R.; Čavlović, A.; Obućina, M., 2009: Effect of feed speed and wood species on roughness of machined surface. Drvna industrija, 60 (4): 229-234.
10. Sofuoğlu, S. D.; Kurtoğlu, A., 2015: Effects of machining conditions on surface roughness in planing and sanding of solid wood. Drvna industrija, 66 (4): 265-272. https://doi.org/10.5552/drind.2015.1406
11. ***BAS EN ISO 4287:2000/AC:2008 Geometrical product specifications (GPS) – Surface texture: Profile method – Terms, definitions and surface texture parameters (ISO 4287:1997/Cor 1:1998/Cor 2:2005).
12. ***ASTM D4442-20 Standard Test Methods for Direct Moisture Content Measurement of Wood and Wood-Based Materials.
13. ***ISO 3131:1975 Wood – Determination of Density for Physical and Mechanical Tests First Edition.

Corresponding address:

HASAN TALIĆ

University of Bihać, Faculty of Technical Engineering, Department of wood industry, dr Irfana Ljubijankića bb, Bihać, BOSNIA AND HERZEGOVINA, e-mail: hasan.talic@unbi.ba