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INFLUENCE OF DIFFERENT MACHINING ON THE ROUGHNESS OF OAK WOOD

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Abstract: *The paper presents research on the differences the in total roughness and the impact of parameters during different kinds of machining processes of oak samples. Oak wood samples were planed referring to a radial surface structure of wood. The planing machine was Weinig Unimat 500 and the planing head had two blades. The planing was conducted at a feed speed of 10, 15, 20, 25, and 30 m·min^{-1}. The cutting depth of the machining grip was 1.00 mm and the rake angle of the tool blade was bio γ = 15°, at 6000°/min. The diameter of the cutting blade was Φ = 125 mm. Sanding was performed on a Viet Opera V contact sanding machine in combination heads with pre-planing knives and a roller with sanding belt. Roughness was measured along the grain in the latewood area of the annual growth using the electro mechanical profiler Mitutoyo SJ-500. The samples which were machined at a feed speed of 10 m·min^{-1} had the lowest roughness. The highest value of the roughness had samples which were machined at a feed speed of 30 m·min^{-1}. After comparing roughness obtained during sanding and planing it was determined that the surface roughness obtained on a sanding machine approximately corresponds to the roughness obtained by planing at a feed speed of 20 and 25 m·min^{-1}.*

Key words: *surface roughness, feed rate, sanding, peripheral milling.*

1. Introduction

In all technological processes, a huge and important role is reserved for surface quality. Surface quality directly affects further production processes, e.g., the quality and strength of the bonded elements. Škaljić, [12] showed that with increasing feed rate, surface roughness increases [12]. Deviations are geometric irregularities from ideal overall geometric shape and surface roughness [2]. Surface geometry is always defined on the basis of irregularities resulting from macroscopic,

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microscopic, and submicroscopic characteristics [5]. Surface roughness depends on the inherent morphological structures of wood and the method of processing [13]. The technological process of wood machining and wood species are factors that significantly affect surface roughness [10]. The quality of the treated wood surface depends on the anatomical structure of the wood species and the wood processing parameters, such as cutting depth, feed speed, tool rotational frequency, feed rate, and cutting angle [11]. Feed speed also has an important influence on the roughness of the machined surface [3]. Surface roughness is considered the main parameter for assessing surface quality after planing or sanding [4]. In one research [1] it was shown that the grain size during sanding affects surface roughness. Milling is one of the most common methods of wood processing [9]. It is assumed that the surface roughness of the machined surface of hardwood increases with the increasing radius of the wedge [8]. We have measured the surface roughness of oak wood samples and the influence of different machining parameters. The main aim of this research was also to compare and find the nearest value of the feed speed for the *Weinig Unimat 500* planing machine which corresponds to the value of the roughness after combined machining on the *Viet opera V* sanding machine. In some production processes this combined sanding machine replaces the classic planing machine, or it is used in parallel with the classic machine as back-up.

2. Material and Methods

The measurements were based on samples of oak wood (*Quercus robur* L.). The dimensions of the oak samples before peripheral milling were: 35×40×5000 mm and we had a total of 180 samples, with an average moisture content of 8%. Figure 1 shows the samples prepared for testing. The samples had the radial surface texture of wood, and before machining they were conditioned at 20°C in relative air humidity 65 ± 5%.

Fig. 1. *Samples for experimental research*

The measurements were made on the samples machined by two different methods of wood processing. The first group of samples were machined by peripheral milling referring to radial wood texture. The surface roughness was measured on a group of 150 samples (30 samples for each feed speed) that were planed (Figure 2), as well as profiled (Figure 3) on the *Weinig Unimat 500*.

Fig. 2. *Four side planer machine*

The planing tool head had two blades and a feed rate of 10, 15, 20, 25, and 30 m·min^{-1} (Figure 4). The cutting depth was 1.00 mm and the blade rake angle was γ=15°. The tool diameter was Φ = 125 mm and the rotational frequency was 6000 min^{-1}.

Fig. 3. *Determined dimensions for planing on the Four-side planer machine*

Fig. 4. *Milling head with 2 blades*

The second group of 30 samples were machined on the combined machine with aggregators for planing and sanding *Viet Opera V* (Figure 5).

The diameter of the milling unit was 250 mm, with four spirally twisted rows of inserted cutting tools. In one row there were 180 cutting inserts of dimensions 14×14×2 mm. The rake angle of the blades was γ=15° and the feed rate of 10 m·min^{-1}. Grain size has an important role in the sanding process and directly affects the surface roughness [7]. The depth of milling and sanding was 1.0 mm. After the milling unit, in the same pass, the samples were sanded with P80 granulation, at a pressure of 6 kg/cm^2. After machining the samples, the surface roughness was measured using the electro-mechanical profiler *Mitutoyo SJ-500* (Figure 6).

Fig. 5. *Machine for sanding and milling Opera Viet V*

Fig. 6. *Control unit of the surface measuring device Mitutoyo SJ-500*

The device consists of a central measuring console with a vertically placed skidless standard stylus, with a radius of 10 µm. The stylus traversed at a constant speed of 1 mm/s, the evaluation length was 40 mm with a total of 8000 datapoints. The measuring range was set to 800 (±400) µm. Resolution in the lateral direction was 5 µm. The measuring standard used was ISO 4287:2009 with a total of 5 sampling lengths; the used filter was simple Gaussian. The cut-off value was set up for 8 mm. The experiment was done on a ring-porous type of wood. Therefore, it is very difficult to exclude wood anatomy from the measurements.

The roughness parameters were measured along the fibers together with the anatomical properties. The prepared samples had a radial wood surface structure and the measurements were conducted in the latewood area (Figure 7) of annual growth. Table 1 shows the setup of the surface quality measuring device *Mitutoyo SJ-500*.

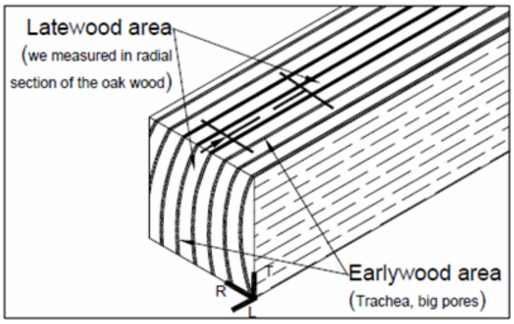

Fig. 7. *Area of conducted measurement*

Table 1

Setup of measuring device for roughness testing (Mitutoyo SJ-500)

Sampling length	8 mm
Number of sampling lengths	5
Traverse speed	1,00 mm/s
Stylus tip radius	10 µm
Stylus tip angle	90°
Surface roughness standard	ISO 4287

After the measurement, the surface roughness results were presented graphically. The measurement was performed with a total of five measuring lengths per sample and for a total of 30 samples for each feed rate.

The parameters Ra, Rz, and Rk were measured according to the ISO 4287:2009 standard. Also, the measurement and evaluation of the surface roughness for the wood products are still lacking a consensus [6], while general standards do not apply or need to be adapted for a heterogeneous material like wood. Inherent wood anatomy is a source of bias, from the choice of the measuring instrument, the selection of the evaluation length and measuring resolution, to the evaluation of the measured data, such as form error removal, filtering, the selection of the cut-off length, and the calculation of the roughness parameters. Ideally, wood anatomy should be removed from the data prior to any evaluation [13].

3. Results

Table 2 shows the values of the measured surface roughness of the samples of oak wood. The samples were planed on the *Weinig Unimat 500* and also machined on an automatic machine with aggregates for milling and sanding. The values of standard deviation and standard error are also given in the same table.

The Analysis of Variance for the tested samples is presented in Table 3. Figure 8 shows diagrams with the summary results of the measured roughness parameters Ra, Rz, and Rk of the oak samples processed at different feed speeds and machined on an automatic machine with aggregate for planing and sanding (Viet opera V).

Table 2

Measured values of surface roughness (Ra, Rz, Rq), standard deviation, and error of oak samples

Breakdown Table of Descriptive Statistics N=180									
Machining	Ra [μm]			Rz [μm]			Rk [μm]		
	Means	Std. Dev.	Std. Err.	Means	Std. Dev.	Std. Err.	Means	Std. Dev.	Std. Err.
Planed 10 m/min	3,3	0,888	0,152	23,8	6,69	1,15	8,7	1,440	0,247
Planed 15 m/min	4,6	0,781	0,138	34,8	9,63	1,70	13,9	2,235	0,395
Planed 20 m/min	6,9	1,324	0,234	46,6	10,84	1,92	20,8	3,748	0,662
Planed 25 m/min	7,6	1,347	0,238	47,4	10,92	1,93	22,5	3,306	0,584
Planed 30 m/min	8,9	1,485	0,262	54,4	9,98	1,76	25,8	5,672	1,003
Sanded P80	7,5	2,019	0,369	46,3	14,69	2,68	22,7	5,575	1,018

Table 3

Analysis of Variance of oak surface roughness measured values Ra, Rq, Rz

Variable [μm]	Analysis of Variance Marked effects are significant at p < ,05000							
	SS Effect	df Effect	MS Effect	SS Error	df Error	MS Error	F	p
Ra	725,65	5	145,129	342,06	180	1,8390	78,91663	0,000000
Rz	20013,49	5	4002,698	21041,50	180	113,1264	35,38254	0,000000
Rk	6796,41	5	1359,282	2896,03	180	15,5700	87,30107	0,000000

The Analysis of Variance is presented in Table 3 with a p-value of 0.05. Table 4 presents the results of the post-hoc Tukey HSD test which shows single step multiple comparisons between the observed surface roughness of the samples machined at different feed speeds and the samples sanded with the granulation of P80 on the Viet Opera. As shown, there is a significant difference in the surface roughness of the samples machined at different feed speeds and the samples sanded with the granulation of P80 on the Viet Opera V.

The Tukey THD test showed a statistically significant difference in the obtained surface roughness parameter Rk at the value of p=0.05. In comparison with the planed samples which were sanded, we can conclude that the lowest roughness had samples which were machined by planing at 10 and 15 m/min and the highest roughness had a feed speed of 30 m/min (Figure 8).

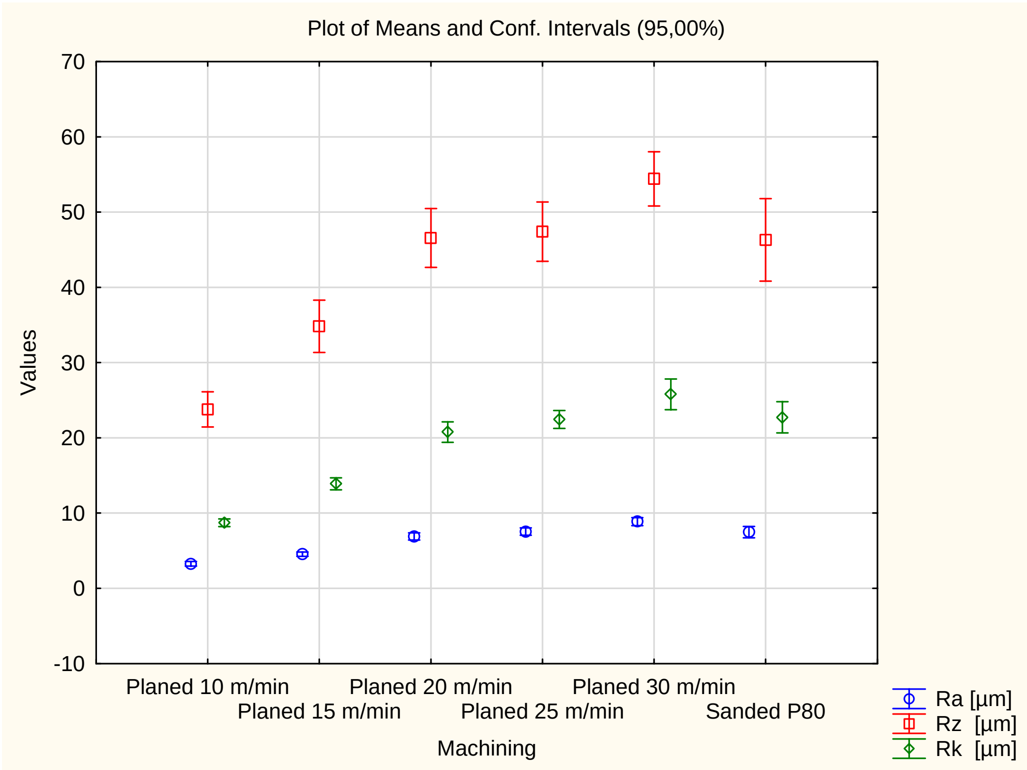

Fig. 8. *Statistical values of surface roughness parameters Ra, Rz, Rq of oak samples*

Table 4

Tukey HSD (Honestly significant difference) test

Machining	Tukey HSD test; Variable: Rk [µm] Marked differences are significant at p < ,05000					
	1 M=8,7282	2 M=13,899	3 M=20,775	4 M=22,454	5 M=25,794	6 M=22,734
Planed 10 m/min 1		0,000022	0,000020	0,000020	0,000020	0,000020
Planed 15 m/min 2	0,000022		0,000020	0,000020	0,000020	0,000020
Planed 20 m/min 3	0,000020	0,000020		0,530338	0,000025	0,369444
Planed 25 m/min 4	0,000020	0,000020	0,530338		0,009279	0,999773
Planed 30 m/min 5	0,000020	0,000020	0,000025	0,009279		0,027601
Sanded P80 6	0,000020	0,000020	0,369444	0,999773	0,027601	

4. Conclusions

It can be seen that all the observed parameters of surface roughness with peripheral milling increase with increasing feed speed. The study results (Table 3) showed significantly different average values of the surface roughness parameters for different machining methods.

- The lowest Rk had samples planed at a feed speed of 10 m·min^{-1};
- The highest Rk had samples planed at a feed speed of 30 m·min^{-1};
- The similar Rk had sanded samples and planed at a feed speed of 20 and 25 m·min^{-1}.

On the automatic milling and sanding machine (which was the second machining method), the measured overall roughness through parameters Ra, Rz, Rk was quite higher than on the planed samples, with the same feed speed (10 m·min^{-1}) (Figure 7).

Therefore, from the standing of productivity, we could achieve a higher production rate with peripheral milling than with sanding of wood elements with the same surface quality or even better e.g., 15 m·min^{-1}. During the analysis of variances, we observed that there was a significant difference between the roughness of the measured samples. Also, significant differences between individual groups could be noted.

Considering the presented results, research will continue in the future, involving new wood species, new parameters of machine processing control, and a higher number of samples. Also for further research, we plan to determine and investigate the strength of bonded samples that were machined with different tool parameters.

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