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Impact of Planing Treatment Regime on Solid Fir Wood Surface

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Abstract

Each wood item has its own surface relief and consists of miniature peaks and valleys. The size and spatial distribution of these peaks may affect certain properties of the wood surface. This paper presents the research work carried out on planing quality of solid fir wood surface.
This paper analyzes the impact of displacement speed and rake angle on the wood surface roughness. Investigations were carried out on the fir samples which were processed in semi radial direction. In this study variable parameters (displacement speed and rake angle of knife edge) and constant parameters (tool speed, depth of cut and the number of cutting edges on the tool) are used.
The quality of the surface was determined by a quantitative method. Within the quantitative method the size of roughness parameters R_a, are measured in "M" system of electromechanical profile meter Mitutoyo SJ-201. Comparing the obtained values, it can be concluded that with the planing processing, when increasing displacement and rake angle of the tool, the surface roughness increases.

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Keywords: planing; surface; displacement speed; wood

1. Introduction

Wood products are composed of smaller or larger number of details. All details are defined by their quality characteristics (dimensions, shapes and their tolerances). These characteristics depend on the purpose and the function of the details in the product. The newly formed surfaces, when cutting wood, is never perfectly smooth whether they are straight or curved. The quality of the details and finished products depends on several factors

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(quality of the source material, quality of construction, quality of treatment, etc.) that are conditioned by the market demands [1,2].
Quality of workmanship is the most important condition for achieving quality products and it includes precision machining and quality of certain surface [3,4]. Characteristics that determine the quality of the surface can be generally classified into five groups: physical properties, mechanical properties, chemical and physical, aesthetic properties and geometric state. When milling wood, the newly formed surfaces are never perfectly smooth.
Through milling process, unevenness of new surfaces has two causes:

1. Structural irregularities that result from anatomical structure of wood. Their size and distribution depend primarily of botanical species. Generally, these unevenness can not be avoided, which means that they follow wood milling [5].
2. Unevenness caused by milling, which belong to the so-called micro-unevenness if they relate to the roughness of new cutting surface. Unevenness caused by cutting, can be specified as: waviness, roughness, waviness and roughness and destructive bumps [5].

The group of structural unevenness includes; unevenness resulting from the different elastic layers of tree rings, unevenness caused by the cutting direction according to the direction of the fibers and unevenness caused by the destruction of wood mass [6].

The surface roughness means the totality micro-geometrical irregularities. These irregularities are reflected in the form of smaller or larger elevations [7]. Roughness depends on the micro-geometry of the cutting tool, wood species, moisture content and direction of milling.

2. Planing and quality of wood treatment

Planing is removal of a thin layer of wood from the surface of the workpiece which is processed. It is mostly flat surface in order to obtain a smooth surface and achieve a certain thickness. Planing is performed on planer machine, wherein the main movement is rectilinear, continuous and consists of working run when the tool operate and returning run when the tool returns to the starting position, Figure 1. Displacement movement is discontinuous, rectilinear and performs after completion of back step of the main movement.

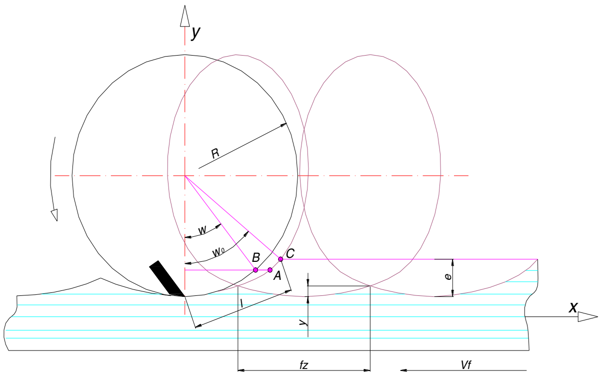

Fig. 1. Planing of wood workpiece.

Planing belongs to the milling processes. Milling is done at various machining systems: planning machines, milling machines, drills, etc. Turning the cutting head with a blade about its longitudinal axis, the blade will remove uniformly chips from the workpiece. In this case the cutting surface does not coincide with the cutting plane. When blade turns and workpiece performs rectilinear movement, cutting surfaces will obtain the cycloid shape ie its slice within longitudinal section, and straight line in cross-section, as shown in Figure 2.

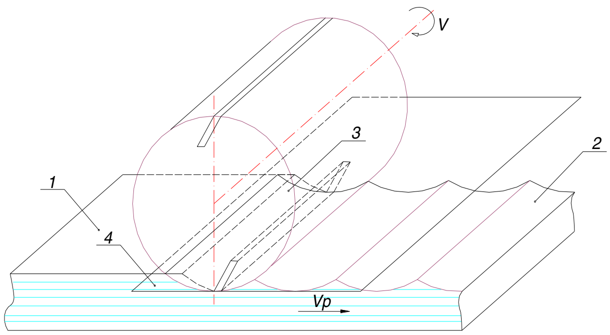

Fig. 2. Movement of the rotary blade (1- surface to be processed, 2- processed surface, 3 - cutting surface, 4- cutting plane).

Workpiece performs auxiliary movement $v_p \left[\frac{m}{min}\right]$ and it is reflected within constant delivery of the treated element toward the cutting zone. In the milling area there are three main areas: surface to be processed (1), processed surface (2) and the surface within cutting phase (3). In almost every milling operation, workpiece performs auxiliary movement. The direction of movement of the workpiece with respect to the direction of the cylindrical milling tool can have same or opposite direction. In opposite direction movement, depth of cut increases from zero to its maximum value a_{max}, near the exit point of the blade.

Thickness of chip is:

$$a = p_z \cdot sin\varphi \; [mm] \qquad (1)$$

Where:

p_z- feed per edge [mm].

φ- current angle of a cutting edge for a given point on the arc of contact.

Feed per edge p_z is the distance between two adjacent vertices of cycloid slice, measured in parallel to the velocity vector displacement. This is one of the most important characteristics of milling process.

$$p_z = \frac{v_p \cdot 1000}{n \cdot z} [mm] \qquad (2)$$

Where:

v_p- displacement speed, [m / min]

n - the number of revolutions of the cutting shaft, $[min^{-1}]$

z - number of blades.

Cutting speed v is the main characteristic of the machining process. Mathematically, cutting speed v is the geometric sum of the cutting speed of the blade and displacement speed v_p.

$$v = \overline{v_o} + \overline{v_p} \qquad (3)$$

Where:

v - linear cutting speed, $\left[\frac{m}{s}\right]$.

In process of cutting wood, displacement speed is always much smaller than the linear cutting speed. It is more convenient:

$$v = v_o = \frac{\pi \cdot D \cdot n}{60 \cdot 1000}, \left[\frac{m}{s}\right] \qquad (4)$$

Where:

D-diameter of cutting circle, $[mm]$
n- rpm of cutting shaft, $[min^{-1}]$
Contact angle between the blade and wood fibers is:

$$\varphi = \varphi_0 \pm \frac{\varphi_0}{2} \quad (5)$$

Where:
φ_0- contact angle of the workpiece following the arc, sign „+“ means the opposite direction, and the sign „-“ means the same direction displacement.

Influence of cutting speed on the quality of the processing wood and the fineness of treated surface is indisputable. If the blade penetrates slowly into the wood, some wood fibers which are in his path remain uncut, but sheared or broken [2]. The surface becomes rough and rugged. Contrary, at high cutting speed wood fibers do not attain to get out in front of the blades and are cut before it damages their interconnections with neighboring wood fibers. Increased cutting speed is twice as useful [5]. On one hand, better and cleaner treated surface is obtained, and on the other, the productivity of machines is increased, although the specific cutting resistance and cutting forces increase.

Length of kinematic waves $l_p = l_z$ [mm], which means that the length of kinematic waves depends on v_p. It is therefore important that the shift is small as possible, and that all blades on the tool describe the equivalent circuit to achieve a lower surface roughness. Length of kinematic waves depends on displacement speed, number of revolutions, diameter of the cutting circle, number of blades and of milling depth.

$$l_v = \frac{v_p \cdot 1000}{n \cdot z} \quad \text{ili} \quad l_v = 2 \cdot \sqrt{h_v \cdot (D - h_v)} \ [mm] \quad (6)$$

Where:
z - number of blades on the tool,
h_v- height or depth of kinematic waves, $[mm]$,

In longitudinal - transverse milling, impact of rake angle γ at height of kinematics bumps R_{zmax} depends on the contact angle with wood fibers. Increasing the angle γ from 30° to 50°, R_{zmax}increases and greater roughness is obtained [4]. With small angle γ, the lobes appear on treated surfaces. In tangential milling with increasing rake angle γ, height of cinematic prominence R_{zmax} decreases.

Increasing displacement speed v_p or feed per edge p_z, the roughness of treated surfaces increases. Figure 3, shows the influence of the feed p_z on the kinematic height of unevenness depending on the angle of the encounter with the wood fibers. Decrease of the feed per edge p_z causes reduction of the thickness of the chips and the creation of chips is manifesting without cracks in front of the cutting edge.

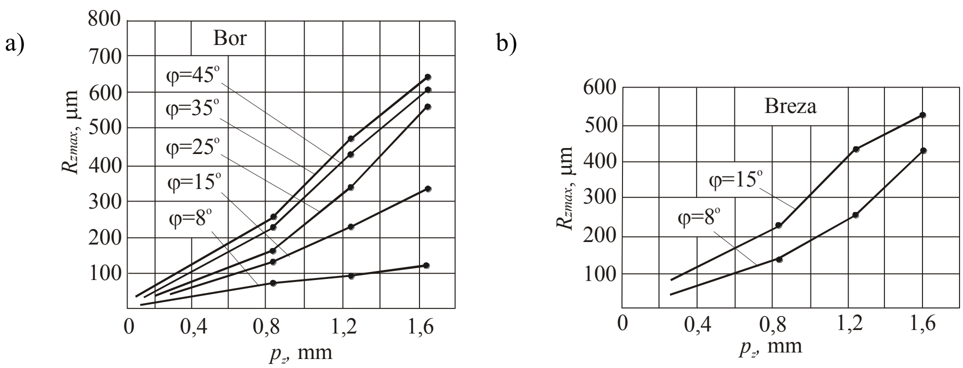

Fig. 3. Impact of feed per edge p_z on kinematic wave’s height; a) pine, b) birch.

3. Materials and methods

3.1. Material

For experimental analysis, the influence of the regime of processing is investigated on the treated surface quality and massive fir wood was used. Colour of the fir is usually bright reddish white and yellow. Anatomically there are no resinous canals as regular structure. Rings are distinctive and transition from young in old wood is slightly sharper. Fir massive wood is soft, the medium strength, medium durable and very good processed. The table 1 shows the data of physical - mechanical properties of fir wood.

Table 1. Physical-mechanical properties of massive fir wood.

Physical Properties			**Mechanical Properties**		
1	2	3	4	5	6
Density ρ_O $[kg/m^3]$		0,41	Hardness [MPa]	in bending	60,8
Shrinkage [%]	volume $[\beta_v]$	11,7		pressure	82,4
	tangentially $[\beta_t]$	7,6		tightening	0,25
	radial $[\beta_r]$	3,8		splitting	4,9
	longitudinal $[\beta_l]$	0,1		shear	42
	Volumetric shrinkage coefficient	0,25	Module of elasticity $[MP_a]$		10,7

Dimensions of massive fir samples for testing were 500x70x21 [mm]. Elements have had semi-radial texture, where moisture was 12 %. For surface treatment of solid fir wood, planer machining system for quadrilateral processing was used, Figure 4.

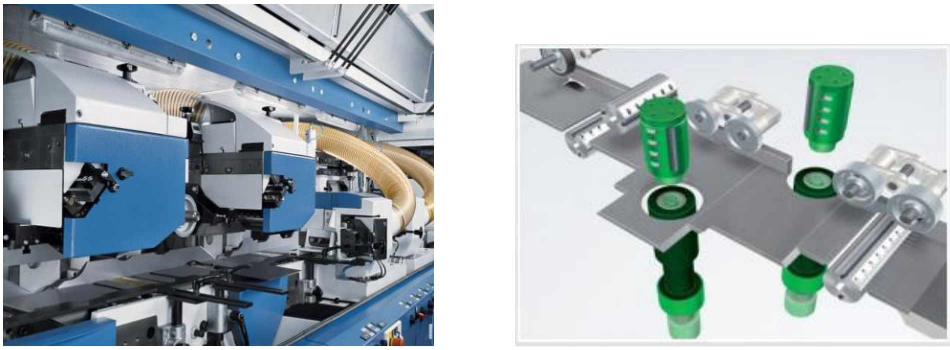

Fig. 4. Planer machining system for quadrilateral processing.

Planing operation is performed on the upper side of the workpiece. Working head-tool with four straight blades is mounted on the second working spindle of planer machine. The table 2 shows applied processing regimes for planning by groups of samples.

Table 2. Applied processing regimes.

Sample's label	$n = 6000[min^{-1}]$; $a = 2,0[mm]$; number of knives 4								
	$v_1 = 6[m/min]$			$v_2 = 12[m/min]$			$v_3 = 15[m/min]$		
	Rake angle γ			Rake angle γ			Rake angle γ		
	42^0	35^0	25^0	42^0	35^0	25^0	42^0	35^0	25^0
JL-A6	*								
JL-A12				*					
JL-A15							*		
JL-B6		*							
JL-B12					*				
JL-B15								*	
JL-C6			*						
JL-C12						*			
JL-C15									*

3.2. Method

In research and practice, for measurement and control of surface roughness two methods and two different measuring systems are used: the method "M" (Medium) and the method "E" (Envelop). Method "M" has been used for experimental analysis of surface roughness of solid fir wood.

Characteristics of the system "M" is reflected in the choice of surface profile length, as shown in Figure 5.

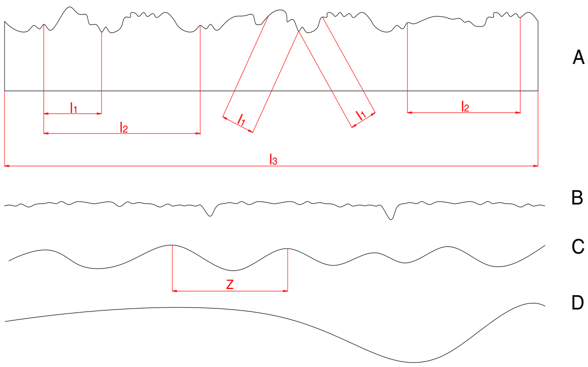

Fig. 5. Uncoupling of certain types of deviation in "M" systems.

Roughness is usually measured regarding to the mid reference line of *m* profile unevenness, which divides the profile that is within the measuring length l the value of square profile deviation is minimum from this line.

Measuring length *l* depends on the type and quality of treatment and also on the method of measurement. For assessment of surface roughness, in practice arithmetic mean deviation of the profile R_a is commonly used, which is equal to the arithmetic mean of the absolute values of the height profile of unevenness on the measuring length *l* (Figure 6).

$$R_a = \frac{1}{n}\sum_{i=1}^{n}|y_i| \qquad (7)$$

Where:

$R_a[\mu m]$ - arithmetic mean of profile deviation,

$l[\mu m]$ - measuring length of the surface roughness,

$y(x), yi[\mu m]$ – height of the surface roughness regarding to the mid reference line,

n – number of points for assessment of profile heights along the measuring length

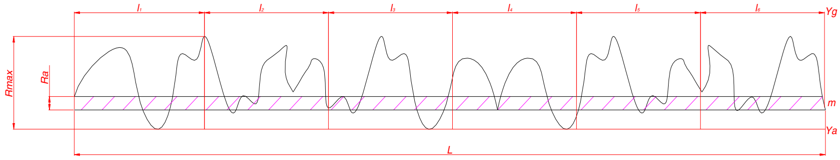

Fig. 6. Mid deviation or maximum depth of profile R_a.

Maximum depth or maximum height of unevenness is the distance between the upper and lower profile line;

$$R_{max} = y_g - y_d$$

Where:

y_g - upper profile line

y_d- lower profile line

Roughness measurement was carried out with electro - mechanical instrument Mitutoyo SJ-201, shown in Figure 7. Output measurement is obtained as a mean deviation of the profile R_a. A measuring instrument works on the principle of electro-mechanical profile recording with diamond needle.

Fig 7. Measurement of surface roughness using a device Mitutoyo SJ-201.

Roughness measurement of samples was done perpendicularly to the direction of extension of the wood fibers. Measurement was carried out in four points perpendicular to the length of the sample.

4. Results and discussion

This paper analyzes the impact of displacement speed and blade rake angle γ on surface roughness parameter of wood planing. Also, this paper analyzes the mean roughness parameters R_a.

Statistical analysis of the measured values of roughness parameters R_a at different displacement speeds for each group of fir samples is given in Table 3 and diagram of interdependency is shown in Figure 8.

Table 3. Statistical analysis of the value of roughness parameter R_a for fir.

		$R_a(\mu m)$				
Rake angle (^{0})	Displacement speed (m/min)	Minimum	Maximum	Arithmetic mean	Variance	Standard deviation
42	6	3,45	6,5	4,901	0,767	0,876
	12	4,18	7,55	5,708	0,756	0,869
	15	4,26	8,14	6,038	1,168	1,080
35	6	3,23	8,38	5,097	1,625	1,274
	12	3,37	7,29	5,240	1,354	1,164
	15	4,03	7,91	5,396	1,381	1,175
25	6	2,54	6,5	4,556	1,081	1,039
	12	2,43	7,08	4,628	1,621	1,237
	15	2,46	7,18	5,042	1,664	1,289

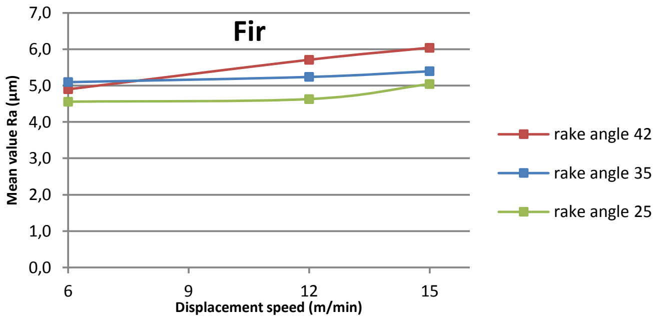

Fig. 8. Influence of displacement speed on the roughness of planed surface, R_a.

Based on the presented diagram it can be concluded that increasing displacement speed there is a higher mean values of parameter R_a.

With t - test method, mean differences of parameter R_a was checked for each pair of sets. Examination of the significance level of 5% between observed values of displacement speeds (6, 12, 15 m/min) and different rake angles (A-42^0, B-35^0, C-25^0) is shown in Table 4.

Table 4. Examination of significance level of 5% for each pair of sets.

ρ	Fir		
R_a	A	B	C
6 / 12	$\rho < 0,05$	$\rho > 0,05$	$\rho > 0,05$
6 / 15	$\rho < 0,05$	$\rho > 0,05$	$\rho > 0,05$
12 / 15	$\rho > 0,05$	$\rho > 0,05$	$\rho > 0,05$

In Table 4, it can be seen that processing the fir wood with rake angle of blade equal to 42^0, between the pairs of speeds 6 m/min and 12 m/min and pairs of speeds 6 m/min and 15 m/min, significant difference in level of significance 5% exists. Also, between the pairs of speeds 6 m/min and 12 m/min and pairs of speeds 6 m/min and 15 m/min, processing the fir wood with other two rake angles (case B and C), significant difference in level of significance 5% does not exist. It can also be seen, that between the pairs of speeds 12 m/min and 15 m/min for three different rake angles, significant difference in level of significance 5% does not exist.

Diagram of the measured mean values of roughness parameter R_a, planing with different rake angles γ, is shown in Figure 9. According to the presented diagram, it can be seen, that in the case of processing fir wood with rake angle γ=25°, R_a takes the lowest value.

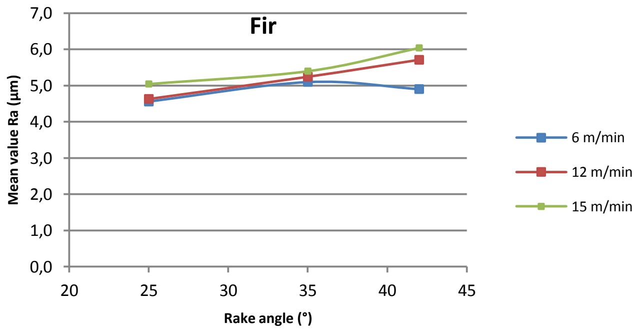

Fig. 9. Influence of rake angle on the roughness of planed surface, R_a.

T - test method was used to check the differences of arithmetic mean of R_a parameters for each pair of sets. Proven significance level of 5% between the observed values of rake angles for certain groups of data is shown in Table 5.

Table 5. Examination of significance level of 5% for groups of different rake angles.

ρ	Fir		
R_a	6	12	15
A / B	$\rho > 0,05$	$\rho > 0,05$	$\rho > 0,05$
A / C	$\rho < 0,05$	$\rho < 0,05$	$\rho < 0,05$
B / C	$\rho > 0,05$	$\rho > 0,05$	$\rho > 0,05$

From presented data it can be seen that for treatment of fir wood or to achieve better workpiece's surface, it is necessary to use a smaller rake angle of the blades then 25^0.

5. Conclusion

By observing the group of planed fir wood samples it can be seen that with increase of displacement speed there is higher mean roughness parameters R_a. The reason for the increase in roughness of planed surfaces at increasing displacement speed is reflected in the fact that the longitudinal and tangential cutting in front of the cutting edge creates cracks, which precedes the penetration of the blade in a wooden mass.

Measured roughness parameter R_a have the lowest value for the rake angle equal to 25^0. The minimum value of roughness parameter in processing fir wood elements is obtained using the displacement speed of 6 m/min and using a rake angle on the cutting edge equal to 25^0. From obtained data, it can be concluded that the greatest influence on the measured roughness parameters R_a of planed surface has a displacement speed while rake angle has a somewhat smaller impact.

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