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EFFECT OF ANGULAR GEOMETRY OF THE CUTTING TOOLS FOR MACHINING QUALITY THERMALLY MOGIFIED WOOD

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Abstract

This paper presents the impact of tool parameters (rake angle α) on the quality of machining for milling thermally modified pine wood. Experimental part of this work focuses on the evaluation tool effects (angular geometry, face angle 15°, 20°, 30°) and material (nature material, thermally modified on 160 °C, 180 °C, 210 °C, 240 °C) on indicators of surface finish (arithmetic average of the roughness profile R_a*). There was evidence of dependency surface finish by reducing the size of the cutting tool face angle.*

Key words: *angular geometry; cutting terms; flat milling; quality of surface; thermo-wood*

INTRODUCTION

Properties of thermally modified wood are examined for quite a long time and are well known to the professional public. Recently, the interest in such thermally modified wood is increased and it finds its application in various fields. Subsequent machining is also related with the growth of consumption of thermally modified wood what has connection with the issues of surface quality after machining such material (Reinprecht 2007). Most prevalent method of mechanical machining of wood is cutting with the formation of chips. This group of machining includes the milling machining as last operation before its use in a specific product with the required surface quality without further machining, such as grinding. In practice, it is very important that the machining process ran with the best output quality of surface finish. The surface quality is dependent on both the physical and mechanical properties of wood, as well as technical and technological conditions of the milling process. Proper choice of cutting conditions can increase the quality of wood surface during operation.

MATERIALS AND METHODS

The production of thermally modified wood is a thermal modification of natural wood at temperatures of 150 – 260 °C, which intentionally modifies the chemical structure of wood. The thermal modification of wood is based on the complex of intentional interference in its chemical structure. The main purpose of thermal modification of growth wood is to prepare such material that balances the following criteria: lower hygroscopicity; higher dimensional stability; higher resistance to wood-destroying fungi and insects, wood-

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coloring fungi and molds; to maintain or improve the aesthetic side – the color, the minimum proportion of cracks, gloss, texture, and others; maintaining or even improving of the mechanical properties – strength, hardness, rigidity (Reinprecht 2008; Cristiane 2012).

Milling

Milling means machining with the rotating tool such as a milling cutter or a milling head. This type of machining is used to achieve a smooth surface and precise dimensions of the workpiece or to create a contoured surfaces. Multiple wedge tools are used at milling. Individual cutting wedges come in and out of the cut sequentially (Siklienka and Kminiak, 2013; Borský 1992).

Surface roughness

Quality of cutting process means the result of whole tool action on the overall quality of product conditional on three types of accuracy: shape, dimensional and surface (roughness rate). Shape and dimensional accuracy of the workpiece is affected mainly by stiffness of the tool, precision of cutting and feeding mechanism of work machine, as well as precision of the cutting edge in multiple wedges tool. Roughness (micro roughness) and waviness (macro roughness) mainly dependent on the kinematic cutting conditions and they are affected by the following factors (Janda, Kminiak, 2013): method of particles separation, which depends not only on the method of machining, but also on the accuracy of operation of the tool and its geometry; cutting conditions (cutting speed, feed, etc.); Micro-geometry (dulling of cutting edge of the tool); physical and mechanical properties of the workpiece (density, hardness, texture) (Lisičan, 1988; Rousek *et al*. 2012).

METHODOLOGY

Impact angular geometry is one of the most important factors affecting the quality of the surface in face milling. Angle tool geometry is directly involved in the machining process the material and also affects the quality of the machined surface of the workpiece. In our case, the change in angular geometry made at values of face angle 15°, 20° a 30°.

Machinery characteristic

Samples were milled on an experimental device which was lower spindle milling machine, feeding was ensured by feeder Frommia (Fig. 1) with the parameters in Tab. 1. The experiment was performed in a development workshop of Technical University in Zvolen.

Fig. 1 Lower spindle mill with feeding mechanism

Tab. 1 Technical parameters of lower spindle mill FVS and feeding mechanism.

Lower spindle milling machine FVS		**Feeder Frommia**	
Supply voltage	360/220 [V]	Type	ZMD 252 / 137
Frequency	50 [Hz]	Feeding range	2,5 / 10 / 15 / 20 / 30 [$m.min^{-1}$]
Power	4 [kW]	Engine	380 [V] / 2 800 [m/min]
Year	1976	Year	1972
Manufacturer	Československé hudební nástroje Hradec Králové	Manufacturer	Maschinenfabrik Ferdinand Fromm

Milling heads characteristic

Milling heads for wood with interchangeable cutting plates FH 45 Stanon, produced in SZT - machinery Turany, with parameters in Tab. 2 were used in experimental measurements (Fig. 2).

Tab. 2 Parameters of the cutter body

Diameter of the cutter body	125 [mm]
Diameter of the cutter body with extended knife	130 [mm]
Thickness of the cutter body	45 [mm]
Number of knives	2
Cutting geometry	β = 45°, γ = 15°, 20°, 30°

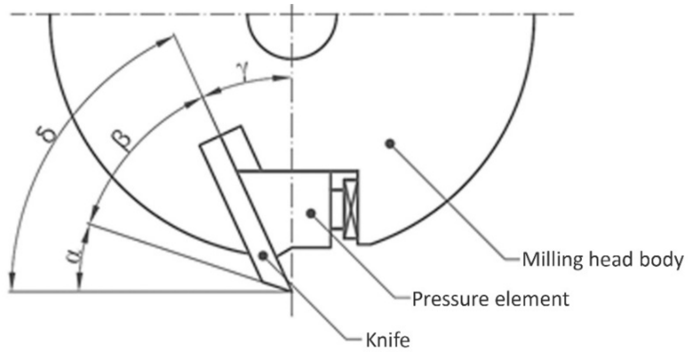


Fig. 2 Tool geometry

Cutting conditions for experimental measurements

Before the measurement sharpening of the replaceable blades of the cutter head was necessary, which was realized in the development workshop of the Technical University in Zvolen. Samples that were intended for experimental measurements were counter-milled along the fiber in various technical parameters and angular geometry of tool, Tab. 3, where there was only one knife in the cut depth of cut of 1 mm.

Tab. 3 Cutting terms

Cutting terms		Value
Feed speed v_f [m.min^{-1}]		6, 10, 15
Cutting speed v_c [m.s^{-1}]		20, 40, 60
Uhlová geometria nástroja [°]	Face angle	γ=15°,20°,30°
	Blade angle	β=45°
Depth of cut a_p [mm]		1
Thermal treatment of samples T [°C]		Native
		T=160
		T=180
		T=210
		T=240

Roughness measurements

Measurement of surface roughness of the samples was performed with laser profimeter LPM – 4 (Fig. 3). Digital camera captures images of laser line at a certain angle. The cross-sectional profile of the object is subsequently evaluated on the basis of image acquisition. The measurement of roughness was performed in three places of the sample – on beginning of the sample, on the center of the sample and on its end, for observation changes in surface roughness on entry of tool, after tool stabilization in cutting and at the tool exiting from the cutting process, and three wide zones, on the edges and in the middle of the sample. During the measurement programm LPMWiew was used for the evaluation. Results were processed in program STATISTICA 10 (Siklienka, 2007).

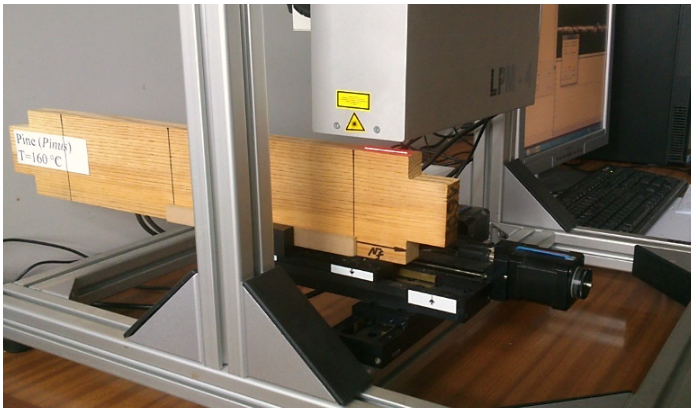


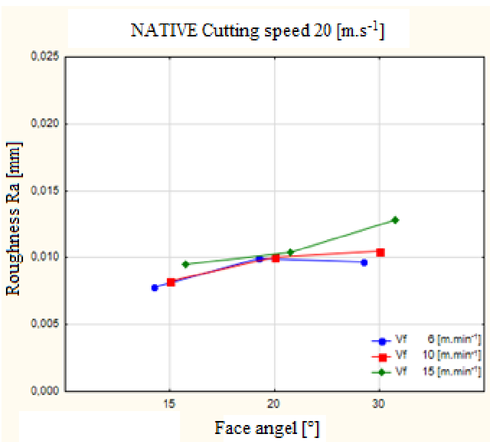
Fig. 3 Laser profilometer LPM – 4 during the measurement

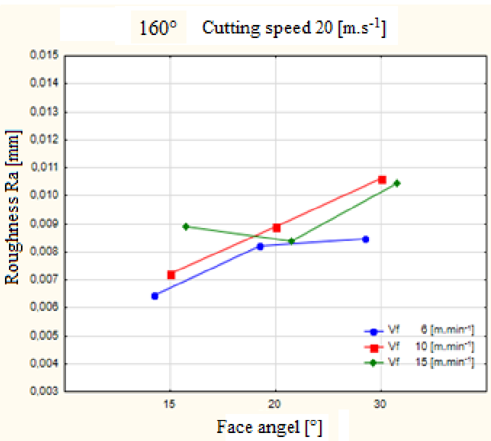
RESULTS AND DISCUSION

After the analysis of variance it was seen that clearly in all samples, the surface quality deteriorates with increasing angle positions. At face angle of 15° is the best surface roughness on all samples as with natural wood and tree species in the thermal treatment. By means of the multifactor analysis of the results it is clear that the best quality for a sample of the material by thermal treatment on 160°C. In terms of face angle, the best quality thermal treatment samples on 160°C are by using a face angle of 15°. The worst quality machined surface is at thermal treatment material on 240°C and at face angle of 30° (Tab. 4), Fig. 4, Fig. 5, Fig. 6, shows the variation of surface roughness on the face angle at different variant, cutting speed and feed speed.

Tab. 4 View dispersal and the likelihood of dependence of surface roughness on face angle at different variants of feed speed, thermal treatment and cutting speed 20, 40 a 60 [m.s^{-1}].

Cutting speed v_c [m.s^{-1}]	Effect	SS	Degr. of Freedom	MS	F	p
20 [m.s^{-1}]	Native	0,000005	4	0,000001	0,2926	0,878945
	160 °C	0,000007	4	0,000002	3,596	0,025304
	180 °C	0,000002	4	0,000001	1,126	0,375179
	210 °C	0,000009	4	0,000002	0,8224	0,527795
	240 °C	0,000014	4	0,000004	3,059	0,043613
40 [m.s^{-1}]	Native	0,000005	4	0,000001	1,040	0,414180
	160 °C	0,000008	4	0,000002	9,322	0,000291
	180 °C	0,000006	4	0,000002	3,485	0,028262
	210 °C	0,000003	4	0,000001	0,2730	0,891536
	240 °C	0,000001	4	0,000000	0,101	0,980883
60 [m.s^{-1}]	Native	0,000004	4	0,000001	1,052	0,408299
	160 °C	0,000003	4	0,000001	1,269	0,318589
	180 °C	0,000002	4	0,000000	0,304	0,871372
	210 °C	0,000002	4	0,000001	0,1772	0,947220
	240 °C	0,000001	4	0,000000	0,114	0,975990





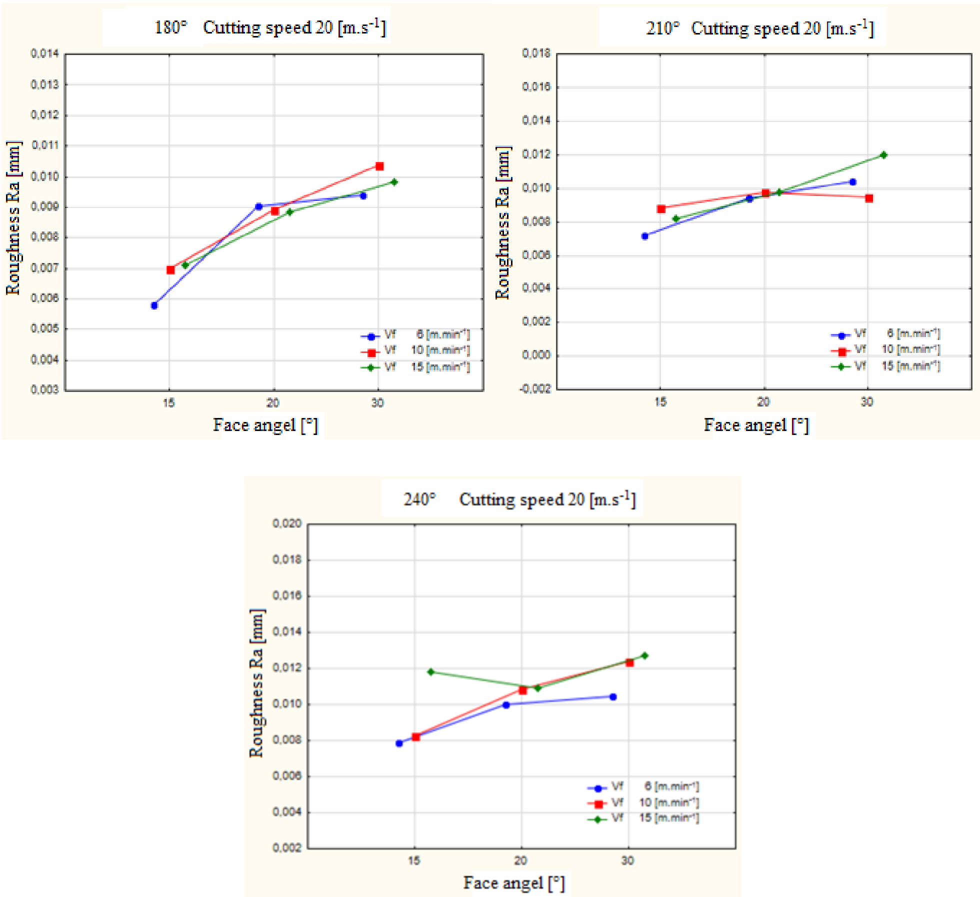
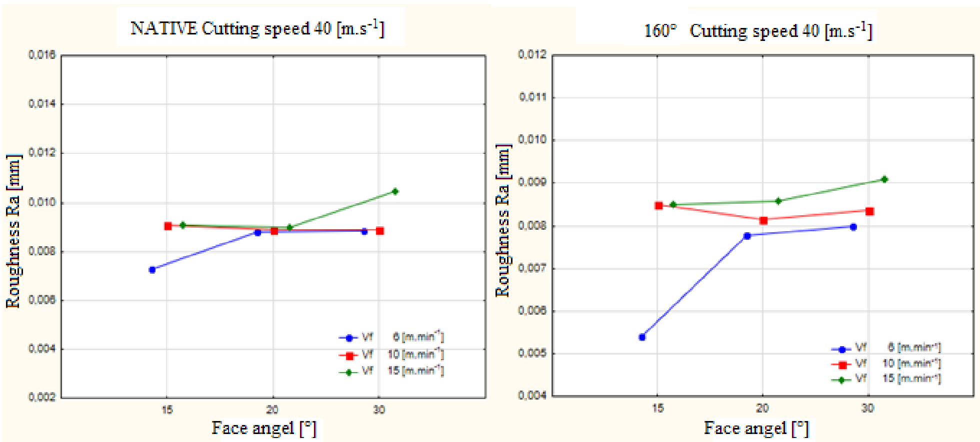


Fig. 4 Multifactor analysis of variance for Ra dependence on face angle, feed speed and cutting speed 20 [m.s^{-1}]



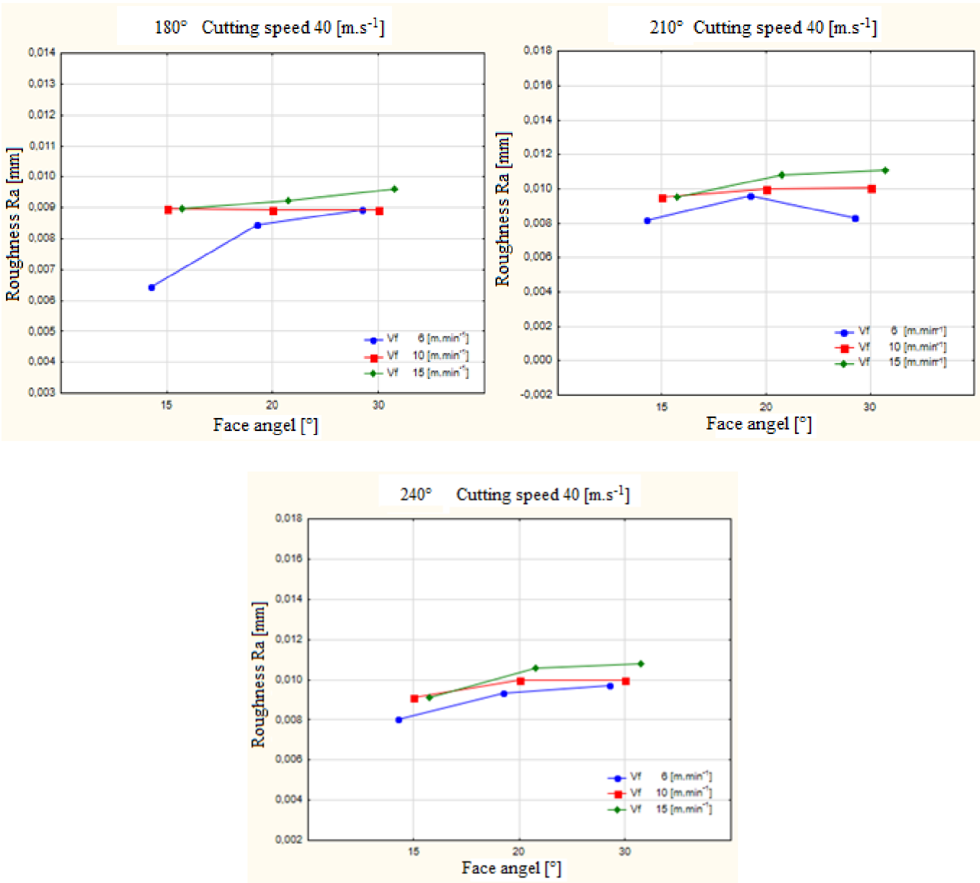
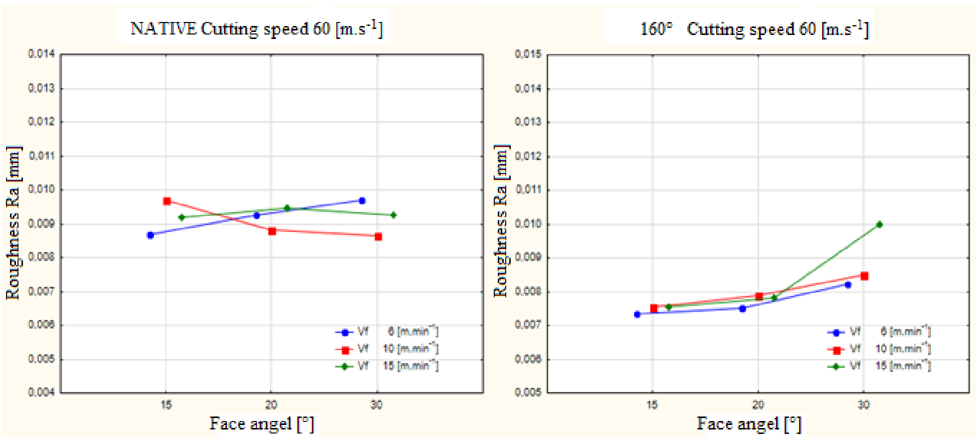


Fig. 5 Multifactor analysis of variance for Ra dependence on the face angle, feed speed and cutting speed 40 [m.s^{-1}]



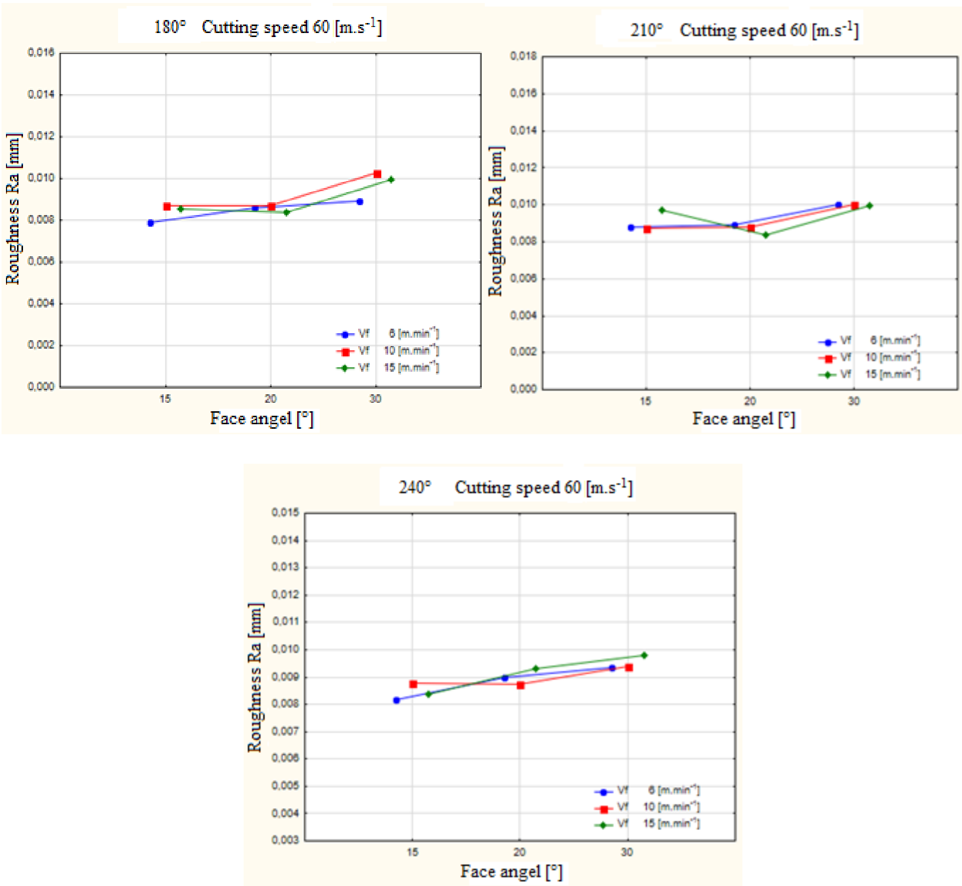


Fig. 6 Multifactor analysis of variance for Ra dependence on the face angle, feed speed and cutting speed 60 [m.s^{-1}]

Tab. 5 View dispersal and the likelihood of dependence of surface roughness on the face angel.

Effect	SS	Degr. of Freedom	MS	F	p
Face angel γ [°]	0,000160	2	0,000080	49,80	0,000000

Impact angular geometry

The most significant change of surface roughness on the thermally modified material is the heat treatment of materials on 160 °C. At this temperature, the surface obtain the best quality properties. As for the distribution of the angular geometries it is clear that decreasing the face angle made the best surface finish. The worst surface quality properties are exhibited in the thermal treatment of 240 °C and at maximum angle positions, which amounted to 30°.

CONCLUSION

Evaluation of experimental measurements can be said that the most influencing factor on the surface roughness is particularly angular geometry tool. Analyzing showed that this parameter has a clear progress for increasing surface roughness. Such a course has proved in all samples of thermal modified material and it was clear that at the slightest face angle is the best for quality pine wood. In view of the thermal treatment the best sample affected to 160 °C. Samples of affected above 200 °C have quality of lower level.

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