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INFLUENCE OF TOOL ANGULAR GEOMETRY ON SURFACE QUALITY AFTER PLAIN MILLING OF THERMALLY MODIFIED OAK WOOD

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Abstract

The article deals with examination of angle geometry of end quality results of natural and temperature modified oak wood during face milling. Experiment part focuses on evaluation of equipment impact (angle geometry - y = 15°, 20°, 30°) of material (of natural and temperature modified oak wood with temperature: 160 °C, 180 °C, 210 °C, 240 °C) and technology factors (such as: cutting velocity - vc = 20 $m.s^{-1}$, 40 $m.s^{-1}$, 60 $m.s^{-1}$) adjustable velocity - vf = 6 $m.min^{-1}$, 10 $m.min^{-1}$, 15 $m.min^{-1}$) on quality processing of surface (Ra - medium aritmetic deviation of surface). We have measured end quality of surface, using contactless method with help of device LPM - 4, which works on a principle of laser profilometry. The best quality of wood, we have gained during wood working with temperature treatment of 210 °C with cutting-edge side rake of 30° and on the contrary, the worst quality of wood, we have gained with the same temperature treatment of 210 °C, but with cutting-edge side rake of 15°.

Key words: *thermowood, angular geometry, surface roughness, thermal modification*

INTRODUCTION

Wood as renewable material is being used in different ways, especially in building industry. During working with natural wood in outdoor conditions, we however have certain restrictions, which are resulting from it's unwanted characteristics, among which we include poor resistance against biological attacks of wood-decaying fungi and wood-destroying insects, dimension instability and changes caused in consideration of atmospheric conditions. Disadvantages caused by these effects were overcome by use of more permanent kinds of hardwood, especially rain forest species, or by the means of wood preservation. To increase resistance of wood against decay are most often being used different chemicals (Kučerová et. al. 2016), but during chemical modification, during process of manufacture, we can get negative impact on environment, life span of wood and as well as during disposal or during recycling of wood. (Kocaefe et. al. 2008).

Because of that, we have to protect the wood against unwanted effects, so that it last's as long as possible. One of most used ways of how to improve it's properties and preservation of wood is temperature treatment. Thermal modification of wood is based on thermal and hydrothermal processing of wood with temperatures ranging from 150 °C to 260 °C. Under high temperatures polymers are degrading and new in water insoluble substances are being formed, in like manner as substances with toxic or repellent effect

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against biological pests, such as fungi and mushrooms (Kaplan et. al. 2018). In basic terms Thermowood requires higher caution during handling like ordinary wood, because during next processing is susceptible to mechanic deterioration due to increased brittleness. Thermo modified wood is more crack susceptible than untreated wood, whereas wooden elements are changing in irreversible way (Kminiak et. al. 2015).

Milling in present age is gaining ground in workmanship. Milling is method of chip formation, during which a layer of material is being removed from workpiece in form of small individual chips with help of multipurpose rotary machine, which we call mill, milling cutter, milling tool, milling machine (Sedlecký et. al. 2018). During milling, milling cutter is turning around it's rotary axis (main process of movement) and it's very teeth are gradually cutting through workpiece material, which at the same time moves in retrograde motion of machine (secondary process of movement), (Prokeš et. al. 1982). Each cutting blade of milling machine gradually removes short chips from workpiece material, at which process of milling is not interrupted (Lisičan et. al. 1996).

Increasing cutting speed results in better surface finish of workpiece from wood (Mithchell et. al. 2002). By end quality of cutting process, we understand operation of machine as a whole (with one or more cutting edges) in overall quality of surface, which are qualified by three kinds of accuracy: shape accuracy, dimensional accuracy and surface accuracy (Vančo et. al. 2017).

As long as we want to achieve high-quality finish of surface, we have to take care of proper sharpness of cutting tool during milling. It is however necessary to remove formation of chips, which are constantly emerging across the grain in a given type of machining on the beginning and on the end of milling, where cutting edge of cutting tool gets out of cut (Lisičan et. al. 2007).

MATERIALS AND METHODS

Sample preparation

For experimental measurements had been used species of oak wood (Ouercus robur L.) from locality Vlčí Jarok (Budča, Slovak Republic), 440 m. n. n.. Average age of round logs after counting annual rings was approximately 96 years. Wood species itself at average of 350 mm – 400 mm, had been in form of sawn timber secured by School's Woodland Enterprise in Zvolen. Experimental samples were made by machining round logs, at which each round log was needed for process of making/machining different series of samples. On log band saw, which is located in campus workshop of Technical University, by cutting round logs, we have gained cut timber with diameter of 25 mm. After cutting, we have fed the cut timber into kiln dryer, where it dried to moisture content of 10 %. During rip sawing, we were left with side tangential timber with width of 110 mm. By following scarfing and by thickness plan sawing the timber had reached exact thickness of 20 mm. On the circular saw, we have shortened the dimension timber on the required length of 500 mm.

Thermal modification of material

The wood samples were thermally modified at Volga State University of Technology, in town Joshkar-Ola, Russia. The development of thermal modification itself is displayed on the Fig. 1. and on the Tab. 1., where are the records of the time intervals of individual phases of thermal modification. During experiment was used one sample in natural state and remaining four were thermally modified by given temperatures.

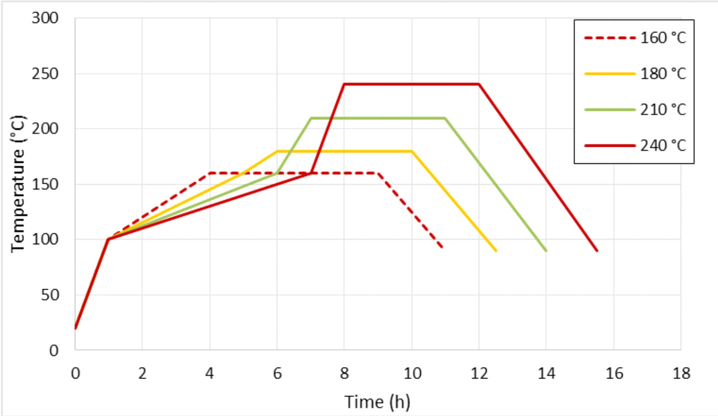

Fig. 1 Graphical progress of thermal modification of samples

Tab. 1 Process of thermal modification – phase of individual heat treatments

Temperature [°C]	Phase 1 [h]	Phase 2 [h]	Phase 3 [h]
160	4	5	2
180	5	5	2.5
210	6	5	3
240	7	5	3.5

Assessing wood density

In accordance to STN 49 0108 norm, for given experiment was being determined density of wood, which was next machined by lower spindle milling machine.

For the sake of wood density determination, 5 samples were made with dimensions of 20 x 20 x 30 mm (width x length x height). Number of individual samples during woodworking of average value was 16 pieces during individual thermal treatments. The samples themselves were measured on a adjustable digital meter with accuracy of 0.01 mm and with laboratory digital scales, weighed with accuracy of 0.01 g. After measuring and weighing were given values recorded in program EXCEL and by certain formula was calculated density of samples.

End measured values were compared with natural and thermally modified oak wood with thermal treatment of (160 °C, 180 °C, 210 °C, 240 °C).

Tab. 2 Measured density values of modified oak wood

Thermal modification [°C]	ρ [kg·m^{-3}]	Percentage change [%]
N	639	-
160	622	2.73
180	619	3.23
210	588	8.67
240	571	11.90

Description and characterization of the machine

For experiment was used Lower Spindle Milling Machine FVS (Limed, Hradec Králové, Czech Republic) with cylinder feeding system FROMMIA. All main parameters are recorded in Tab. 3.

Fig. 2 Lower Spindle Milling Machine with attached Feeder

Tab. 3 Technical parameters

Lower spindle mill FVS		Feeding device Frommia	
Supply voltage	360, 220 (V)	**Type**	ZMD 252 / 137
Cutting speed	20, 40, 60 (m·min^{-1})	**Feed**	2.5;10; 15; 20; 30 (m·min^{-1})
Input power	4 (kW)	**Motor**	360 (V), 2 800 (m·min^{-1})

Characteristics and description of the milling head

For experiment measurements were used 3 milling heads for milling wood, brand STANON made in SZT - machinery Turany with changeable cutting disks with type of marking FH 45, shown on the Fig. 3., with parameters in Tab. 4. Each milling head was equipped with two knives. One knife was attached so, the cut reduction of knife was 1 mm and the second knife was inserted in the milling head whole, so it really has been used to just balance the machine. Used cutting disks were made from steel Maximum Special 55: 1985/5 with hardness of 64 HRC WOOD-B, Nové Zámky, Slovakia).

Fig. 3 Used milling heads

Tab. 4 Milling heads parameters

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

Experimental milling

All samples were cross milled alongside fibers of wood, under given cutting requirements. Used cutting requirements are displayed in the Tab. 5, whereby on the Fig. 4 is stated the principle of experimental milling. Whole development of experimental plain milling happened in premises of development workshop in Zvolen.

Tab. 5 Cutting conditions for experiment

Cutting terms		Value
Feed speed v_f (m·min^{-1})		6, 10 15
Cutting speed v_c (m·s^{-1})		20, 40, 60
Cutting geometry (°)	**Face angle**	β = 45°
	Blade angle	γ = 15°, 20°, 30°
Depth of cut a_p (mm)		1
Thermal modification T (°C)		N
		160
		180
		210
		240

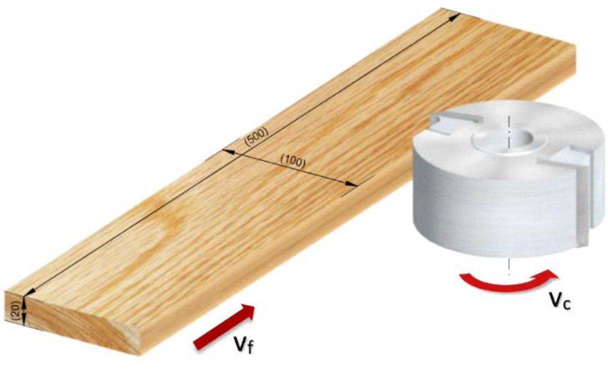

Fig. 4 Graphical representation of principle of machining samples

Measuring roughness of surface

The samples before experimental measuring, which were thermally modified had moisture content of 3 - 6 %. On the machined samples we have next measured roughness of surface with help of contactless laser profilometer LMP - 4 (Fig. 5), which works on a principle of laser profilometry. In Table 6 are displayed technical parameters of laser profilometer.

Fig. 5 For experimental measuring was used Laser profilometer LMP – 4

Tab. 6 Technical parameters of laser profilometer LMP – 4

Technical parameters LMP – 4	
Measuring range in axis (vertical)	420 mm to 470 mm
Measuring range in axis z	± 0.15 mm
Measuring range in axis x (transverse)	200 mm
Number of samples in axis x	1350
Processing speed	25 prof./s
Dispered laser angle	30°
Roughness parameters	R_p, R_v, R_z, R_a, R_q, R_c
Waviness parameters	W_p, W_v, W_z, W_a, W_q, W_c

All measurements taken with profilometer were evaluated and displayed on the personal computer, with help of software program LPM-View. The output figures gave us result of quality of surface, as well as it's primary profile and profile of it's roughness. Through the use of program STATISTICA 10 (StatSoft CR s.r.o., Prague, Czech Republic) were next the data taken processed. For the purpose of data evaluation has been used this program for interpretation of a single factor and of a two - factor analysis of dispersion with graphs and it's given relativity.

RESULTS AND DISCUSSION

Influence of angle geometry on surface roughness

Dispersion multifactor analysis in dependence on rake angle geometry from surface coarseness is displayed on the Fig. 6 and analysis of dispersion depending on rake angle geometry from surface coarseness is displayed on the Fig 7. From multifactor dispersion analysis we can see, that the best end quality finish of surface we have gained with thermal modification of 160 °C. The best values of wood machining of surface we have gained with sample thermally modified at 210 °C with machine rake angle of 30°. By contrast the worst values of surface wood machining were gained with machine rake angle of 15° and thermal modification of 210 °C.

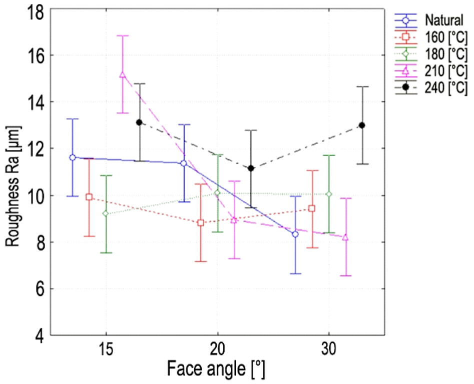

Fig. 6 Multifactor analysis of variance for the dependence of rake angle speed on surface quality

In Table 7 are dispersal 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 [$m.s^{-1}$]. Via this table we can see, that statistically important result is thermally modified wood treated at 210 °C with cutting speed 60 $m.s^{-1}$.

Tab. 7 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	Native	66,053	4	16,513	1,7961	0,158767
	160 °C	23,468	4	5,867	0,4672	0,759202
	180 °C	34,477	4	8,619	2,645	0,055319
	210 °C	119,424	4	29,856	1,6828	0,183019
	240 °C	19,654	4	4,913	0,4392	0,779148
40	Native	20,196	4	5,049	0,6934	0,603003
	160 °C	46,491	4	11,623	0,8065	0,531908
	180 °C	16,204	4	4,051	1,2696	0,306258
	210 °C	67,367	4	16,842	0,9597	0,445484
	240 °C	23,499	4	5,875	0,7233	0,583666
60	Native	69,509	4	17,377	0,9832	0,433247
	160 °C	19,005	4	4,751	0,3023	0,873858
	180 °C	13,080	4	3,270	0,8571	0,502010
	210 °C	1673,940	4	418,485	6,7363	0,000678
	240 °C	27,040	4	6,760	0,2090	0,931166

From worked out analysis of dispersion it is visible, that with each graph with increasing face angle the quality of machined surface is at the same time decreasing. The best quality of machined surface, we have gained during thermal treatment of 210 °C, with use of face angle of 30°. The worst quality, we have gained during thermal treatment of 210 °C and with tool face angle of 15°. During machining all samples of natural character and samples with thermal treatment the best results worked out to be with use of tool with face angle of 30°.

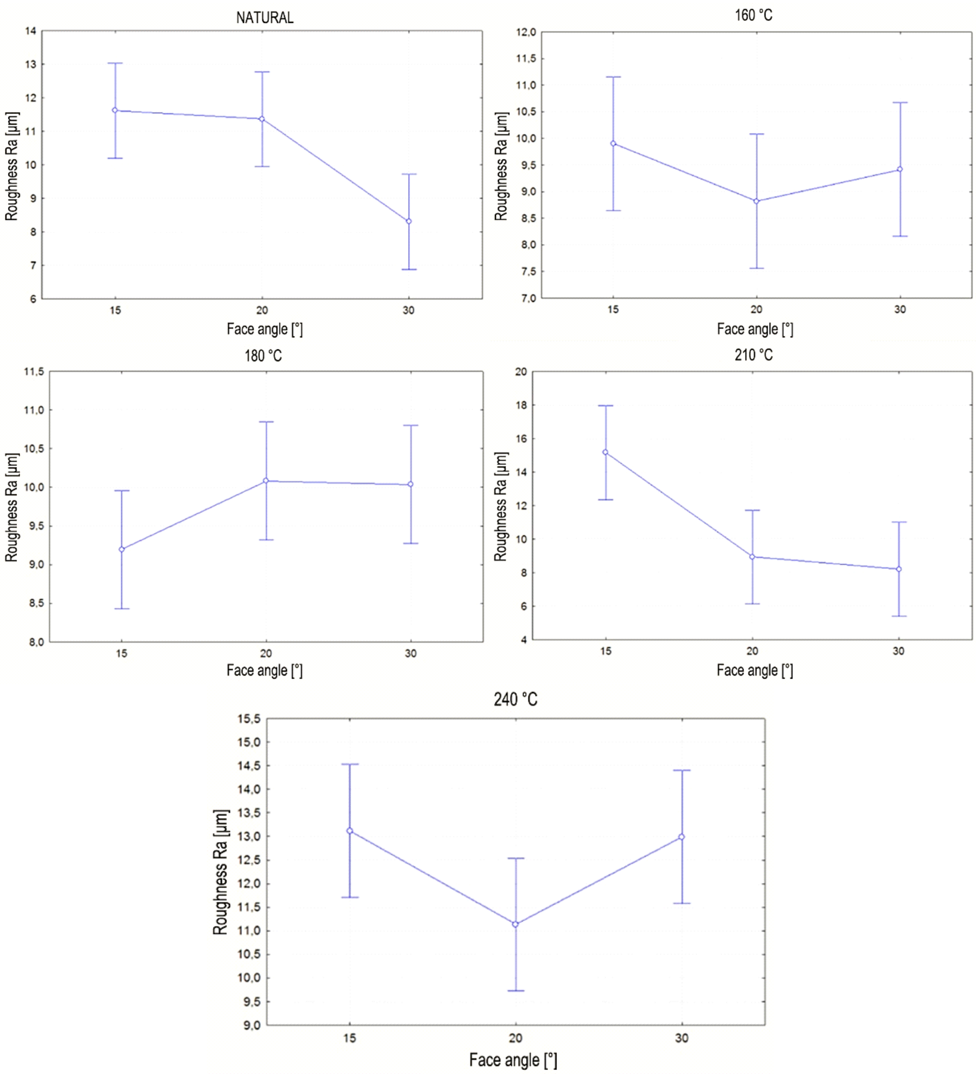

Fig. 7 Analysis of variance for the dependence of surface roughness on the rake angle

CONCLUSIONS

The report has been fixated on reaching most optimal tool face angle during wood machining samples, during which one sample was in natural state and the ones left were thermally modified. During measuring we have realized, that during wood machining of used samples the lowest value of roughness was reached during heat treatment of 210 °C with tool face angle of 30°. With gradual tool face angle increase was found, that roughness of surface of all samples was decreasing. In our experiment it has been proven, that during the smallest face angle was roughness of surface the worst and with gradual growth of face angle, we have gained the best roughness of wood machined surface. During given experiment wasn't proven the fact, during which with increasing tool face angle, simultaneously worsens the quality of wood machined surface of material. On basis of roughness research of thermally modified wood, we can in present time compare our work with authors, such as Barcík et. al. 2014 and Kvietková 2015. The authors were in their works dealing with pinewood (Barcík) and with beech wood (Kvietková). The surface roughness measurement and it's evaluation in their case was executed with contact method.

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REFERENCES CITED

BARCÍK, Š. ,GAŠPARÍK, M., HOUSKA, A., RAZUMOV, E., JU., SEDLECKÝ, M. 2014. "Vliv technologických faktorů na kvalitu opracování povrchu při frézování termicky modifikovaného borovicového dřeva [Influence of technological factors on the surface quality after milling of thermally modified pine wood]," In: Trieskové a beztrieskové obrábanie dreva 2014: Zborník prednášok [Chip and Chipless Woodworking Processes 2014: Conference Proceedings], Zvolen, Slovakia pp. 11-22.

BOONSTRA, M. J., VAN ACKER, J., PIZZI, A. (2007). "Anatomical and molecular reasons for property changes of wood after full-Scale industrial heat-treatment," Proceedings of the Third European Conference on Wood Modification, Cardiff, UK, pp. 343-358.

GAFF, M., KVIETKOVÁ, M., GAŠPARÍK, M., KAPLAN, L., BARCÍK, Š. (2015) "Effect of selected parameters on the surface waviness in plane milling of thermally modified birch wood," BioResources 10(4), 7618-7626. DOI: 10.15376/biores.10.4.7618-7626

HORÁČEK, P. 1998. Fyzikální a mechanické vlastnosti dřeva 1. vyd. [Physical and Mechanical Properties of Wood, 1st edition], Mendel University, Brno, Czech Republic

KAČÍKOVÁ, D., KAČÍK, F. 2011. Chemické a mechanické zmeny dreva při termickej úprave [Chemical and Mechanical Changes During Thermal Treatment of Wood], Technical University in Zvolen, Zvolen, Slovakia

KAPLAN, L., SEDLECKÝ, M., KVIETKOVÁ, MS., SIKORA, A. (2018). "The Effect of Thermal Modification of Oak Wood on Waviness Values in the Planar Milling Process, Monitored with a Contact Method," BioResources 13(1), 1591-1604. DOI: 10,15376 / biores.13.1.1591-1604

KMINIAK, R., GAFF, M., (2015). "Roughness of Surface Created by Transversal Sawing of Spruce, Beech, and Oak Wood," BioResources 10(2), 2873-2887. DOI: 10.15376/biores.10.2.2873-2887

KOCAEFE, D., PONCSAK, S., BOLUK, Y. (2008). "EFFECT OF THERMAL TREATMENT ON THE CHEMICAL COMPOSITION AND MECHANICAL PROPERTIES OF BIRCH AND ASPEN," BioResources 3(2), 517-537.

KUČEROVÁ, V., LAGANA, R., VYBOHOVA, E., HYROGOVÁ, T. (2016). "Effext of Chemical Changes during Heat Treatment on the Color and Mechanical Properties of Fir Wood," BioResources 11(4), 9079-9094. DOI: 10.15376/biores.11.4.9079-9094

LISIČAN, J. (2007) Teória a technika spracovania dreva [Theories and Techniques of Wood Processing], Mat Centrum, Zvolen. Slovakia, pp. 102-104

MITCHELL, PH., LEMASTER, RL. (2002). "Investigation of machine parameters on the surface quality in routing soft maple," BioResources 52(6), 85-90

PROKEŠ, S. (1982). Obrábění dřeva a nových hmot ze dřeva [Machining of wood and new wood materials], SNZI, Prag, Czech Republic

REINPRECHT, L., VIDHOLDOVÁ, Z. 2008. Termodrevo – Príprava, Vlastnosti a Aplikácie [Thermowood – Preparation, Properties and A

pplications], Technical university in Zvolen, Zvolen, Slovakia

SEDLECKÝ, M., KVIETKOVÁ, MS., KMINIAK, R. (2018). "Medium-density Fiberboard (MDF) and Edge-glued Panels (EGP) after Edge Milling-Surface Roughness after Machining with Different Parameters," BioResources 13(1), 2005-2021. DOI: 10.15376/biores.13.1.2005-2021

VANČO, M., JAMBEROVÁ, Z., BARCÍK, Š., GAFF, M., CEKOVSKÁ, H., KAPLAN, L. (2017). "The Effect of Selected Technical, Technological, and Material Factors on the Size of Juvenile Poplar Wood Chips Generated during Face Milling," BioResources 12(3), 4881-4896.