The Effect of Thermal Modification of Oak Wood on Waviness Values in the Planar Milling Process, Monitored with a Contact Method

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This article focuses on the evaluation of the process of planar milling of natural and thermally modified oak wood. The standard Thermowood process was used for the thermal modification. The quality of the machined surface was evaluated after planar milling. Various machining process parameters were set for individual samples. The effects of individual technical and technological factors on the quality of the newly created surface were subsequently evaluated. The mean arithmetic deviation of the waviness profile (W_a) was chosen as the evaluation parameter for milling. The effects of the following factors were monitored: cutting speed, feed rate, rake angle, and their mutual combinations. Natural and thermally modified oak wood were milled and subsequently evaluated. The quality of the machined surface was determined using a contact measuring device. Reducing the cutting speed increased the waviness, and decreasing the feed rate decreased the waviness. However, the cutting speed was not a statistically significant factor. The rake angle proved to be a factor that significantly affected the surface waviness. Thermal modification had a statistically significant effect on the surface waviness.

Keywords: Surface waviness; ThermoWood; Planar milling; Machining parameters

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INTRODUCTION

Wood as a renewable raw material has been used for centuries for energy purposes. As a raw material it has been suitable for the construction of houses and furniture production (Gaff 2014; Gašparík and Gaff 2015; Sarvašová *et al*. 2015). This is due to its favorable properties, including flexibility, low density, and easy machinability. As other materials, wood also has some unfavorable properties such as anisotropy, easy ignitability, and finally, its relatively poor resistance to wood-destroying insects and wood-decaying fungi (Bekhtam *et al.* 2014; Gottlöber *et al.* 2016).

For several centuries, efforts have been made to maximize the protection of wood against wood-decaying fungi. In recent decades, wood has been protected with the help of assorted chemicals with varying degrees of negative impact on human health and the environment. Wood protection by thermal modification is currently beginning to expand. During thermal treatment, the wood is exposed to high temperatures under atmospheric pressure and with either a normal oxygen content or a reduced oxygen content (Brito *et. al.* 2006). The thermal modification method consists of heating the material for a certain period of time to 160 to 260 °C (Vovelle and Mellottee 1982; Guedira 1988; Welzbacher *et al.* 2008; Welzbacher *et al.* 2011).

The degree of color change that occurs during the treatment process depends on the final thermal modification temperature. The higher the treatment temperature, the darker the shade of the modified wood (Gündüz *et al.* 2008; Kačík *et al.* 2012; Lahtela and Kärki 2016; Metsä-Kortelainen, and Viitanen 2017). Thermal modification of wood also changes the internal structure of the material, which is associated with changes in both physical and mechanical properties.

Both air-dried and wet wood can be subjected to thermal modification. During the production process, thermal energy is supplied by either electric heaters or by thermal oil tanks. The gases released from the wood can be used for energy purposes by combustion, while simultaneously ensuring the environmental aspect of the production process, with no environmental pollution (Reinprecht and Vidholdová 2008).

Thermally modified wood is used as a substitute for natural wood in places where higher resistance is required or for its aesthetic properties, which are different from those of natural wood.

Because of the wide possibilities of its use, it is necessary to machine the modified wood. Thermally modified wood is machined with technological devices that are used for machining wood without additional thermal treatment. Planar milling is considered to be a very popular machining process. During planar milling, material is removed by a rotating tool; in this process there is the linear motion of the machined material as well as the rotary motion of the tool, which results in the cycloidal motion of the tool blades (Lisičan 1996).

For further wood processing, it is very important to monitor the quality achieved during the individual machining processes (Kminiak, and Gaff 2015). During milling, a very important factor, in terms of the quality of the machined surface, is the waviness (W_a - mean arithmetic deviation of the waviness profile). Waviness means regularly recurring peaks and recesses of generally identical shape and size. The resulting quality is influenced by many individual factors and their interaction.

The goal of this work was to expand our knowledge and determine the effect of different cutting speeds and feed rates on the quality of the treated surface of both natural oak wood and oak wood thermally modified at different degrees of thermal modification.

EXPERIMENTAL

Materials

The samples were prepared from oak wood (*Quercus robur* L.) that was logged in Vysočina, near Polná, in the Czech Republic. Radial cut wood from the trunk was used to produce 20 x 100 x 450 mm (h x w x l) samples. The machining and measurement were performed on the tangential parts of the samples. The samples were divided into four groups by five samples according to temperature: untreated wood (20 °C), and thermally treated wood (160, 180, or 210 °C).

Before the thermal modification, all samples were dried to 0% moisture content. The samples were dried at 103 ± 2 °C (Table 2).

The next step after drying was thermal modification, which was performed with the standard “Thermowood” process. The oak wood was thermally modified in the Katres chamber (Katres Ltd., Jihlava, Czech Republic). The samples were placed on metal plates, which were subsequently placed in a thermal modification chamber.

After the thermal modification, the density of each sample was determined (Table 2).

The Thermowood process took place in three stages:

Stage 1 – Heating and drying
Stage 2 – Thermal modification
Stage 3 – Cooling and climatization

The duration of each stage is recorded in Table 1 and Fig. 1.

Table 1. Thermal Modification Process Parameters

Thermal Modification Process						
Parameters	**T-160**		**T-180**		**T-210**	
Heating	20-160 °C	10.6 h	20-180 °C	11.4 h	20-210 °C	14.6 h
Thermization	160 °C	3 h	180 °C	3 h	210 °C	3 h
Cooling	160-20 °C	2.2 h	180-20 °C	2.8 h	210-20 °C	3.1 h
Total modification time	**15.8 h**		**17.2 h**		**20.7 h**	

Table 2. Average Density

At the Time of Testing				
Test samples	T - 20	T - 160	T - 180	T - 210
Density (kg m^{-3})	722.1	713.2	697.1	655.4
Moisture content (%)	0	0	0	0

Methods

The prepared samples were machined using a one-spindle FVS milling cutter (Table 3), which was equipped with a 125 x 45 x 30 mm milling head (Fig. 1). Three milling heads were used (each with a different angle of attachment of the "*Maximus*" milling cutter and therefore a different rake angle).

Fig. 1. Milling tool

The machined material was fed by the Maggi Steff feeder (Maggi Technology, Certaldo, Italy) Table 3 shows that the samples for measuring waviness were created for all combinations of variable parameters for all types of machined material (T - 20; T - 160;

T - 180; and T - 210 °C). The variable parameters are: cutting speed (20 m/s; 30 m/s; and 40 m/s), feed rate (4 m/min; 8 m/min; and 11 m/min), and rake angle (15°; 20°; and 25°). For each temperature, 27 samples were used, totaling 108 samples.

The material removal in one passage of the milling cutter was 1 mm. The machined side and the feed direction were marked on the resulting samples.

The cutting speed was defined by the spindle speed and the diameter of the used milling head with the tool.

Table 3. Machine Parameters

Machine Parameters		
Parameter / Machine	**Milling Machine**	**Feeder Device**
Manufacturer	Československé hudební nástroje	Maggi
Type	FVS	Steff
Year of manufacture	1975	2005
Current system (V)	380	380
Power (kW)	5,2	0,6 / 0,8
Frequency (Hz)	50	50
Cutting speed ($m.s^{-1}$)	20, 30, 40*	-
Feed rate ($m.min^{-1}$)	-	4, 8, 11

The Talysurf Intra 2 measuring device (Taylor Hobson, Leicester, UK) was used to measure the waviness (Fig. 2). The longitudinal axis of the measured sample was parallel to the travel path of the measuring device. The sample was measured at the center and 60 mm from each end of the sample on the longitudinal axis. Each of the three parts where the sample was labeled was measured 3 times, which is 9 measurements on each sample for waviness.

Fig. 2. Detail of scanning arm

The surface was scanned with a diamond tip arm (Fig. 3) that was inserted in the inductive sensor. This sensor converts the surface structure into electronic form. The arm is placed in the sensor with a cutting insert, and it is also inserted into a housing that transfers its movements to an anchor surrounded by a coil. This coil induces a voltage that is further converted to the USB bus data stream. All measurements were performed according to ISO 4287 (1997) and ISO 4288 (1996).

RESULTS AND DISCUSSION

Table 4 shows the average values of the monitored characteristics, values measured for each set of test specimens, and the corresponding coefficient of variation.

Table 4. Effect of Individual Factors on the Monitored Characteristics in Wood without Thermal Modification and Wood Thermally Modified at 160°C, 180 °C, and 210 °C

Temperature (°C)	Cutting Speed (m*s^{-1})	Angle (°)	Feed Rate (m*min^{-1})	W_a (μm)
20	**20**	**15**	**4**	6.8 (12.4)
20	**20**	**15**	**8**	11.0 (13.3)
20	**20**	**15**	**11**	14.5 (5.8)
20	**30**	**15**	**4**	7.5 (19.4)
20	**30**	**15**	**8**	10.2 (11.8)
20	**30**	**15**	**11**	14.5 (19.3)
20	**40**	**15**	**4**	12.3 (17.4)
20	**40**	**15**	**8**	10.2 (10.0)
20	**40**	**15**	**11**	10.2 (14.6)
20	**20**	**20**	**4**	7.5 (17.5)
20	**20**	**20**	**8**	10.7 (13.4)
20	**20**	**20**	**11**	15.5 (11.2)
20	**30**	**20**	**4**	7.5 (17.9)
20	**30**	**20**	**8**	9.8 (17.0)
20	**30**	**20**	**11**	10.4 (8.0)
20	**40**	**20**	**4**	15.8 (10.1)
20	**40**	**20**	**8**	11.7 (19.3)
20	**40**	**20**	**11**	8.9 (12.6)
20	**20**	**25**	**4**	4.2 (17.8)
20	**20**	**25**	**8**	8.5 (16.6)
20	**20**	**25**	**11**	6.2 (14.7)
20	**30**	**25**	**4**	4.0 (19.6)
20	**30**	**25**	**8**	6.8 (10.6)
20	**30**	**25**	**11**	4.7 (11.6)
20	**40**	**25**	**4**	3.0 (9.7)
20	**40**	**25**	**8**	**4.9 (10.4)**
20	**40**	**25**	**11**	**7.1 (13.8)**
160	**20**	**15**	**4**	**7.9 (15.7)**
160	**20**	**15**	**8**	**11.8 (9.0)**
160	**20**	**15**	**11**	11.5 (10.6)
160	**30**	**15**	**4**	13.7 (15.1)
160	**30**	**15**	**8**	7.3 (13.3)
160	**30**	**15**	**11**	15.8 (19.8)
160	**40**	**15**	**4**	7.7 (16.5)
160	**40**	**15**	**8**	4.9 (11.7)
160	**40**	**15**	**11**	4.6 (8.4)
160	**20**	**20**	**4**	7.8 (14.0)
160	**20**	**20**	**8**	12.4 (18.2)
160	**20**	**20**	**11**	14.9 (10.5)
160	**30**	**20**	**4**	5.6 (5.4)
160	**30**	**20**	**8**	6.9 (14.7)

Temperature (°C)	Cutting Speed (m*s^{-1})	Angle (°)	Feed Rate (m*min^{-1})	W_a (µm)
160	**30**	**20**	**11**	5.8 (11.5)
160	**40**	**20**	**4**	8.2 (14.7)
160	**40**	**20**	**8**	7.8 (9.1)
160	**40**	**20**	**11**	8.1 (13.1)
160	**20**	**25**	**4**	2.9 (19.8)
160	**20**	**25**	**8**	5.4 (18.3)
160	**20**	**25**	**11**	8.3 (18.7)
160	**30**	**25**	**4**	4.3 (11.5)
160	**30**	**25**	**8**	2.7 (14.4)
160	**30**	**25**	**11**	3.5 (10.5)
160	**40**	**25**	**4**	2.0 (4.3)
160	**40**	**25**	**8**	5.3 (19.8)
160	**40**	**25**	**11**	4.6 (18.3)
180	**20**	**15**	**4**	5.3 (13.9)
180	**20**	**15**	**8**	9.9 (14.2)
180	**20**	**15**	**11**	13.2 (16.1)
180	**30**	**15**	**4**	10.9 (14.2)
180	**30**	**15**	**8**	16.7 (17.9)
180	**30**	**15**	**11**	14.9 (17.4)
180	**40**	**15**	**4**	9.8 (12.2)
180	**40**	**15**	**8**	9.3 (19.4)
180	**40**	**15**	**11**	10.6 (8.7)
180	**20**	**20**	**4**	7.1 (10.5)
180	**20**	**20**	**8**	10.1 (12.5)
180	**20**	**20**	**11**	14.9 (7.0)
180	**30**	**20**	**4**	5.2 (13.6)
180	**30**	**20**	**8**	9.4 (11.7)
180	**30**	**20**	**11**	4.9 (18.4)
180	**40**	**20**	**4**	23.8 (12.2)
180	**40**	**20**	**8**	6.9 (18.7)
180	**40**	**20**	**11**	12.0 (14.6)
180	**20**	**25**	**4**	2.0 (3.2)
180	**20**	**25**	**8**	4.8 (11.2)
180	**20**	**25**	**11**	6.5 (9.3)
180	**30**	**25**	**4**	2.7 (15.5)
180	**30**	**25**	**8**	3.0 (14.2)
180	**30**	**25**	**11**	4.6 (17.4)
180	**40**	**25**	**4**	2.2 (3.5)
180	**40**	**25**	**8**	3.8 (10.1)
180	**40**	**25**	**11**	5.5 (12.9)
210	**20**	**15**	**4**	3.3 (17.9)
210	**20**	**15**	**8**	8.0 (17.0)
210	**20**	**15**	**11**	12.0 (11.2)
210	**30**	**15**	**4**	23.4 (18.6)
210	**30**	**15**	**8**	13.2 (16.5)
210	**30**	**15**	**11**	20.4 (13.9)
210	**40**	**15**	**4**	4.9 (12.5)
210	**40**	**15**	**8**	12.5 (14.3)
210	**40**	**15**	**11**	12.6 (18.5)
210	**20**	**20**	**4**	10.5 (11.3)
210	**20**	**20**	**8**	8.3 (19.6)

Temperature (°C)	Cutting Speed (m*s^{-1})	Angle (°)	Feed Rate (m*min^{-1})	W_a (µm)
210	**20**	**20**	**11**	16.0 (10.4)
210	**30**	**20**	**4**	15.1 (17.4)
210	**30**	**20**	**8**	6.1 (16.9)
210	**30**	**20**	**11**	10.2 (19.0)
210	**40**	**20**	**4**	16.8 (7.1)
210	**40**	**20**	**8**	8.6 (17.0)
210	**40**	**20**	**11**	9.7 (3.2)
210	**20**	**25**	**4**	5.8 (18.5)
210	**20**	**25**	**8**	6.8 (7.6)
210	**20**	**25**	**11**	7.0 (9.6)
210	**30**	**25**	**4**	3.1 (11.9)
210	**30**	**25**	**8**	4.4 (14.7)
210	**30**	**25**	**11**	9.7 (15.8)
210	**40**	**25**	**4**	2.4 (13.2)
210	**40**	**25**	**8**	3.9 (16.9)
210	**40**	**25**	**11**	5.6 (15.7)

Values in parentheses are coefficients of variation (CV) in %.

Table 4 shows the average values of the monitored characteristic, the values measured for each set of test specimens without thermal modification (20 °C) and thermally modified at 160 °C, 180 °C, and 210 °C and the corresponding coefficient of variation.

A multifactor analysis of variance (ANOVA) evaluating the effect of individual factors as well as the effect of two-, three-, and four-factor interactions was used to evaluate the measured values.

Table 5. Statistical Evaluation of the Effect of Factors and Their Interaction on the Mean Arithmetic Deviation of the Waviness Profile

Monitored Factor	Sum of Squares	Degree of Freedom	Variance	Fisher's F- Test	Significance Level *P*
Intercept	24362.15	1	24362.15	1637.927	***
1) Cutting speed (m.s-1) “CS”	24.09	2	12.04	0.810	NS
2) Tool's rake angle (°) “TRA”	2471.52	2	1235.76	83.083	***
3) Feed rate (m/min) “FR”	284.19	2	142.09	9.553	***
4) Thermal modification °C “TM”	208.43	3	69.48	4.671	***
“CS” * “TRA”	813.93	4	203.48	13.681	***
“CS” * “FR”	431.42	4	107.86	7.251	***
“TRA” * “FR”	180.96	4	45.24	3.042	***
“CS” * “TM”	342.94	6	57.16	3.843	***
“TRA” * “TM”	64.25	6	10.71	0.720	NS
“FR” * “TM”	86.54	6	14.42	0.970	NS
“CS” * “TRA” * “FR”	405.43	8	50.68	3.407	***
“CS” * “TRA” * “TM”	301.57	12	25.13	1.690	NS
“CS” * “TRA” * “TM”	326.03	12	27.17	1.827	***
“TRA” * “FR” * “TM”	214.07	12	17.84	1.199	NS
“CS” * “TRA” * “FR” * “TM”	409.02	24	17.04	1.146	NS
Error	3212.73	216	14.87		

NS- not significant, *** - significant

The results of the analysis of variance for W_a values (mean arithmetic deviation of the waviness profile) are shown in Table 5. Based on the levels of statistical significance of "P" 0.05 shown in Table 5, it is shown that the rake angle of the tool, the feed rate, and the thermal modification can be considered factors with a statistically significant effect on the values of the monitored characteristic (W_a).

Based on the level of significance of "P", which is higher than 0.05, the CS, two-factor interactions TRA and TM; FR and TM; three-factor interactions CS, TRA, and TM; TRA, FR, and TM, and four-factor interaction CS, TRA, FS, and TM, can all be considered as statistically insignificant. Other two- and three-factor interactions can be considered as statistically significant (Table 5).

Figures 3 to 6 show the influence of the factors of rake angle, feed rate and thermal modification on waviness, where the waviness values are the average of all the observed factors.

Figure 3, which shows the effect of the cutting speed on W_a values, indicates that the cutting speed does not have a significant effect on the values of the monitored characteristic, but one can see from the graphical record that increasing the cutting speed reduces the waviness values. Research by Sedlecký and Kvietková (2017) resulted in the same finding.

Figure 4 shows the effect of the rake angle on waviness values. The figure shows that increasing the rake angle results in a reduction in waviness. This reduction in waviness is particularly noticeable at a rake angle of 25°, where the average waviness value is 56 % smaller than at a rake angle of 15°. The statistically significant effect of the rake angle on the waviness during machining was also confirmed by the research of Kuljich *et al.* (2013).

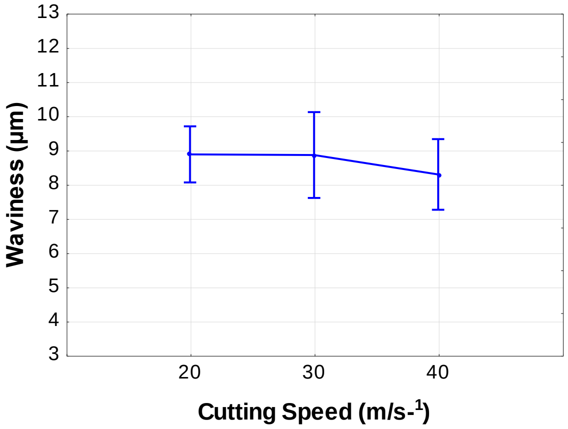

Fig. 3. Effect of the cutting speed on waviness values

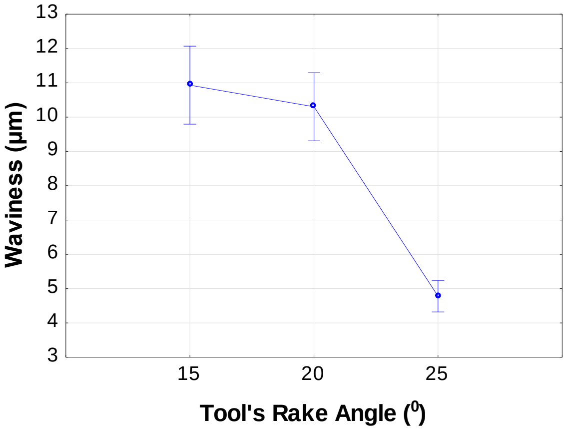

Fig. 4. Effect of the rake angle on waviness values

Figure 5 shows the effect of the feed rate on the values of the monitored characteristic. The values shown in Fig. 5 clearly show that as the feed rate increased, the values of the monitored characteristic also increased. The difference between the lowest and highest feed rate was 27%. The same effect of the feed rate during the milling of thermally modified wood was also reported by Gaff *et al.* (2015). Thermo-modified oakwood, when monitoring the effect of feed rate on wool, showed the same dependence as oak uncooked.

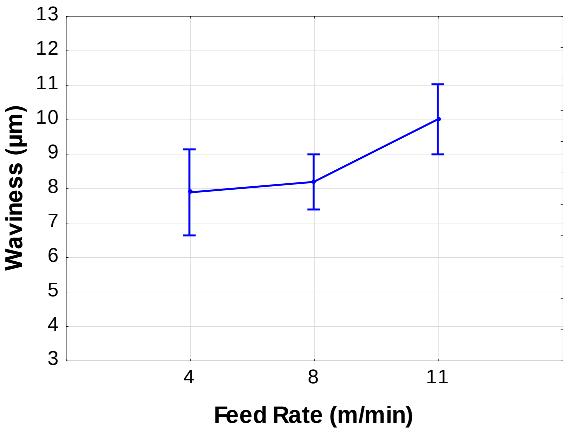

Fig. 5. Effect of the feed rate on waviness values

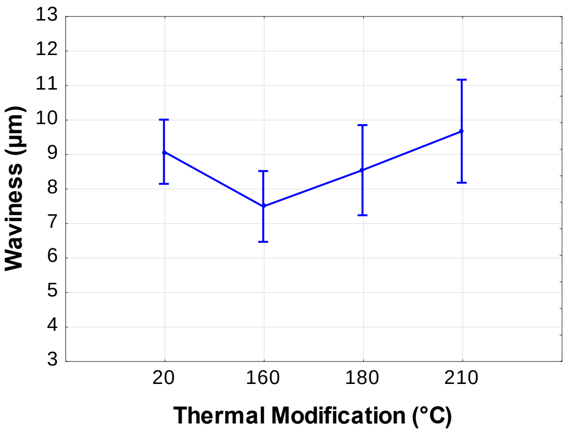

Fig. 6. Effect of thermal modification on waviness values

The effect of thermal modification is shown in Fig. 6. Wood thermally modified at 160 °C exhibited a better quality of the machined surface, and the quality deteriorated with higher degrees of thermal modification. Untreated wood reached values similar to those of wood thermally modified at higher temperatures. The average waviness value at 160 °C was 17.6% lower than at 20 °C, and 22.7% lower than at 210 °C. Deterioration in quality with the increasing temperature of thermal modification is partly due to the loss of matter due to chemical reactions during thermal modification. According to research by Tuong and Li (2010), the weight loss is dependent on the temperature of the wood exposed and the time of exposure.

If one considers the research of Korkut and Guller (2008), it has been shown that increasing the thermal modification temperature improves the surface quality. In research by Kvietková *et al*. (2015a), it was confirmed that the quality of the surface of thermally modified wood after machining only improved up to 210 °C; when the temperature was increased to 240 °C, the quality deteriorated.

According to Duncan's test (Table 6), it is obvious that a statistically significant difference occurred when changing Tool's rake angle from 15 ° and 20 ° to 25 °. There was no significant difference in average waviness at the cutting speed. In the analysis of feed rate, a significant difference in waviness between 4 m*min^{-1} and 11 m*min^{-1} and also between 8 m*min^{-1} and 11 m*min^{-1} was shown. The effect of the thermal treatment was as follows: A comparison of a thermally unadjusted sample and a temperature of 160 ° C, showed a significant difference; a similar result occurred between 160 °C and 210 °C.

Figure 7 shows the effect of the studied factors on the W_a in wood without thermal treatment. For all feed rates, the lowest waviness was achieved when using a tool with a rake angle of 25°. At a feed rate of 4 m*min^{-1} and a cutting speed of 40 m*s^{-1}, the highest quality of the machined surface was achieved. At a feed rate of 4 m*min^{-1} and rake angles of 15° and 20°, increasing the cutting speed to 40 m*s^{-1} led to a great increase in surface waviness. At a feed rate of 8 m*min^{-1} and a rake angle of 20°, the surface quality also deteriorated at a cutting speed of 40 m*s^{-1}; at a feed rate of 11 m*min^{-1}, this trend manifested itself with a tool having a rake angle of 25°. In all other cases, increasing the cutting speed led to a reduction in waviness.

Table 6. Comparison of the Effects of Individual Factors Using Duncan's Test on the W_a Values with a Contact Profilometer

Cutting Speed (m.s-^{1})		**(1)** **8.88**	**(2)** **8.85**	**(3)** **8.29**
1	**20**		0.971	0.294
2	**30**	0.971		0.278
3	**40**	0.294	0.278	
Tool's Rake Angle (°)		**(1)** **10.93**	**(2)** **10.30**	**(3)** **4.78**
1	**15**		0.232	0.000
2	**20**	0.232		0.000
3	**25**	0.000	0.000	
Feed Rate (m/min)		**(1)** **7.87**	**(2)** **8.17**	**(3)** **9.99**
1	**4**		0.564	0.000
2	**8**	0.564		0.001
3	**11**	0.000	0.001	

Thermal Modification (°C)		**(1)** **9.05**	**(2)** **7.46**	**(3)** **8.52**	**(4)** **9.65**
1	**20**		0.012	0.376	0.328
2	**160**	0.012		0.083	0.001
3	**180**	0.376	0.083		0.078
4	**210**	0.328	0.001	0.078	

Figure 8 shows the effect of factors on the values of the monitored characteristics for wood thermally modified at a final temperature of 160 °C. At a feed rate of 4 m*min^{-1} and cutting speed of 40 m*s^{-1}, as with untreated wood, the highest quality of the machined surface was achieved. At a feed rate of 8 m*min^{-1} and a rake angle of 20°, the surface quality also deteriorated at a cutting speed of 40 m*s^{-1}; at a feed rate of 11 m*min^{-1}, this trend manifested itself with a tool having a rake angle of 25°.

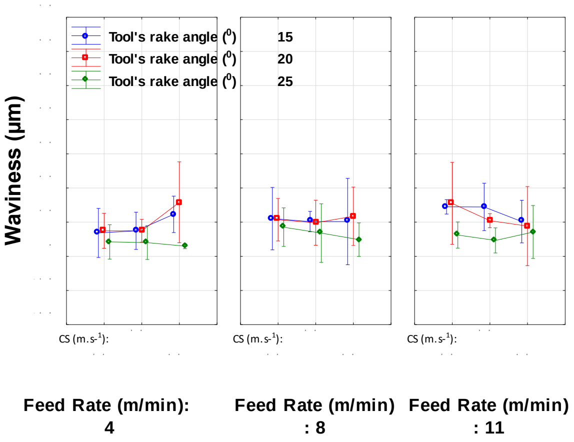

Fig. 7. Synergistic effect of the studied factors on the W_a in wood without thermal treatment

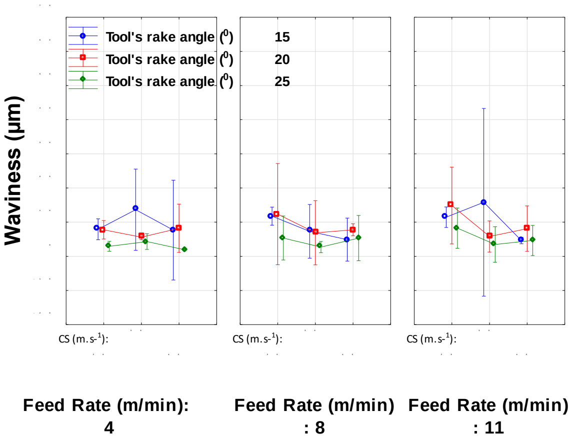

Fig. 8. Synergistic effect of the studied factors on the W_a in wood thermally modified at 160 °C

Figure 9 shows the effect of factors on the value of the monitored quantity characteristics for wood thermally modified at a final temperature of 180 °C. At a feed rate of 4 m*min^{-1}, the lowest waviness values were achieved at a tool rake angle of 25° at any cutting speed. The abovementioned also applied to other feed rates.

Figure 10 shows the effect of factors on the values of the monitored quality characteristics for wood thermally modified at a final temperature of 210 °C. As with wood thermally modified at a final temperature of 180 °C, the highest quality was achieved using a rake angle of 25° for all feed rates. When a tool with a rake angle of 15° was used, there was a marked deterioration in the values of the monitored characteristic at a cutting speed of 30 m*s^{-1}.

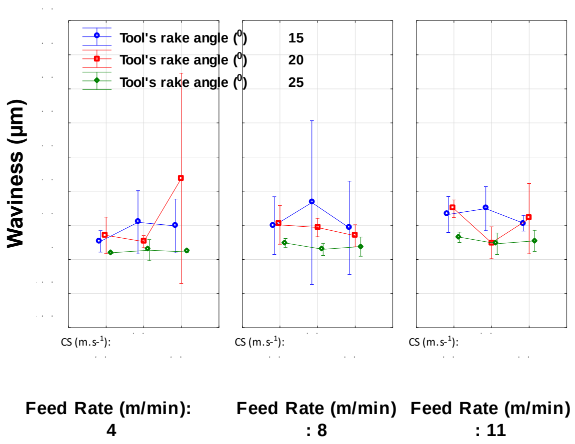

Fig. 9. Synergistic effect of the studied factors on the *W*$_a$ in wood thermally modified at 180 °C

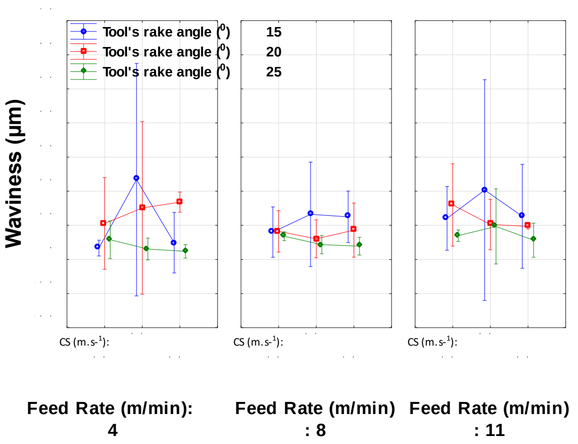

Fig. 10. Synergistic effect of the studied factors on the *W*$_a$ in wood thermally modified at 210 °C

The waviness of the milled surface itself largely depends on the combination of the cutting speed and feed rate settings. Ideally, the depth of the wave should decrease as the cutting speed increases and the feed rate decreases (Prokeš 1982; Rousek *et al*. 2012). In practice, there are many other influences that affect the waviness of the resulting workpiece, such as blade clamping, the vibration of the milling cutter's engine, spindle runout, slippage when the material is cut, *etc*. The effect of the feed rate on the surface quality has already been demonstrated by a number of authors, namely Costes and Larricq (2002), Lu (2008), Škaljić (2009), Kubš *et al*. (2016), and Sedlecký (2017). When milling thermally modified wood, the temperature at which the modification is performed as well as the exposure time in the thermal chamber influence the final surface quality (Salca and Hiziroglu 2014; Kvietková *et al.* 2015b,c).

CONCLUSIONS

1. When comparing thermally modified oak wood with untreated wood, the following treatment at 160 and 180 °C showed a decrease in the waviness value, and at 210 °C the quality of the machined surface deteriorated in terms of waviness. If one were to only evaluate thermally modified wood, the increase in waviness was almost linear with the increasing temperature of the thermal modification of oak wood.

2. For the machining of thermally modified oak wood, the most appropriate tool was one with a rake angle setting of 25°, where there was a significant reduction in waviness. The average value for a rake angle of 25° was more than 2x lower than the values for rake angles of 15° and 20°.
3. Increasing the cutting speed was found to reduce the waviness of the milled surface, namely when the speed is increased from 20 to 40 m*s^{-1}. The greatest increase in waviness values was recorded when the cutting speed changed from 40 to 30 m*s^{-1}.
4. On the contrary, increasing the feed rate in the range of 4 m*min^{-1} to 11 m*min^{-1} resulted in a deterioration of the surface quality, *i.e.*, an increase in waviness values. The waviness was therefore dependent on a combination of feed rate and cutting speed settings.

ACKNOWLEDGMENTS

The authors are grateful for the support of the University-wide Internal Grant Agency (CIGA) of the Faculty of Forestry and Wood Sciences at the Czech University of Life Sciences Prague, project No. 2016 – 4309.

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Article submitted: October 12, 2017; Peer review completed: December 4, 2017; Revised version received and accepted: January 10, 2018; Published: January 18, 2018.
DOI: 10.15376/biores.13.1.1591-1604