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SURFACE QUALITY OF MILLED BIRCH WOOD AFTER THERMAL TREATMENT – ROUGHNESS PROFILE (R_a)

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Abstract

This paper focuses on the surface quality assessment of thermally modified birch wood after plane milling while taking into account technological parameters which have substantial effects on the processed wood surface's arithmetic mean deviation of the roughness profile (R_a). The milling process was affected by the cutting speed, varying from 20 to 60 m/s and with the feed speed of 4, 8, and 11 m/min. The results obtained on the set of thermally modified test samples, were compared with the results obtained on test samples without heat treatment. The surface finish was measured using various milling parameters. The results indicate that the thermal modification of wood influenced significantly neither the waviness profile, nor the roughness profile. Cutting speed and feed speed had the most significant effects among the monitored factors on both the waviness and roughness profile. The lowest waviness value was determined at the minimum feed speed, to wit 4 m/min, and its value increased altogether with the feed speed. The lowest waviness was tracked at the second highest cutting speed of 40 m/s. As for the roughness, its lowest value was achieved also when the minimum feed speed was used. It was due to direct proportionality between the value of feed speed and roughness. On the other hand, the relation is opposite in a case of cutting speed.

Key words: *ThermoWood, plane milling, feed speed, cutting speed, surface waviness, surface roughness*

INTRODUCTION

In the 1st part of this paper we did general introduction to this paper by presenting crucial concepts of ThermWood, birch wood which was used in our experiment, process of wood milling and different kinds of imperfections resulting from this kind of machining.

We know which material was used in our experiment, how we prepared thermally modified samples and untreated samples and which means we used for plane milling of our samples.

In this 2nd part we are going to assess roughness - we investigate impacts of plane milling of birch ThermWood on arithmetic mean deviation of the assessed profile, $R_{a.}$ So this time we focus on the microscopic level of the wood surface.

Roughness is determined by the wood surface morphology and the surface machining method (Philbin and Gordon 2006; Boucher *et al*. 2007). This characteristic has a very important influence on the selection, application, and durability of surface finish coatings (Dornyak 2003). Only few works are focused on surface roughness of milled wood. For

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example, Keturakis and Juodeikienė (2007) examined the surface roughness of birch wood milled at different feed and cutting speeds. Novak *et al*. (2011) investigated the surface roughness of the three wood species after milling using a non-contact method.

EXPERIMENTAL

Methods

The measurement of roughness profile was carried out according to the same standards using the same roughness meter and in the same way as waviness measurement. The surface roughness was evaluated based on the arithmetic mean deviation of the assessed profile, $R_{a.}$ R_a, the mean roughness value, is the average distance from the profile to the mean line over the length of assessment (Mummery 1992; Karagoz *et al*. 2011).

Evaluation and Calculation

The influence of factors on roughness was statistically evaluated also using ANOVA, mainly by Fisher's F-test, in STATISTICA 12 software (Statsoft Inc.; USA). Calculation was carried out according to the same equations as in the case of waviness.

RESULTS AND DISCUSSION

Table 4 contains a statistical evaluation of the impact of the individual factors and the simultaneous interaction of all factors.

Table 4. Effect of Individual Factors on Roughness

Monitored factor	Sum of squares	Degrees of freedom	Variance	Fisher's F - Test	Significance level P
Intercept	4,654.9	1	4,654.9	3,314.3	0.000
Cutting speed	19,133	2	9,566	6.811	0.001
Feed speed	14,778	2	7,389	5.261	0.005
Treatment	4,174	4	1,044	0.743	0.563
Cutting speed × Feed speed × Treatment	21,554	16	1,347	0.959	0.501
Error	442,428	315	1.405		

According to the roughness results represented in Table 4 and Fig. 7, the cutting speed was a statistically significant factor. Increasing the cutting speed decreased the surface roughness of the birch wood. Lower roughness values correspond to better surface quality. This influence was confirmed by and Keturakis and Juodeikienė (2007) Costes and Larricq (2002).

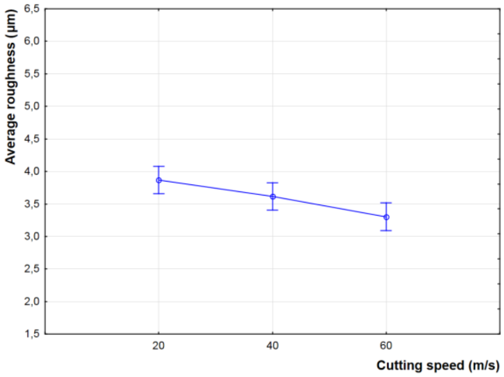

Fig. 7. 95% confidence interval showing the influence of the cutting speed on the average roughness

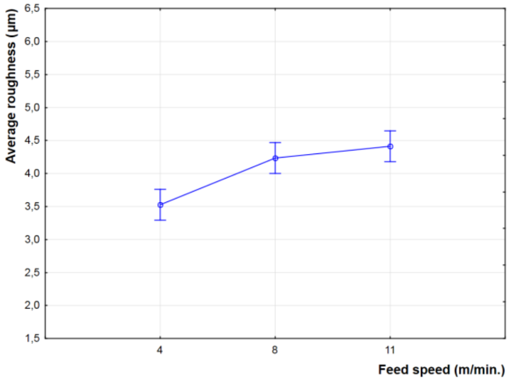

Fig. 8. 95% confidence interval showing the influence of the feed speed on the average roughness

When the plane milling feed speed was increased, the arithmetic mean deviation of the roughness profile increased (Fig. 8). However, the increase in roughness was minimal when the feed speed was changed from 8 to 11 m/min. Based on the significance values shown in Table 4, it is evident that this factor was statistically significant in relation to the roughness value. Škaljić *et al*. (2009) as well as Keturakis and Juodeikienė (2007) also found the same effect of the feed speed on the surface roughness of wood.

The effect of heat treatment on the wood surface roughness was not statistically significant in this work (see Table 4). Figure 8 shows that the roughness values measured for native wood were higher than those of the heat-treated wood, although the difference was small. Gündüz *et al*. (2008) determined a 16.3% difference between the surface roughness of wood thermally-modified at 180 °C and reference (untreated) wood. A clear effect on of thermal treatment surface roughness is difficult to prove because this influence is strongly influenced its final temperature and treatment duration. These conclusions were also found in the works of Budakçı *et al*. (2011) and Budakçı *et al*. (2013).

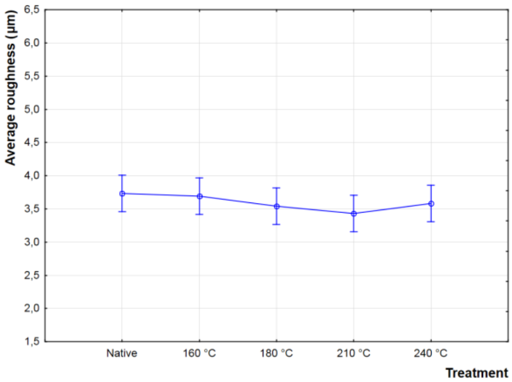

Fig. 9 A 95% confidence interval shows the influence of treatment on average roughness

Fig. 10 shows the impact of all factors studied on surface roughness of thermally-treated and native wood. As shown by the individual curves, it is difficult to unambiguously discern the direction of the trend of roughness (increase or decrease), depending on the examined factors. The combination of all factors exhibited a similar trend for both types of wood and was not statistically significant with respect to the surface roughness.

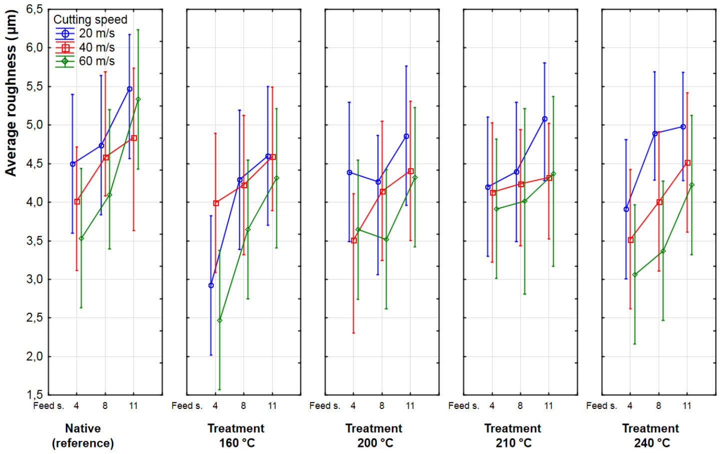

Fig. 10. 95% confidence interval showing the influence of the cutting speed, feed speed, and treatment on the average roughness

The difference in the average roughness between the native and thermally-treated wood was 7.1%. Many authors, such as Korkut and Akgül (2007), Unsal *et al*. (2011), Candan *et al*. (2012), and Baysal *et al*. (2014), have confirmed that thermal treatment has a positive effect on the quality of the wood surface (*i.e.*, thermal treatment reduces surface roughness). On the other hand, Unsal and Ayrilmis (2005) observed larger surface roughness decreases of 27.9% for wood thermally-treated at 180 °C for 10 h as compared to that of untreated wood. Also, Korkut *et al*. (2013) found about 25.6% lower surface roughness in thermally-treated wild cherry wood than in untreated wood.

CONCLUSIONS

1. Thermal treatment did not significantly affect the average surface roughness of birch wood after plane milling. The surface roughness decreased gradually with increasing temperature up to 210 °C, and a slight increase was observed at 240 °C. Untreated wood had higher surface roughness by about 7.1%.
2. Changing the cutting speed during milling had a positive impact on the quality of the surface. Higher cutting speed corresponded to lower surface roughness.
3. The opposite effect occurred when changing the feed speed: increasing the feed rate increased the average surface roughness of birch wood. The increase in the roughness between the feed speeds 4 and 11 m/min was 20.5%.

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