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Influence of specific pressure on cutting power and wood removal by disc sander*

Utjecaj jediničnog tlaka na snagu rezanja i količinu izbruska pri brušenju brusnim diskom

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ABSTRACT • *This paper presents the testing results of experimental measurements of cutting power during sanding of natural and modified beech wood depending on the value of specific pressure of 0.66; 0.84; 1.04; 1.47 N·cm^{-2}. The sand discs with a diameter of 150 mm and grit size of 40, 80 and 120 made by the firm SIAFAST (Germany) were used in this experiment. The measurement was carried out on experimental equipment designed by the Department of Woodworking at the Technical University in Zvolen . The highest values of wood removal at the cutting speed v_c = 4.57 m·s^{-1} in transverse direction were at the grit size 120 and the lowest at 40 for natural beech wood, as well as for hydrothermally treated wood. The influence of hydrothermally treated wood on the value of wood removal is the least important in terms of significance (unit pressure, grit size, hydrothermally treated wood).*

Key words: *sand disc, specific pressure, wood removal, cutting power, grit size, grain direction*

SAŽETAK • *Rad predočuje rezultate eksperimentalnih mjerenja snage rezanja za vrijeme brušenja neobrađene i modificirane bukovine u ovisnosti o vrijednosti specifičnog tlaka (0,66; 0,84; 1,04; 1,47 N·cm^{-2}). U eksperimentu su upotrebljavani brusni diskovi promjera 150 mm, granulacije 40, 80 i 120, tvrtke SLAFAST (Njemačka). Mjerenje je obavljeno eksperimentalnom opremom konstruiranom na Odjelu za obradu drva na Tehničkom sveučilištu u Zvolenu. Najveće vrijednosti rezanja drva pri brzini rezanja v_c = 4,57 m·s^{-1} u poprečnom smjeru, uz granulaciju brusnog diska 120, a najmanje pri granulaciji 40 za neobrađenu, kao i za hidrotermički obrađenu bukovinu. Utjecaj hidrotermičke obrade drva na vrijednost količine izbruska pri brušenju manje je značajan nego na utjecaj jediničnog tlaka i granulacije.*

Ključne riječi: *brusni disk, jedinični tlak, količina izbruska, snaga rezanja, granulacija, smjer vlakanaca*

1 INTRODUCTION
1. UVOD

Sanding is characterised as a special case of cutting, where a certain layer of workpiece surface is removed by sanding agent. In woodworking and furniture industry, the process of surface working of wood material by sanding is often used for increasing the surface quality of a product and enhancing its aesthetic appearance, which increases its aesthetic value. It is also used

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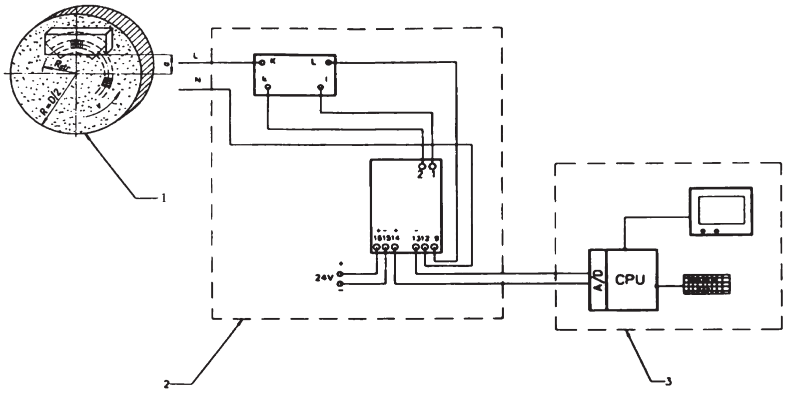


Figure 1 Layout chart of monitoring equipment and its mechanical part: 1 – Sander, 2 – Measuring equipment, 3 – Evaluation equipment
Slika 1. Shema opreme za eksperiment i njezini sastavni dijelovi: 1 – brusilica, 2 – oprema za mjerenje, 3 – oprema za obradu rezultata

for roughening the surface of wood material in various techniques of bonding for ensuring the outer or inner dimensions of a workpiece.

The proper choice of technical and technological parameters of sanding in practice helps to achieve higher efficiency and quality of working and leads to significant economic savings (Očkajová, 1999; Siklienka, 2000; Nemec et al, 1986; Ratnasingam et al, 2002). The Problems of sanding of wood and wood materials is very wide and complex. At the same time it is an issue, which is permanently developing from the viewpoint of tool, machine and wood materials. Theoretically, this field of science has been investigated in many ways and there are many basic relations for the determination of individual parameters (Mayer, 1968; Barcík and Vacek, 1999; Pahlitzch, 1970; Krakovský, 1978; Siklienka and Očkajová, 2001).

The main goal of investigation was based on the measurement of the influence of unit pressure on cutting power (energy demand and wood removal) as well as the grit size and the cutting speed of sanding process of natural and modified beech wood (BK) in sanding on a disc sander. Consequently, the experimental goal was to compare the results with previous results achieved on a belt sander under the same conditions, and to evaluate the influence of cutting speed vector depending on sanding direction.

Cutting power was evaluated on the basis of electric power consumption (W) of the sander.

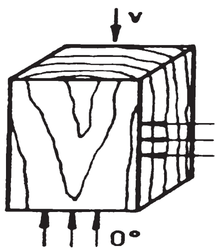
2 METHODS AND MATERIAL
2. METODE I MATERIJAL

2.1 Machinery and abradant
2.1. Stroj i alat

The experiments were carried out on the mechanical part of monitoring equipment (Siklienka et al, 1999) showed in Figure 1, whose basis was formed by manual disc sander by BOSH, type GWS-14-125 CE with parameters P_M = 1400 W, n_{em} = 2800-1100 min^{-1}. The monitoring equipment was tested with the control of setting accuracy of individual motion mechanisms. The tool – abradant was the conditioned sand disc (T = 20 °C; φ = 65 %), with the diameter of 150 mm and grit sizes of 40, 80, and 120 made by the firm SIA-FAST. In the experiment, medium cutting speed v_c = 7.65 m·s^{-1} was used in sanding parallel and perpendicular to grain and v_c = 4.57 m·s^{-1} for sanding transverse to grains. The experiments were performed at four reference pressures 0.66; 0.84; 1.04; and 1.47 N·cm^{-2}.

2.2 Characteristic of raw material
2.2. Obilježja obrađivanog materijala

The basic experimental raw material consisted of beech samples (*Fagus silvatica*) with the dimensions 50 x 50 x 50 mm, natural and hydrothermally treated (HTU) with grain inclination 0°; 90° and transverse to grains (Figure 2). Hydrothermal treatment was carried out by steaming in autoclave at parameters p_{max} = 0.35 MPa, T = 112-120 °C with the period of steam application t = 5.5 h. The samples were climatized at conditions = 65 %, T = 20°C w_{kon} = 12 % with determination of their density, according to STN 490108 (ρ_{OBK} = 0.684 g·cm^{-3}). The dimensions of samples were limited by technical possibilities of the equipment with the sanding area 50 x 50 mm.



0°- sanding parallel to grains, 90°- sanding perpendicular to grains, *V* – sanding transverse to grains
0°- brušenje paralelno s vlakancima, 90° - brušenje okomito na smjer vlakanaca, *V* – brušenje poprečno na vlakanca

Figure 2 Tested sample
Slika 2. Istraživani uzorak

2.3 Measurement of cutting power and wood removal
2.3. Mjerenje snage rezanja i količine izbruska

In experimental measurement, the engine output in idle run P_1 was recorded, required by a non-working machine exclusively for overcoming the losses of engine or woodworking machine as well as the output at load – sanding P_2. The cutting power P_r (W) is the output required by a tool for ensuring its cutting power and in this case for its calculation the following equation is used:

$$P_r = P_2 - P_1 \qquad (1)$$

Measuring of cutting power was performed by means of automatic measuring system of converter W/and PS.

For the measurement of the sanding agent efficiency wood removal was chosen ($g \cdot cm^{-2} \cdot m^{-1}$) expressed in grams of abraded mater per minute from an area of 1 cm^2 , which was determined by the quotient of minute abrasion acquired by weighing on laboratory scales and sanding area of the sample.

2.4 Experimental measurements
2.4. Eksperimentalna mjerenja

5 samples were chosen from the total number of prepared samples for each case of investigation i.e. natural and hydrothermal beech, with grain direction 0°, 90° and transverse to grains, with abradant grit size of 40, 80, and 120, unit pressure 0.66; 0.84; 1.04 and 1.47 $N \cdot cm^{-2}$, and cutting speed $v_c = 7.65$ $m \cdot s^{-1}$ and $v_c = 4.57$ $m \cdot s^{-1}$ with initial weighing.

Individual testing samples were sanded under given conditions, and the engine output of disc sander was recorded every ten seconds during one minute

$$P_r = \frac{\sum_{i=1}^{n} P_{ri}}{n} \qquad (2)$$

where $n = 30$ is the number of measured values.

After repeated sanding in one-minute intervals, with minimum number $n = 30$, the samples were weighed, and after recalculation we have got the values of wood removal which were subsequently statistically evaluated.

3 RESULTS AND DISCUSSION
3. REZULTATI I DISKUSIJA

For objective approach, the results are presented in the form of graphs, mean values of cutting power and wood removal depending upon observed factors or their reciprocal interactions (chosen). Theoretical assumption of individual parameters (their interactions – important influence) as a factor influencing the cutting power and wood removal has been partly confirmed.

Based on the obtained results, it can be concluded that all observed parameters of cutting power influence its rate, although in some cases no significant differences were recorded among some levels.

With increasing unit pressure, the cutting power of sanding increases, and the highest values were reached at the highest unit pressure and the lowest at 0.66 $N \cdot cm^{-2}$. This is true for both natural hydrothermally treated wood. In natural beech, the increase of these values is lower than in hydrothermally treated wood, as a result of wood plastification (Fig. 3).

In general, it can be said that with the increase of grit size of the sanding agent, the cutting power also increases; at higher grit size and at the same unit pressure, there is a higher number of active grains, which increases the cutting power.

Hydrothermal treatment (HTU) of wood has proved as one of the factors significantly influencing the cutting power in sanding. Considering the grain direction to the vector v and in hydrothermally treated wood the cutting power decreases at perpendicular and parallel direction at all unit pressures and grit sizes (figure 3, 4).

The obtained results were compared with Siklienka, Očkajová (2001), Siklienka (2001), Očkajová

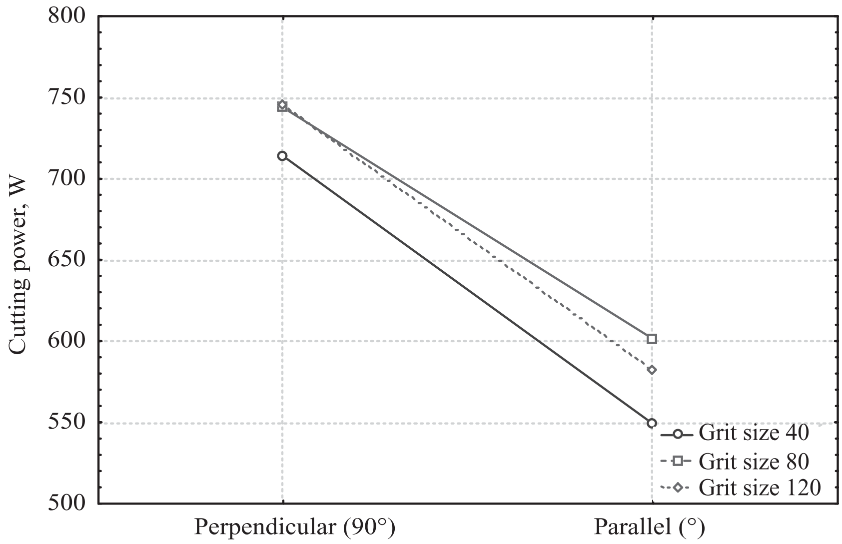


Figure 3 Dependence of cutting power on observed parameters for $v_c = 7.65$ $m \cdot s^{-1}$
Slika 3. Ovisnost snage rezanja o promatranim parametrima za $v_c = 7,65$ $m \cdot s^{-1}$

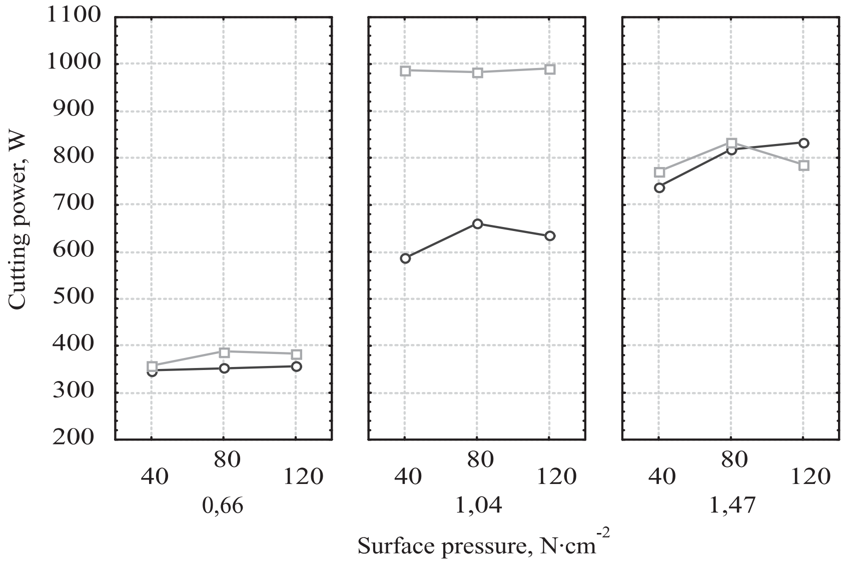


Figure 4 Dependence of cutting power on interaction between observed parameters for natural beech and hydrothermally treated beech at $v_c = 7.65\ m \cdot s^{-1}$

Slika 4. Ovisnost snage rezanja o interakciji promatranih parametara za neobrađenu i hidrotermički obrađenu bukovinu pri $v_c = 7,65\ m \cdot s^{-1}$

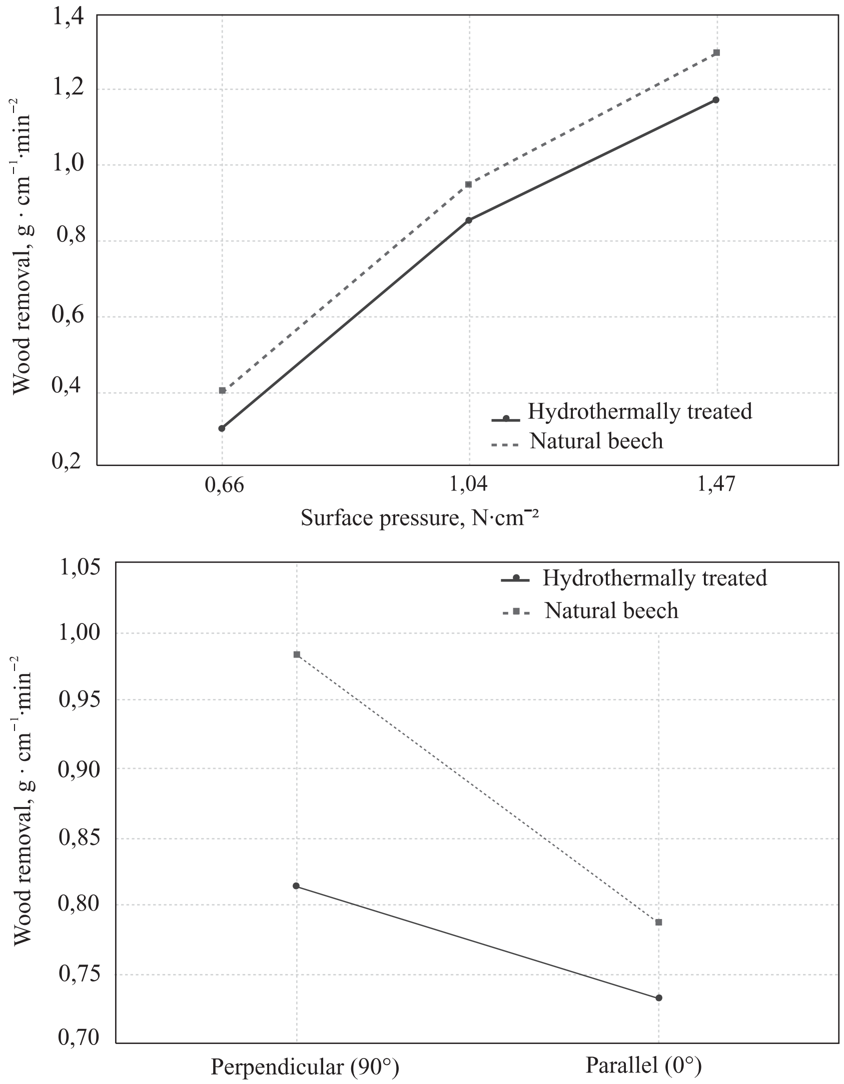


Figure 5 Dependence of wood removal on unit pressure and sanding direction for natural beech and hydrothermally treated beech at $v_c = 7.65\ m \cdot s^{-1}$

Slika 5. Ovisnost količine izbruska drva o jediničnom tlaku i smjeru brušenja za neobrađenu i hidrotermički obrađenu bukovinu $v_c = 7,65\ m \cdot s^{-1}$

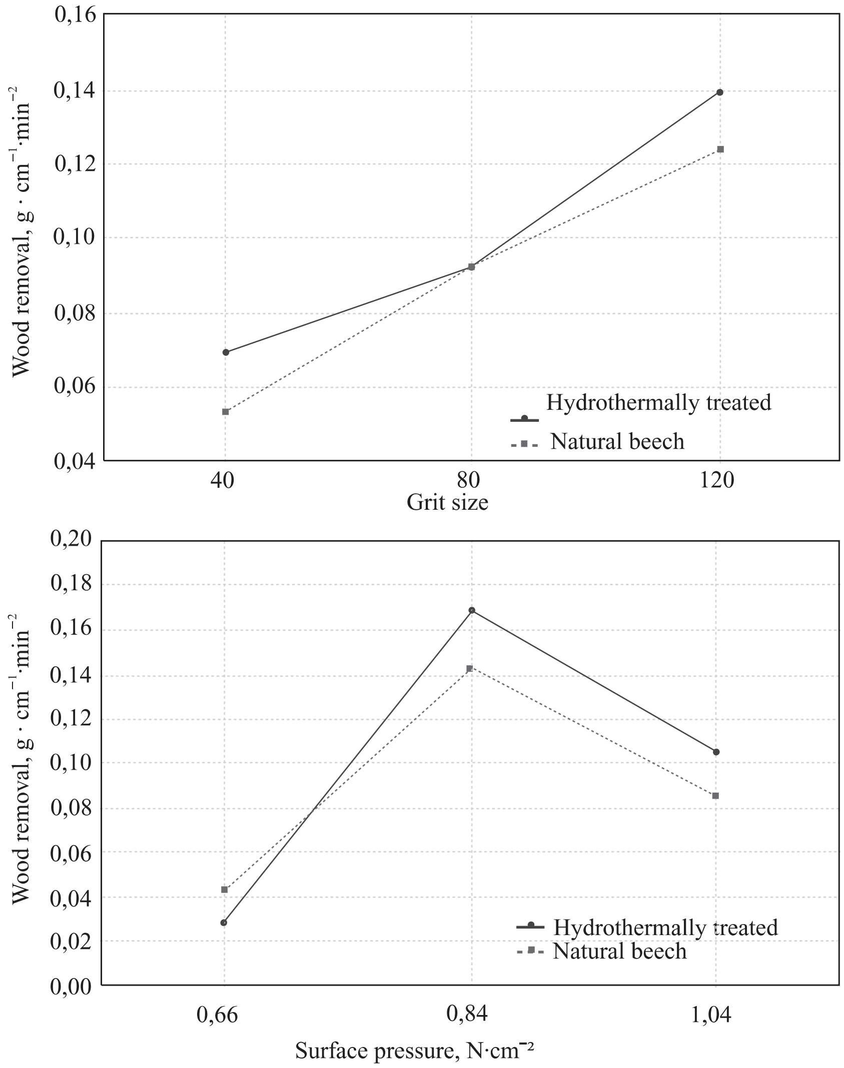


Figure 6 Dependence of wood removal on unit pressure and grit size for natural beech and hydrothermally treated beech in sanding transverse to grains for $v_c = 4.57$ m·s^{-1}
Slika 6. Ovisnost količine izbruska drva o jediničnom tlaku i granulaciji brusnog sredstva za neobrađenu i hidrotermički obrađenu bukovinu pri poprečnom smjeru brušenja za $v_c = 4,57$ m·s^{-1}

(1999), and it can be concluded that most values are comparable with sanding on belt sander.

The amount of wood removal increases with the increase of the value of unit pressure. This course of values of wood removal is valid for all used grit sizes both with natural wood and hydrothermally treated wood, Figure 5.

The highest values of abrasion at cutting speed $v_c = 4.57$ m·s^{-1} in the direction transverse to grains were recorded at the pressure of 0.84 N·cm^{-2} and the lowest at 0.66 N·cm^{-2}. The fact that at the pressure of 1.04 N·cm^{-2}, a lower value of wood removal was recorded than at 0.84 N·cm^{-2} may be explained by insufficient cleaning of abradant due to too high pressure, Figure 6.

The value of wood removal depending on the grit size increases with its growth (40, 80, 120). The highest values of abrasion at the cutting speed $v_c = 7.65$ m·s^{-1} in the direction parallel and perpendicular to grains were recorded at the grit size 80, except the pressure 0.66 N·cm^{-2} in natural and hydrothermally treated wood, where the highest value of wood removal is at the grit size 120 and the lowest at 40. The differences in wood removal at the pressure of 1.04 and 1.47 N·cm^{-2} and the grit size 80 and 120, where the abrasion at the grit size 120 is lower than at 80, can be explained by quicker choking of abradant and its insufficient self-cleaning on the small sanding radius, Figure 7.

The highest values of wood removal at the cutting speed $v_c = 4.57$ m·s^{-1} in transverse direction were at the grit size 120 and the lowest at 40 for natural beech wood as well as for hydrothermally treated one. The influence of hydrothermally treated wood on the value of wood removal is the least important from the viewpoint of significance (unit pressure, grit size, hydrothermally treated wood).

4 CONCLUSION
4. ZAKLJUČAK

The problems of sanding, as outlined in the introduction, are demanding and comprehensive. There are many parameters, whose proper choice and adjustment

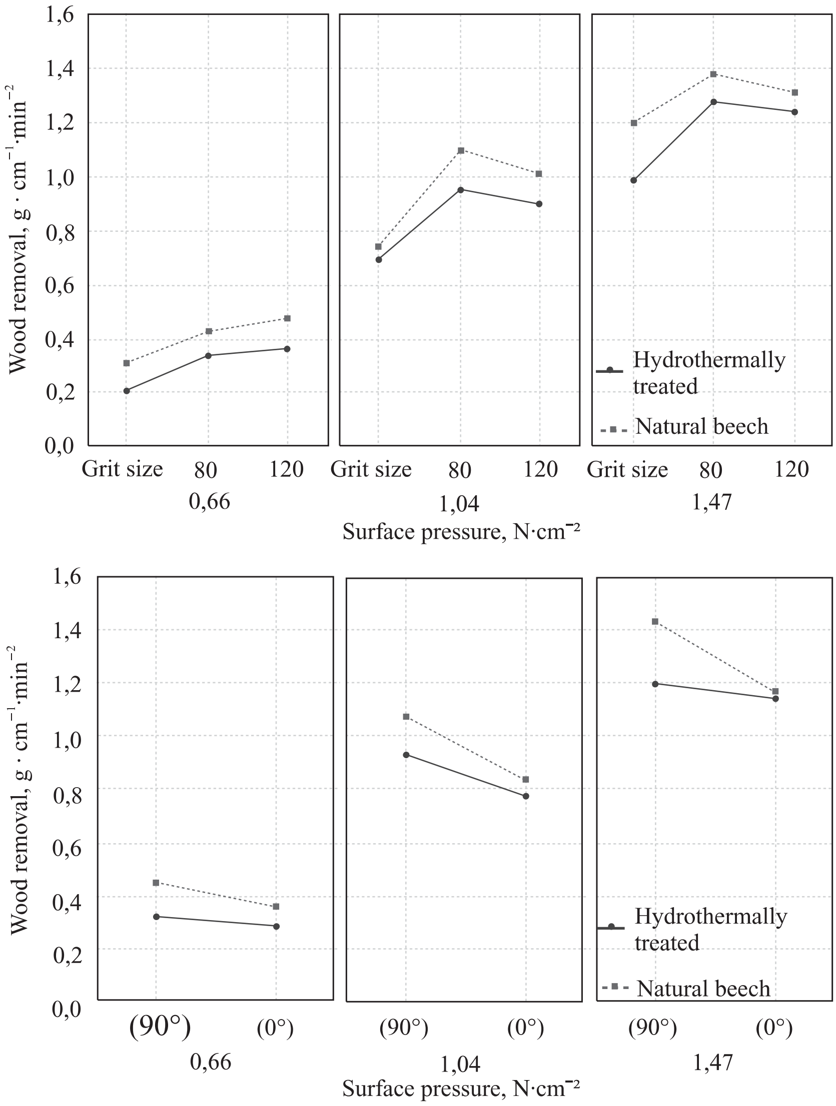


Figure 7 Dependence of wood removal on interaction of individual factors for natural beech and hydrothermally treated beech at $v_c = 7.65\ m \cdot s^{-1}$

Slika 7. Ovisnost količine izbruska drva o interakciji individualnih činitelja za neobrađenu i hidrotermički obrađenu bukovinu pri $v_c = 7,65\ m \cdot s^{-1}$

influence not only the quality of machining but also energy and economic demand of sanding as well as the efficiency of the sanding agent.

The results obtained by the experiments can be used for the choice of a unit pressure using the given sanding grit size in connection with the direction of wood grain for disc sanders and given conditions.

The experiments unambiguously confirmed an order of importance of individually investigated factors as well as their reciprocal interactions i.e. grit size, direction angle of wood grain with cutting vector, as well as the unit pressure and hydrothermal treatment. Verification experiments covered only a part of the above mentioned parameters, so they do not represent a comprehensive solution of the problem of sanding on the disc sander under given conditions.

The obtained results of these investigations will give a deeper insight into the area of experimental wood sanding on disc sander by comparison with well known results of other authors, which can serve as the framework of further research into the problems of sanding.

In conclusion it should be impasised that only very little attention has been given to the problems of sanding on disc sanders so far, and therefore it was only partly possible to compare these results with the results of sanding on belt sanders as given by Siklienka (2001) and Barcík (2002).

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