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Wood species, sanding direction and efficiency of a sanding belt

Vrsta drva, smjer brušenja i učinkovitost brusne trake

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SUMMARY The article deals with the efficiency of the sanding belt for the chosen wood species – beech, alder, oak and pine – for various directions of sanding relative to the wood grain – 0°, 60°, and 90°. The efficiency of a sanding belt in our experiments is indicated by the amount of material removed from a solid surface per unit of time, which depending on time presents wear of the sanding belt.

Wear of the sanding belt was observed by means of decrease of stock removal weight $[g \cdot cm^{-2} \cdot min^{-1}]$ *depending on sanding belt running time which was stated for 480 minutes. Results were plotted in the graph presenting the curves of wear of the sanding belt for beech, alder, oak and pine when sanding along the grain of 0°, perpendicular to the grain of 90° and at the angle of 60° to the grain. Obtained curves were evaluated from the viewpoint of maximum and minimal removals, time of sanding for a concrete wood species, and direction of sanding. The shortest sanding time were obtained when sanding along the grain for alder – 80 minutes, for sanding direction of 60° for pine - 160 minutes and when sanding perpendicular to grain for alder - 140 minutes. The time interval of 480 minutes when sanding along the grain was obtained when sanding oak, at the sanding direction of 60° to grain when sanding beech and oak, and when sanding perpendicular to grain for pine. On the basis of the obtained results we can state a value of removal and above all sanding time of a sanding belt are different for particular wood species and directions of sanding.*

Key words: wood species, sanding direction, sanding time, wear of sanding belt

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SAŽETAK U radu se istražuje učinkovitost brusne trake pri brušenju određenih vrsta drva – bukovine, johovine, hrastovine i borovine – za različite smjerove brušenja u odnosu na smjer drvnih vlakanaca - 0°, 60° i 90°. Učinkovitost je brušenja u ovome istraživanju određena masom izbruska po jedinici brušene površine u jedinici vremena, a koja ovisi o vremenu trošenja brusnog sredstva (brusne trake).

Trošenje brusne trake praćeno je prema smanjenju izbruska $[g \cdot cm^{-2} \cdot min^{-1}]$ *u vremenu rada trake tijekom 480 minuta. Rezultati su istraživanja prikazani grafovima koji sadrže krivulje trošenja brusne trake pri brušenju bukovine, johovine, hrastovine i borovine paralelno s vlakancima, okomito na vlakanca i pod kutom 60° na smjer vlakanaca. Dobivene su krivulje analizirane s obzirom na najveće i najmanje količine izbruska, vrijeme brušenja za pojedine vrste drva i smjer brušenja. Najkraće vrijeme brušenja izmjereno je pri brušenju johovine paralelno na vlakanca – 80 minuta, pri brušenju borovine pod kutom 60° na smjer vlakanaca – 160 minuta te pri brušenju johovine okomito na vlakanca – 140 minuta. Najduže vrijeme brušenja, odnosno vrijeme brušenja od 480 minuta, izmjereno je pri brušenju hrastovine paralelno s vlakancima, hrastovine i bukovine pod kutom 60° na smjer vlakanaca i pri brušenju borovine okomito na vlakanca.*

Na osnovu dobivenih rezultata može se zaključiti da količina izbruska a posebno vrijeme učinkovitog rada brusne trake uvelike ovisi o vrsti drva koja se brusi i o smjeru brušenja u odnosu na smjer drvnih vlakanaca.

Ključne riječi: vrste drva, smjer brušenja, vrijeme brušenja, trošenje brusne trake

1 INTRODUCTION
1 UVOD

Sanding is a time-consuming and financially very demanding operation (Taylor et al. 1999) and its investigation is important both from the viewpoint of work piece quality and that of efficiency of sanding, as has been discussed in a number of published papers (Pahlitzsch, 1970; Stewart, 1976; Krakovsk, 1978; Očkajová et al. 1999; Matsumoto and Murase, 1999; Barcík and Vacek, 1999; Siklienka, 2002; Banski, 2002).

A number of difficulties that arise in modeling the process of sanding relates to the nature of a given operation – the multiple-spot contact of the tool which is composed of small and extremely hard, sharp particles with geometry, shape and arrangement that is not exactly identified. As not all points are in contact at any given time, and the dynamics of this process and the structure of grit cause these active points to be broken up, such a complex mechanism can be difficult to model.

Most authors solve the stated problem from the viewpoint of short-term tests. However, on the basis of experiments we already carried out (Siklienka and Očkajová, 2001) we can state: even though concrete parameters of the sanding process are suitable for short-term tests, after a certain running time of a sanding belt they won't be satisfactory (specific pressure, the chosen type of sanding, pattern, etc.).

Problems concerning the impact the direction of sanding relative to the wood grain has on the rate of removal are given only a little attention in literature and the results are not uniform. Whereas Lisičan et al. (1996) showed maximum removal at the sanding direction of 60°, and a large decrease of removal at a sanding direction of 90°, other authors show maximum removal for a sanding direction perpendicular to the grain 90°.

The economics of sanding is determined not only by the amount of sanding time available until complete blunting (or, alternatively, to rupture of the sanding belt), but also by the minimum rate of removal. Pahlitzsch (1970) shows a value of 0.05 $[g \cdot cm^{-2} \cdot min^{-1}]$.

The aim of our experiments was work concentrated on:

- the efficiency of the sanding belt from the viewpoint of the long-term effect of interaction with the work piece material, which in fact is the wear rate of the sanding belt for chosen wood species and cho-

sen directions of sanding;
- comparing the efficiency of sanding belts from the viewpoint of chosen wood species and directions of sanding;
- the economics of sanding using as the criterion the minimum removal within the observed interval for all wood species and directions.

2 MATERIAL AND METHODS
2 MATERIAL I METODE

Sanded material – ***Uzorci za brušenje***

Samples were chosen from the typical wood species used in our furniture industry, joinery manufacture, etc. At the same time they are typical representatives of deciduous diffuse porous (soft and hard) wood species, ring porous wood species, and coniferous wood species. Kafka et al. (1989) give the following characteristics of the chosen wood species:

Beech (*Fagus silvatica*) – diffuse porous wood species, its wood is hard and medium-heavy with density of 684 kg · m^{-3}, good machining.

Alder (*Alnus glutinosa*) - diffuse porous wood species, its wood is light and soft with density of 528 kg · m^{-3}, good machining.

Oak (*Quercus robur*) - ring porous wood species, its wood is hard and heavy with density of 744 kg · m^{-3}, good machining.

Pine (*Pinus sylvestris*) – conifer, light wood containing resin, density of 550 kg · m^{-3}, good machining.

The material in the form of sawn timber of 55 mm thickness was provided by the Bucina company, Zvolen. From the material the 50x50x50 mm samples were gradually made by machines so that the direction of the cutting speed vector and the direction of the wood grain could form the following angles (Figure 1):

0° sanding along grain,
60° sanding with the angle of 60° between the cutting speed vector and the direction of the wood grain,
90° sanding perpendicular to the grain.

The samples prepared like this were conditioned at the temperature of 20°C and relative air humidity of 65% to the wood moisture content of 12%.

Sanding belt – ***Brusna traka***

For the experiments the LS 309 XH sanding belts from the Klingspor company were used. They had the following characteristics:

- dimension of 100x610 mm
- grain size distribution – 80
- grit – artificial corundum (aluminium oxide)
- bonding agent – resin
- source material – cotton texture, heavy
- close-coated pattern.

For the whole time before being mounted on the experimental equipment the sanding belts were conditioned at the temperature of 20°C and relative air humidity of 65%; 24 hours before carrying out the experiment the experimental belts were placed in the room where the experiment would be conducted.

Experimental equipment – *Mjerna oprema*

The experiments were performed using equipment for observing the contact phenomena (Siklienka et al. 1999) whose base was the GBS 100 AE hand belt sander from the Bosch company (Figure 2).

Experimental conditions – *Uvjeti mjerenja*

- cutting speed – 7.8 m · s^{-1}
- specific pressure between the work piece and sanding belt of 1.04 N · cm^{-2}.

Long-term experiments – *Dugotrajni eksperimenti*

For long-term experiments the two groups of samples were prepared. Check samples A had approximately the same number of annual rings on the front section and approximately the same weight. Other sam-

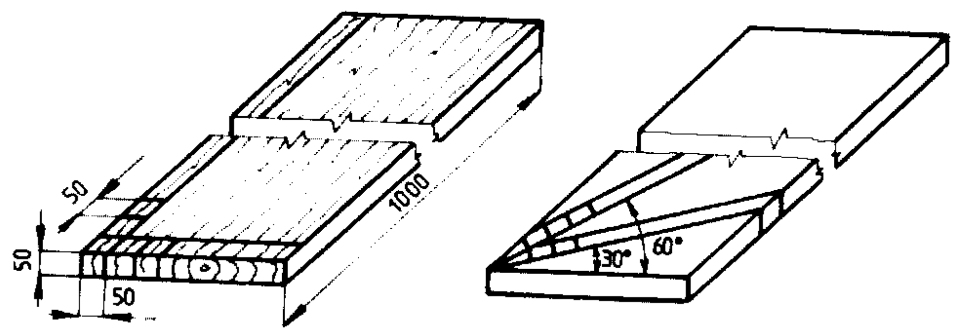

Figure 1
Preparing the samples Priprema uzoraka

ples were included in the B group. Thus, the samples were prepared for all chosen directions of sanding – 0^o, 60^o and 90^o. Sanding time was set at 480 minutes. Measurements, checking the efficiency of the sanding belt, were taken every 20 minutes by the three check A samples which were sanded for 1 minute. The weight of samples before and after sanding was recorded to determine stock removal weight. These values were the base for determining wear of the sanding belt.

Between checking measurements the B samples (3 – 4 pieces) were sanded for 20 minutes.

3 RESULTS AND DISCUSSION
3 REZULTATI I DUSKUSIJA

Results are given in the form of graphs which show the dependencies of stock removal weight upon sanding time for all chosen wood species (beech, alder, oak, and pine) for the sanding direction along the grain (Figure 3), for sanding direction at the angle of 60^o to the grain (Figure 4) and for sanding direction perpendicular to the grain (Figure 5).

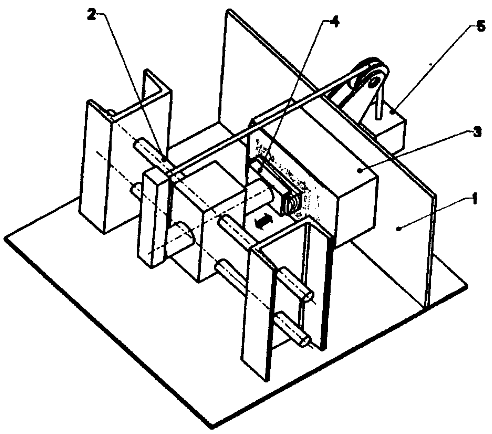

Figure 2 *Experimental equipment: 1 – frame, 2 – guide, 3 – hand belt sander, 4 – sample fixation, 5 – pressure unit*
Mjerna oprema: 1 – okvir, 2 – vodilica, 3 – ručna tračna brusilica, 4 – učvršćenje uzorka, 5 – pritisna naprava

On the basis of these graphs we can state that the amount of removal decreases with time for all the wood species at all the chosen sanding directions. Sanding time is various.

Sanding direction of 0^o – along grain
Smjer brušenja 0^o – paralelno s vlakancima

Sanding time recorded: 80 minutes for alder, 120 minutes for pine, 320 minutes for beech, and 480 minutes – the whole observed interval - for oak. For all the wood species (except for oak), the course of wear is marked by a sharp fall in the rate of wood removal in the first 20 minutes, the sharpest being for pine – from the value of 0.5 g · cm^{-2} · min^{-1} to the value of 0.28 g · cm^{-2} · min^{-1}. Then this is followed by a period when values of removal for all the wood species are balanced, fluctuating from 0.2 to 0.3 g · cm^{-2} · min^{-1}. When sanding along the grain at a given pressure, soft wood species and light wood species (alder, pine) quickly fill space between abrasive grains with long fibrous material causing the work conditions of sanding to become more and more difficult, and shutdown (breaking) occurs relatively quickly. After this section there is a stage, characteristic by a more balanced course. For oak it is a removal value balanced up to sanding belt shut-down from running (its breaking), which is 320 minutes. As for oak we observed lower removal values than for beech, with a constant decrease of removed amount to the end of the observed interval, from the value of 0.25 g · cm^{-2} · min^{-1} down to the value of 0.004 g · cm^{-2} · min^{-1}. From the viewpoint of economy, however, after 400 minutes of running the criterion of minimal removal is no longer met.

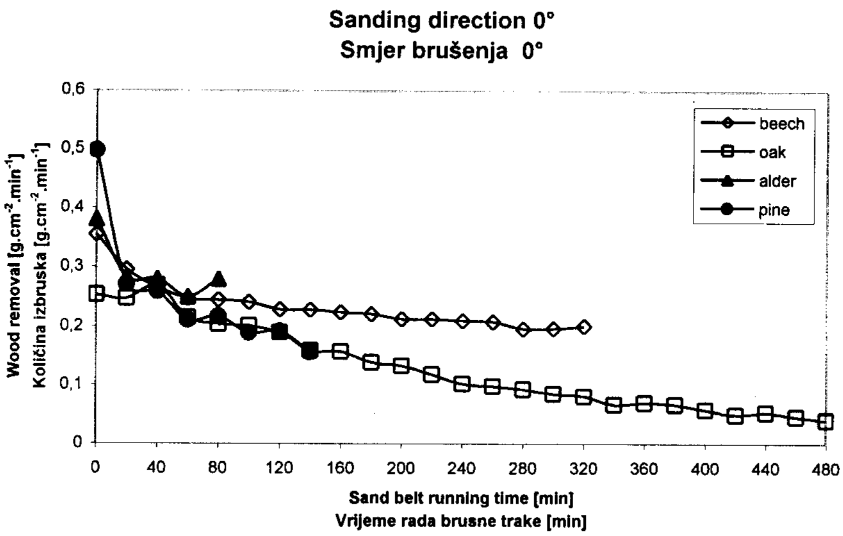

Figure 3 *Dependence of stock removal weight on sanding time for all chosen wood species – beech, alder, oak, pine for sanding direction along the grain*
Ovisnost količine izbruska o vremenu brušenja za sve ispitivane vrste drva – bukovinu, johovinu, hrastovinu i borovinu pri brušenju paralelno s vlakancima

Sanding direction of 60^{o} to the course of grain
Smjer brušenja pod kutom 60^{o} u odnosu na smjer vlakanaca

When sanding in this direction we have obtained the following sanding times: 160 minutes for pine, 400 minutes for alder and 480 minutes for beech and oak. From the viewpoint of removal size we obtained much larger differences in values within the range of observed wood species than when sanding along grains, initial removal values are higher than at the sanding direction of 0^{O} and sanding time is in all cases longer. From the obtained results we can state that woodworking conditions at this sanding direction either slitting grains, putting and taking dust out of space between abrasive grains or self-sanding effects are easier in this case for all the chosen wood species. Diffuse-porous wood species reach very high values of removal during the whole sanding time obtained. When sanding oak and evaluating all the observed criteria (especially the criterion of minimum removal), the sanding time is shorter, around 280-300 minutes. Again after the first 20 minutes, there is a very sharp decrease of removal, and the stage of reduced removal starts for diffuse-porous wood species with approximately the same removal value in the interval from 0.4 to 0.5 $g \cdot cm^{-2} \cdot min^{-1}$, and for oak with the value falling to zero.

Sanding direction of 90^{o} – perpendicular to grain
Smjer brušenja 90^{o} – okomito na vlakanca

Also at this sanding direction we have obtained long periods of sanding time, with the valid criterion of minimal removal for pine being 480 minutes, for beech 460 minutes, for oak 380 minutes. In this case we observed the shortest sanding time – 140 minutes when sanding alder. Again we have obtained big differences in values of removal within the range of the observed wood species, with the maximum removal for alder and beech. For all the curves there is again a very sharp decrease in removal in the first 20

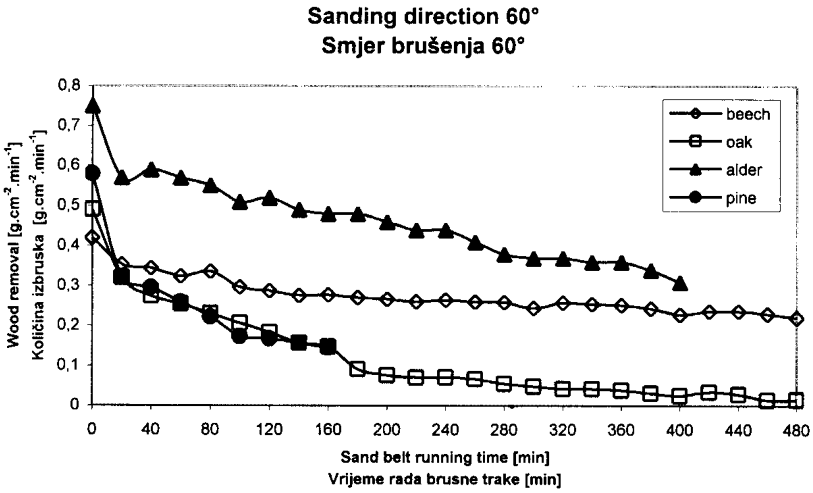

Figure 4 *Dependence of stock removal weight on sanding time for all chosen wood species – beech, alder, oak, pine for sanding direction at the angle of 60^{O} to the grain   Ovisnost količine izbruska o vremenu brušenja za sve ispitivane vrste drva – bukovinu, johovinu, hrastovinu i borovinu pri brušenju pod kutom od 60^{O} u odnosu na smjer vlakanaca*

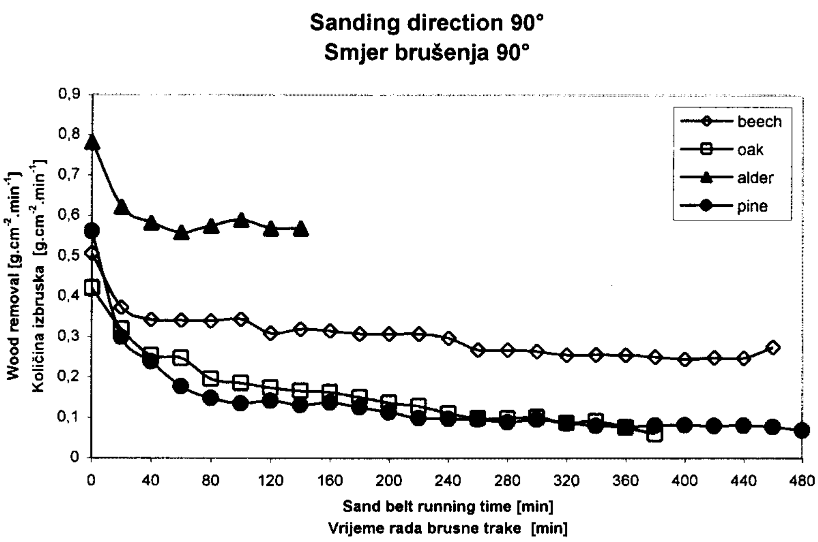

Figure 5 *Dependence of stock removal weight on sanding time for all chosen wood species – beech, alder, oak, pine for sanding direction perpendicular to the grain   Ovisnost količine izbruska o vremenu brušenja za sve ispitivane vrste drva – bukovinu, johovinu, hrastovinu i borovinu pri brušenju okomito na vlakanca*

minutes, followed by a period of more stable values, which did not change or changed only very slightly up to finishing the sanding belt. For alder and beech, stock removal rates during the observed interval are comparable with rates at the sanding direction of 60°, but periods of running are shorter in this case. The results for pine are interesting, in that the sanding belt lasts (i.e. "survives") for the whole chosen interval – 480 minutes.

It follows from the foregoing analysis that sanding direction influences not only the removal rate, but also and above all the time period of running a belt. On the basis of the obtained results we can state that, not for all wood species, from the viewpoint of extending the sanding time we can consider a semi-coated form of the pattern, alternatively with lower pressure. For pine it would be suitable to carry out the given experiments with antistatic belts and to compare the results. When sanding oak, the lowest efficiency of sanding belt is reached, even though periods of running were long. However, the experiments at the Department (Siklienka and Očkajová, 2002) prove that by increasing pressure to reach higher efficiency, the belts broke after 60 minutes, and that lower pressures led to even lower efficiency of sanding belt, which immediately after the first 20 minutes fell below the value of $0.05\ g \cdot cm^{-2} \cdot min^{-1}$.

The obtained results show that for, all the observed wood species, for the sanding directions of 60° and 90°, the efficiency of a sanding belt is very similar. We again have to emphasize the need for long-term tests, because many results we obtained at our Department during short-term tests were different.

4 CONCLUSION
4 ZAKLJUČAK

Based on our stated aim, we can state that the obtained results are very valuable from the standpoint of theory as well as practice. Long-term tests which helped to obtain wear curves unambiguously provide a picture of maximum and minimal removal rates for individual wood species and sanding directions, sanding time, suitability of the type of sanding belt used, and suitability of initial technical and technological parameters. The results enable choosing whether to prefer higher pressure and shorter sanding time or a lower efficiency of the sanding belt and longer sanding time. The sanding direction of 60° to the grain seems to be the most suitable from the viewpoint of efficiency of the sanding belt and sanding time, as well as meeting the criterion of minimal stock removal weight.

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