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Roughness of Sanded Wood Surface: an Impact of Wood Species, Grain Direction and Grit Size of Abrasive Material

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For the research the samples of ash (*Fraxinus excelsior L.*), birch (*Betula L.*), black alder (*Alnus glutinosa L.*), Scots pine (*Pinus sylvestris L.*) and spruce (*Picea abies L.*) wood were used with dimensions of (270×215×15) mm. All wood samples were tangentially planed, defect free and kiln dried. Before the research, the average moisture content, wood density, number of annual rings per 1 cm, average width of annual ring and wood surface grain direction were evaluated. Different wood surface roughness of the samples was obtained sanding wood samples in the eccentric sanding stand, using standard open-type sandpaper with different grit size. The arithmetic mean value of the single roughness depths of consecutive sampling lengths parameter R_z of the sanded wood samples were measured in five sectors along the wood grain, across and in the angle of 45°, using a contact stylus profilometer. In total 1800 measurements were done during testing series. In the research the dependence of wood surface on wood species, grain direction and grit size of abrasive material was evaluated. It was obtained that with increasing of the grit size of abrasive material, the roughness of wood surface decreases in all three measurement directions, but a linear dependence has not been established due to features of wood microstructure. In order to assess the quality of sanded wood surface accurately, it is recommended to measure the roughness of wood surface along and across the grain.

Keywords: surface roughness, sanding, grit size of abrasive material, wood grain direction.

INTRODUCTION

Wood surface roughness is substantial parameter influencing final quality of the wood products. Wood sanding quality is particularly important for the final wood processing stage – wood finishing [1]. Surface roughness impacts not only aesthetical characteristics of products, but also the adhesion, penetration and wettability of wood coatings. Surface roughness depends on wood species, anatomy, moisture content, density, porosity and machining conditions [2 – 5].

Surface roughness commonly is defined by surface irregularities: R_a – arithmetic average of the absolute values of the roughness profile ordinates; R_z – arithmetic mean value of the single roughness depths of consecutive sampling lengths; R_{max} – the largest single roughness depth with the evaluation length. Wood surface roughness can be measured by the means of contact and non-contact methods. The first type includes contact stylus tip, tactile sensation and pneumatic methods. One of the most popular methods is to register the profile of the surface using a stylus drawn along the surface to be measured. The diamond stylus is the main component of a profilometer. This method makes it possible to evaluate the main parameters of the surface roughness in different directions of wood grain [6 – 7]. The method for evaluation of wood surface roughness should be proper and chosen very accurately [8]. Gurau L. et. al. compared several standard filters that are not very suitable for oak, beech and spruce surfaces due to distortions, but the Gaussian regression filter avoids these limitations and provides a reliable method of obtaining a roughness profile for measuring wood surface [9].

Wood heat treatment influences surface roughness. The value of wood surface roughness decreases when the processing temperature is higher and the processing time is longer [10 – 11].

Comparing different methods of processing wood (sawn, planed, sanded) it was found that the highest surface roughness was produced by sawn wood. Planed and sanded with P60 grit sandpaper wood surface roughness was comparable. Also it was noticed, that using a finer size grit sanding paper, wood surface roughness started to decrease [3].

Comparing the surface roughness of planed Locust acacia (*Robinia pseudoacacia L.*) and European oak (*Quercus petraea* (Mattu.) Lieble.) wood, it was found that surface roughness of Locust acacia wood was lower than European oak wood [12]. Also it was determined that surface roughness decreases when the feed speed and the cutting depth decreases and increases when the number of the knives on the cutter heads decreases.

Roughness also depends on the direction of sawing – tangential or radial [5]. Research shows that radially sawn wood has a bit lower surface roughness than tangentially sawn wood. Also different surface roughness is obtained in the late and early wood areas [4]. Early wood roughness is higher that late wood.

As researches shows, many factors impacts wood surface roughness, consequently the aim of this research is to evaluate the dependence of wood surface roughness along the grain, across the grain and in the angle of 45º on wood species and grit size of abrasive material.

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MATERIALS AND METHODOLOGY

For the research different species of hardwoods and softwoods were used: ash (*Fraxinus excelsior L.*), birch (*Betula L.*), black alder (*Alnus glutinosa L.*), common Scots pine (*Pinus sylvestris L.*) and spruce (*Picea abies L.*) wood samples with dimensions of (270×215×15) mm. For one wood species and grit size of abrasive material four samples were prepared. In total 120 samples were taken. All the samples were tangentially planed, defect free and kiln dried. Samples dimensions (length×width×thickness) were measured in accuracy of ±0.01 mm. Weight of the samples was established by electronic scales in accuracy of ±0.01 g. In order to determine the grain direction the orientation of growth rings on the sample's end in relation to the sample's surface was measured using the angle ruler. Average wood density is presented in the Table 1.

Some characteristics of the studied wood samples are presented in the Table 1.

Table 1. Characteristics of wood samples

Wood species	Average density, kg/m^3	Number of annual rings per 1 cm	Average width of annual ring, mm	Wood surface grain direction, %
Scots pine	543	8.26	1.21	55.9 T[1] 35.8 T/R[2] 8.3 R[3]
Spruce	480	8.85	1.15	54.1 T 41.6 T/R 4.3 R
Birch	614	3.80	2.63	49.7 T 50.3 T/R
Black Alder	516	3.60	2.78	55.6 T 44.4 T/R
Ash	649	4.10	2.44	34.2 T 63.1 T/R 2.7 R

[1] – tangential surface grain direction, [2] – tangential/radial, [3] – radial.

Initially the samples where conditioned at temperature of 20 ºC and relative humidity of 65 % in order to reach equilibrium moisture content. Moisture content of the wood samples was 12 % ±1 % on average. After conditioning samples were sanded for 1 minute, using commercially available open-type P80, P120, P150, P180, P220 and P240 grit (according to FEPA, Type E) sandpaper. All tests were done in the eccentric sanding stand (revolution of sanding tool 6800 min^{-1}, sanding stroke 5 mm).

Surface roughness parameter R_z was measured using contact stylus profilometer (Mahr Marsurf PS1) a diamond stylus tip radius of which is equal to 2 μm and measurement angle is 90º. Five measurements sectors (12.5 mm × 12.5 mm) for each sample of wood species and grit size were selected. According to wood grain direction three measurements in each sector were done. In total 1800 measurements were performed. All measurement results were processed using a digital Gaussian filter according to DIN EN ISO 11562. Measurement error did not exceed ±10 %. Wood surface roughness parameter R_z was evaluated in three directions: along the wood grain, across and in the angle of 45º.

RESULTS AND DISCUSSION

Typical surface roughness profiles are presented in Figure 1.The results of softwood and hardwood samples surface roughness are shown in Figure 2.

Fig. 2 presents a good correlation between abrasive material and substrate surface roughness parameter R_z. For all wood species surface roughness was reduced mostly along the wood grain, while the roughness obtained across the grain and in the angle of 45° was almost similar to each other. Most of all reduced surface roughness was observed during the investigation of softwood samples. After changing the grain of sandpaper from P80 to P240, surface roughness for wood of Scots pine decreased by: 65.8 % along the wood grain, 61.5 % across the grain, and 62.1 % in the angle of 45º; for wood of spruce: 57.7 % along the grain, 58.0 % across the grain, and 58.3 % in the angle of 45º. As it is seen from Table 1 and Fig. 2, the best correlation of roughness parameters with the grit size of abrasive material was obtained while investigating the samples of spruce wood. The surface of spruce is relatively uniform due to the absence of vessels / pores [13]. It is seen from the results of research that low density, a large number of annual rings and small width of annual rings is inherent to the samples of Scots pine wood. Scots pine wood has 1.07 times less annual rings in 1 cm plot of investigated sample compared to spruce wood but the width of annual rings is 1.05 times larger in comparison with the average width of spruce wood annual rings. Such difference is also influenced by the direction of investigated wood surface grain. Tangential grain direction on the surface of spruce wood composed 54.1 % of the whole samples area, and 55.9 % in the samples of Scots pine wood. Thus, number of annual rings together with the amount of early wood increased in the case of higher percent of tangential / radial and radial wood grain. It is the explanation for 1.18 times higher surface roughness of spruce wood in all samples' groups compared to samples' groups of Scots pine wood. It is also known that softwood is resinous. Surface roughness parameter R_z is slightly influenced by the presence of resin canals in wood macrostructure.

The other samples' group was composed of hardwood. Herein the difference between the highest and the lowest values of roughness parameter R_z after changing the grit size of abrasive material from P80 to P240 decreased for birch wood: along the wood grain by 57.0 %, across the grain by 36.1 % and in the angle of 45º – by 39.5 %. Roughness parameter R_z of black alder wood altered by 48.5 % – 52.9 % respectively. Proportional dependence of R_z parameter variation was not observed in the investigation of roughness of these wood species. When investigating birch wood samples, the lowest values of R_z parameter across the wood grain and in the angle of 45º were obtained after processing the received wood samples with P220 sandpaper. The latter values are 3.22 % across the wood grain and 6.66 % in the angle of 45º lower compared to those when processing the wood with P240 sandpaper. Such uneven alteration of wood surface roughness might be influenced by the quality of mechanical surface processing. The main reason is that it is difficult to distinguish the surface irregularities caused by timber processing from the roughness due to wood anatomy

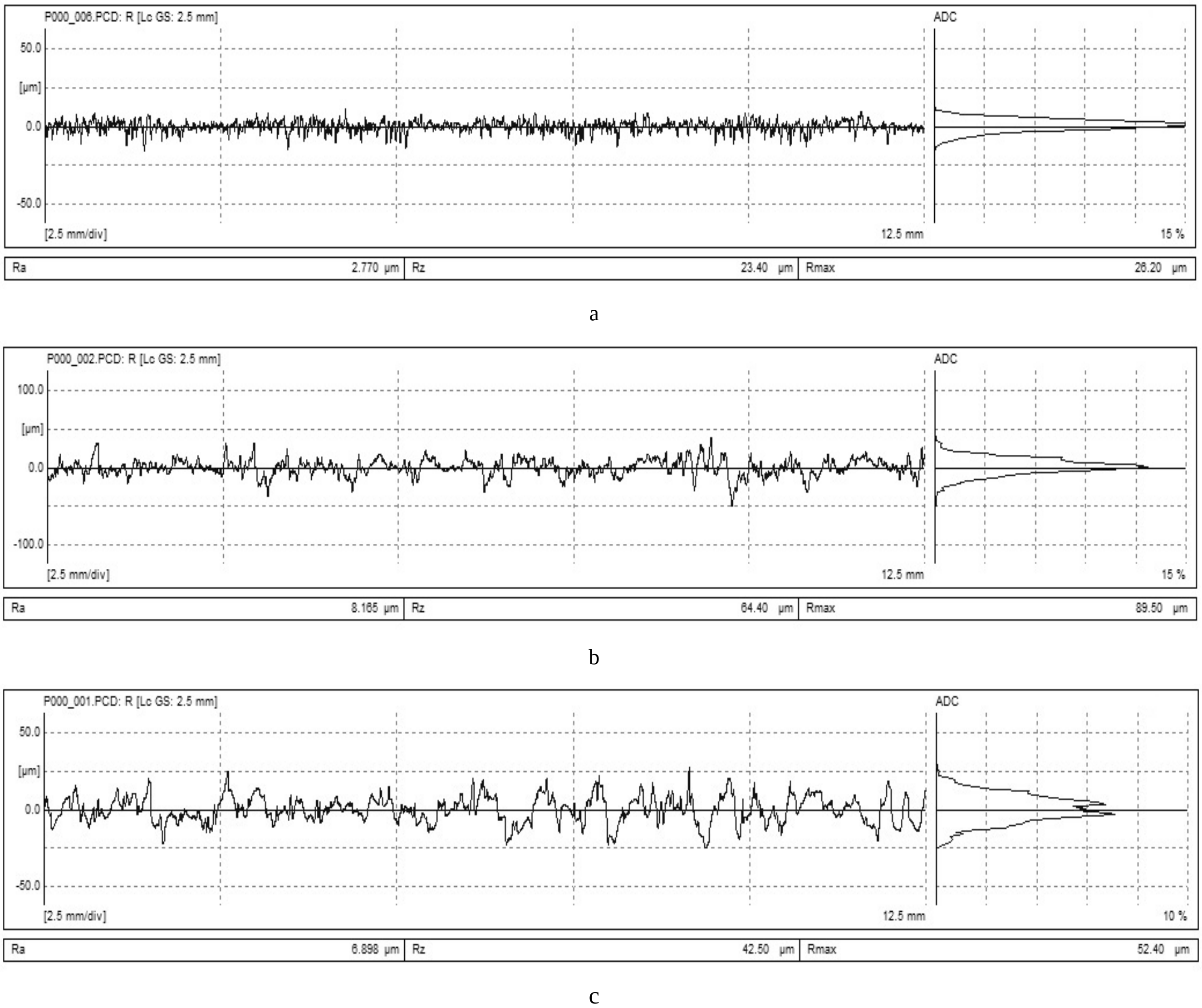
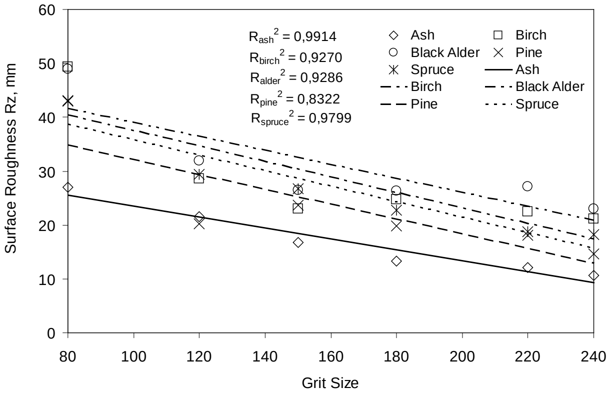


Fig. 1. Typical surface roughness R_z profiles of birch wood: a – along the wood grain; b – across the grain; c – in the angle of 45º

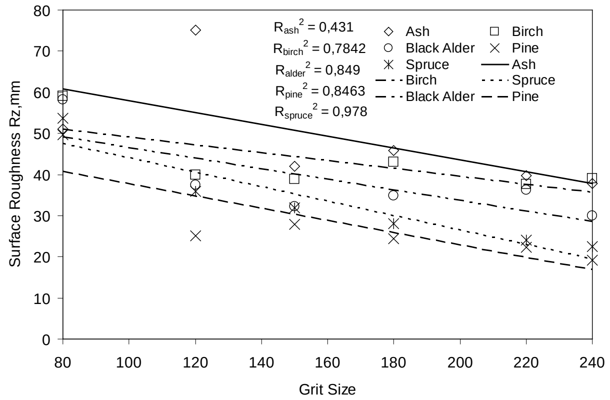
variations [14]. Birch wood, same as black alder wood, has not got clearly expressed annual rings and is discursively porous. Ladder vessels perforation is typical for these wood species, and therefore, the values of wood surface roughness parameter R_z distribute evenly in the whole area of investigated sector (Fig. 2), resulting in similar results of wood surface roughness in all three directions. Thus average surface roughness R_z of birch wood in all measurement directions was only 1.06 times larger in comparison to average roughness of black alder samples. It was also observed during research that annual rings of black alder wood were slightly waved. Surface roughness of wood can be affected by various factors such as annual ring variation, wood density, cell structure, and late wood / early wood ratio [3]. Average width of annual rings in black alder wood samples is 2.78 mm and number of rings per 1 cm is 3.60. Meanwhile in the samples of birch wood, the width of rings was 1.06 times less and number of annual rings per 1 cm was 1.06 times larger compared to corresponding values of black alder wood samples due to grain direction on the surfaces of wood samples (Table 1). Larger average surface roughness of birch wood was also influenced by wood density which was 1.19 times bigger than density of black alder wood samples.

The largest variation of the values of wood surface roughness parameter R_z was estimated when investigating ash wood samples. In the group of ash wood samples, the largest correlation discrepancy was obtained between roughnesses of different processing groups except for research of roughness parameter R_z along the wood grain.

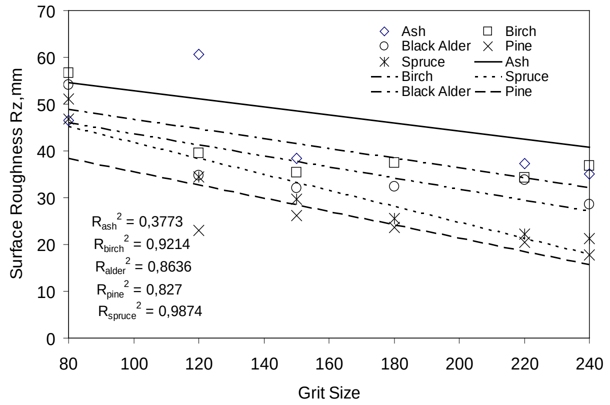
When investigating ash wood along the grain, the difference between the largest and the smallest roughness values was linear and composed 60.8 %. Meanwhile after analysis across the ash wood grain, the largest R_z was obtained in P120 samples group and in the angle of 45º – in P180 samples group. Differences between the highest and the lowest roughness values composed 49.7 % across the wood grain and 46.6 % in the angle of 45º respectively when average width of annual rings was 2.44 mm and the number of rings per 1 cm was 4.10. Such uneven alteration of surface roughness is caused by vessels in wood microstructure that are set in circular rows in early wood. Wood species with large vessels in the early wood may locally cause large surface irregularities which have nothing to do with the machining process [2]. Without the deep valley removal, the surface roughness parameters



a



b



c

Fig. 2. Surface roughness dependence on the grit size and wood species: a – along the grain; b – across the grain; c – in the angle of 45º

obtained do not always show a good correlation with the grit number [8]. It is also worth mentioning that tangential sawing surfaces comprised only 34.2 % of all samples when investigating ash wood samples' group. Therefore, the results of wood surface roughness are different compared to those where surface roughness of other wood species was investigated in all three directions.

It was determined when comparing all five wood species that the biggest differences between the largest and the smallest R_z values in all three directions were obtained in the cases of spruce and ash wood samples, i. e. wood surface roughness most decreased with increasing grit size of sandpaper, especially for ash wood samples along the wood grain of late wood. The best correlation of roughness parameter in all three directions when changing grit size of sandpaper was estimated in the group of spruce wood samples (Fig. 2). In this group the coefficient of variation varied from 9.19 % to 11.02 % in all three measurement directions. The samples of spruce wood had the largest number of annual rings (8.55 per 1 cm) and the smallest average width of the annual ring (1.15 mm) compared to the other wood species. Variation coefficient of the roughness parameters of the rest wood species by the grain direction was only 1.24 – 1.42 times higher, except for ash wood, where the coefficient of variation was 2.61 times higher. Such low values of determination coefficient and high values of variation coefficient can be explained by the anatomical features of ash wood.

According to wood grain direction the largest determination coefficient was determined along the wood grain. Here surface roughness dependence on the grit size and wood species was almost linear. Meanwhile the measurements, performed across the wood grain and in the angle of 45º, were less statistically reliable.

CONCLUSIONS

Wood surface roughness is directly dependent on the grit size of sandpaper, anatomic characteristics of wood species and direction of wood grain. When using a finer size grit sanding paper, wood surface roughness started to decrease in all three directions of wood grain but strict linear dependence was not estimated. After investigating five wood species, it was determined that the least surface roughness was observed when analysing the wood along the grain. Wood surface roughness in the case of across the wood grain was 1.46 times larger compared to that of along the wood grain and 1.06 times higher in comparison to wood grain in the angle of 45° respectively. The highest surface roughness was obtained when analysing wood samples in P80 samples group and the lowest was found in P240 samples group. The difference between the highest and the lowest values was equal to 1.97 times. The best dependence of roughness parameter R_z from wood grain direction and grit size of abrasive material was obtained when investigating spruce wood samples. While investigating the roughness of ash wood samples additional studies of parameters should be established in order to eliminate the distortions of wood roughness due to large vessels in the measurement way. In order to evaluate the surface roughness effectively, it is recommended to perform the measurements not only along, but and across the wood grain.

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