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Analysis of surface roughness in wood milling

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Abstract: *Analysis of surface roughness in wood milling.* The surface roughness of wood products depends on many factors related both to wood properties and machining parameters. Probably, this is the reason why there are no useful mathematical models which would allow to determine surface roughness parameters. The aim of this study was to estimate effect of various factors on the surface roughness of fir (Abies alba), pine (Pinus silvestris) and larch (Larix decidua) wood. Properties of milled surface were determined with usage of contact profilometer. Roughness parameters measured for each analyzed surface were following: average arithmetic deviation of roughness profile (Ra), mean peak-to-valley height according 10 points (Rz), and greatest height of irregularity (Rmax). The results analysis was conducted with usage of statistical significance test (t-Student) and multivariate tests of significance (ANOVA). A significant impact of the tool wear degree, wood species and machining direction on observed roughness parameters was proved. Two statistically significant interactions between factors affecting the quality of milled wood surface were found.

Keywords: wood working, milling, roughness parameters

INTRODUCTION

The surface of wood subjected to different ways of machining, for given species, depends on many factors connected as well with the process of cutting (parameters of cutting, direction of machining, degree of tool wear etc) as with specific properties of machined material (wood defections, humidity of wood, contribution of late wood). Hard species give usually better surface quality than soft species. Similarly, late wood distinguishes by lower level of roughness [Staniszewski 1974]. Higher values of surface roughness are obtained by measurement across the fibers than along the fibers [Siemiński 1962]. Changes of humidity caused the changes of roughness [Staniszewski 1974, Krzysik 1978]. Alone structure of wood and his anatomic elements (vessels, tubes, wood fibers and parenchyma) has great significance too [Magoss 2008]. According to Sandak et al. [2008] wood surface roughness in industry conditions is a result of alone process and interactions which take a place between tool and machined element. Many irregularities of wood surface is caused by features of material and structure of wood. Therefore, porous surface of wood can't be never dead smooth. Keturakis and Juodeikiene [2007] proved in their researches which concern roughness of wood after milling, that the best surface quality is obtained by usage of sharp tool and feed per tooth in range from 0,5mm to 1,5mm. Moreover, the cutting speed should amount 40,8m/s. According to authors, increasing of cutting speed improve quality of surface regarding to fact that process of cutting comes faster and the wood fibers are regularly sliced instead of partly crushing. Magoss [2008] noticed the same phenomena. Author concluded, that surface of species with lower density is more sensitive to cutting speed changes.

Multiplicity and variety of many factors makes the analyzing of correlation relationships between each other and parameters which characterize given surface much more complicated. Maintaining of scientific works number in this area on huge level, proves significance and unabated interest in this problem. According to above statements, the influence of chosen factors on three basic roughness parameters (Rz, Rmax, Ra) was analyzed. The interactions existing between them were taken into account too.

MATERIALS AND METHODS

Coniferous sawn timber of three species: fir, larch, and pine with humidity in range 12-15% was machined. Close-grained timber (with average width of annual rings above 3mm) with rectilinear scheme of fibers with rarely occurring knots, without cracks, over colourings, bends, putrefactions, and pavements of insect was machined during experiments. Dimensions of sawn timber: thickness above 25mm, length – about 1000mm, width in range from 200 to 400mm. Inspection work pieces of analyzed wood species with dimensions 40x40x230mm were prepared, 20 pc per each species. These work pieces were used to surface roughness measurements after milling.

Machining of material was carried out by usage of portable milling machine of FERM, model FBF-1200 (Fig.1a). This is typical device, widely used in small workbenches. Three two edges router bits from HSS (GUHDO no 7120.100.80) were taken in experiments (Fig.1b). Diameter of tool holder amounted 8mm, length of working part – 20mm, diameter of working part – 10mm, whole length of tool – 48mm, maximal rotational speed 27 000 RPM.

a) **b)**

Fig.1. a) Portable milling machine FERM FBF-1200 b) Two edges router bit GUHDO HS 355

One tool was necessary to estimate criterion of tool wear. The tool with this value of wear was treated as unfit for the further exploitation. The machining was started with brand new tool and then climb milling of fir sawn timber wood was realized up to moment when the surface quality obtained by visual and contact subjective assessment was inadmissible. The feed distance of tool in machined material was calculated. After breaking of machining what happened after feed distance of 80m, the value of direct tool wear indicator was measured by usage of microscope. It was assumed that it will be measured indicator VBmax, in other words, maximal abrasion on clearance face of edge. The measuring of this indicator was conducted on two edges and average value for the whole tool was calculated. In return value of VBmax was assumed on level 0,12mm. This value became tool wear criterion for the next tools which were used in case of larch and pine. It means that the milling was stopped after achieving by tool this level of blunting. Similarly as first tool, remaining two tools achieved mentioned above degree of wear after feed distance of 80m. Showed above procedure of tool wearing was paused by milling with usage of the same tool, inspection work pieces with dimensions 40x40x230mm (necessary to surface roughness measurement), after 0m (brand new tool), 20m, 40m, 60m i 80m. These work pieces were sliced off from the sawn timber used to tool wearing. Four variants of machining schema were realized in respect of kind and direction of milling: climb milling across fibers, climb milling along fibers, conventional milling across fibers, conventional milling along fibers. In practice, terms which correspond to direction of machining are widely used. Thus, there is common in literature expression such as longitudinal milling [Duchnowski 1997]. In this researches was conducted longitudinal milling – feed direction was parallel to fibers and across milling – feed direction was perpendicular to fibers direction (Fig.2). Sixty work pieces, twenty from each wood species were gathered as result of this experiment. Wearing of tool as well as milling of inspection work pieces was carried out with constant cutting parameters:

- rotational spindle speed – 9 000 RPM,
- diameter of cutting – 10mm,
- cutting speed – 4,7m/s,
- feed speed (manual) – about 3 m/min,
- feed per tooth – about 0,17mm,
- depth of milling – 20mm,
- width of milling – 5mm.

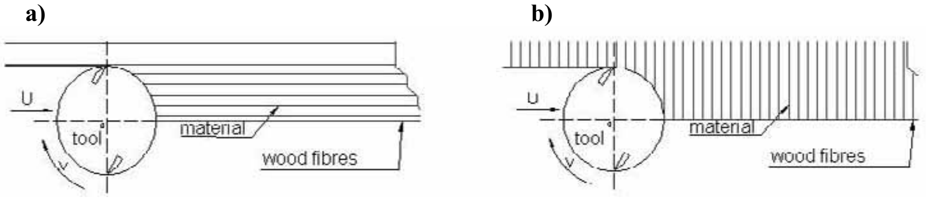

Fig.2. a) along fibers b) across fibers

The second stage of work was carried out in laboratory conditions in Department of Wood Machining WTD SGGW. Work pieces from the first stage of experimental researches were investigated by means of profilometer MITUTOYO Surftest 501 in respect of surface roughness. This device is standard contact profilometer assigned to direct measurements. The top of the needle had a radius of curve 100 µm and angle of cone slope 90°. Measurement distance amounted 8mm and consisted of three elementary sections (each 2,5 mm of length, according to PN-84/D-01005). The surface of each work piece was divided into eight areas where were conducted three roughness measurements. Therefore, each work piece was described by 24 values. There were obtained following surface roughness parameters: R_z, R_{max}, R_a.

RESULTS AND DISCUSSION

In Fig.3 was showed influence of feed distance on surface roughness of machined elements. The highest determination coefficient amount 0,9 for R_z parameter (Fig.3) and the lowest (0,7) for R_{max} parameter. These values of coefficients proved close linear dependences between feed distance and analyzed surface roughness parameters. Larch turned out the best in respect of machining quality. However, the difference between larch and pine was not statistically important (Fig.4). The highest values of roughness parameters were obtained for fir-wood (Fig.4).

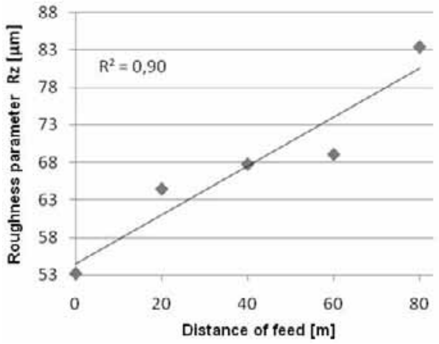

Fig.3. Dependency of machined surface roughness (parameter R_z) from feed distance

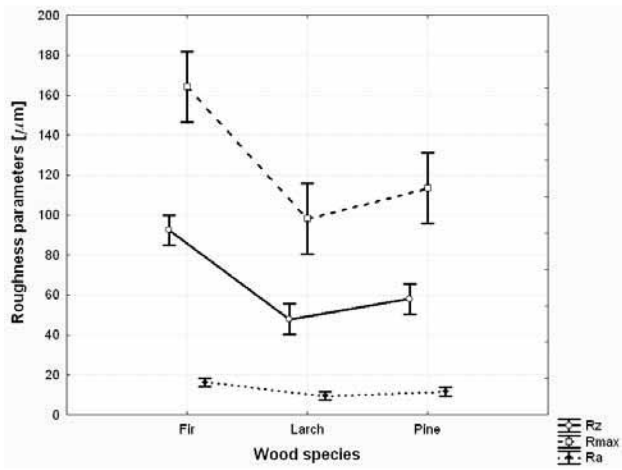

Fig.4. The influence of wood species on machined surface roughness

Significantly, higher values were noticed for direction of machining across fibers than along fibers. In this case, these differences were statistically significant.

For all investigated roughness parameters, values of these parameters were lower after conventional milling than after climb milling. However, it is necessary to add that these differences were not statistically significant.

Besides, basic factors such as feed speed, species of wood or direction of milling, two statistically significant interactions have the influence on surface roughness after milling:

- species of wood * kind of milling (climb, conventional),
- direction of milling * kind of milling.

These interactions are visible in Fig. 5 and 6.

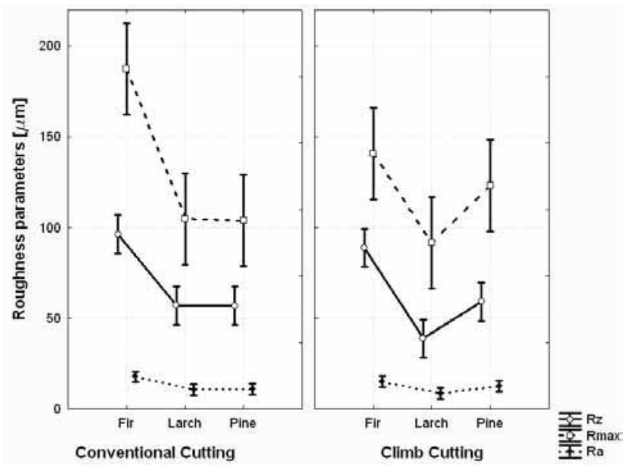

Fig.5. Influence of interactions between species of wood and kind of milling on machined surface roughness

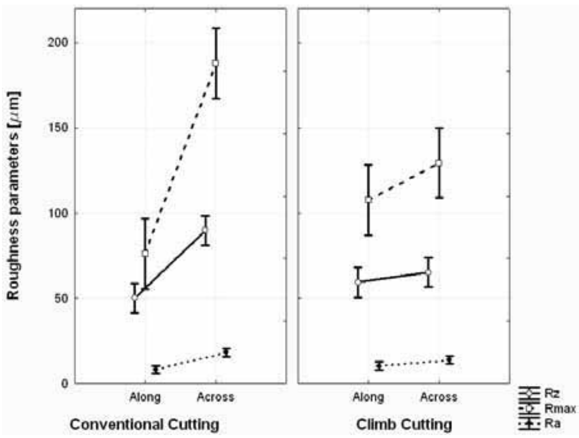

Fig.6. Influence of interactions between direction of milling and kind of milling on machined surface roughness

CONCLUSION

Obtained results allow to formulate following conclusions:

1. Surface roughness increased with increasing of feed distance and it was strongly linear relationship.
2. Surface roughness after milling with usage of blunt tool was higher than brand new one independently from species of machined wood.
3. The highest roughness during machining was obtained for pine and the lowest for larch.
4. Wood which was sliced across fibers had definitely higher roughness than wood milled along fibers, independently from wood species. The influence of this factor was statistically significant.
5. Wood which was milled conventionally distinguishes by lower roughness than climb milled wood. The influence of this factor was not statistically significant.

6. Two statistically significant interactions between factors affected the analyzed roughness parameters were proved:
   - species of wood * kind of milling,
   - direction of milling * kind of milling.
7. All three roughness parameters (R_z, R_{max} i R_a) showed similar character of changes which concern dependency and statistical importance. This fact proves their equivalent usefulness in investigations of wood surface roughness after milling.

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Streszczenie: *Analiza chropowatości powierzchni frezowanego drewna.* Chropowatość powierzchni wyrobów z drewna zależy od wielu czynników związanych zarówno z właściwościami drewna, jak i parametrami obróbki. Prawdopodobnie to jest powodem, dlaczego tak trudno zbudować funkcjonalne modele matematyczne, które by pozwoliły na wyznaczanie parametrów chropowatości. Celem przeprowadzonego badania była ocena wpływu różnych czynników na chropowatość powierzchni drewna jodły (Abies alba), sosny (Pinus silvestris) i modrzewia (Larix decidua). Cechy powierzchni frezowanej były określane przy użyciu profilometru stykowego. Dla każdej analizowanej powierzchni mierzono następujące parametry chropowatości: średnie arytmetyczne odchylenie profilu chropowatości (Ra), wysokość nierówności profilu według 10 punktów (Rz) i największa wysokość nierówności profilu (Rmax). Analizę wyników przeprowadzono z wykorzystaniem testów istotności różnic (t-Student) i wielowymiarowych testów istotności (ANOVA). Wykazano istotny statystycznie wpływ stopnia zużycia narzędzia, gatunku drewna i kierunku obróbki na badane parametry chropowatości. Stwierdzono dwie istotne statystycznie interakcje pomiędzy czynnikami wpływające na jakość frezowanej powierzchni drewna.

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