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THE INFLUENCE OF CUTTING SPEED AND FEED SPEED ON SURFACE QUALITY AT PLANE MILLING OF POPLAR WOOD

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ABSTRACT

The paper aims at pointing out the influence of technological parameters (technological conditions of woodworking, kind of wood) on surface quality at plane milling of poplar wood. This paper reports the differences in surface quality between juvenile and mature poplar wood depending on cutting speed and feeding speed. It was shown that the better surface quality arises by processing of juvenile wood in comparison with mature wood.

KEYWORDS: poplar wood, juvenile wood, plane milling, surface roughness

INTRODUCTION

The quality of machined surface is characterized by the accuracy of its manufacture with respect to the dimensions specified by the designer. Every machining operation leaves characteristic evidence on the machined surface. This evidence in the form of finely space micro irregularities is left by the cutting tool. Each type of cutting tool leaves its own individual pattern which therefore can be identified. This pattern is known as surface finish or surface roughness (Cyberman education page 2007).

The juvenile wood achieves different values of physical and mechanical properties. The effect of changed wood properties on their processing is supposed. It is important to know the particularities of juvenile wood, mainly the different quality which wood processors will have to prepare for. After recognizing the differences of juvenile wood, it will be possible to eliminate disadvantages or to utilize the positive properties properly.

The wood surface roughness directly concerns the final use of wood products. If its surface roughness is known, its quality for a specific function can be determined. Also the machining parameters or the tools can be changed to enhance productivity and increase quality of wood products by a continuous control of the surface roughness (Aguilera and Martin 2001).

The surface roughness is geometrical property of surface and it do not exists methods and means at its direct measurement. There are measuring an appropriate characteristics and parameters, what they are considered by criteria of surface roughness. The standard STN EN ISO 4287 (1997) goes from profile method at evaluation of surface pattern, i. e. it evaluates the surface from profile of surface, i. e. from line, what it rises by cut of the real surface by the definitive plane.

The height, shape, arrangement and direction of surface irregularities (surface roughness) on the workpiece depend upon a number of factors such as (Cyberman education page 2007):

- The machining variables which include cutting speed, feed speed and depth of cut
- The tool geometry
- Workpiece an tool material combination and their mechanical properties
- Quality and type of the machine tool used
- Auxiliary tooling, and lubricant used
- Vibrations between the workpiece, machine tool and cutting tool.

Ones of the most important factors are technological conditions of cutting process (cutting speed, feed speed) and properties of workpiece (juvenile and mature wood).

Juvenile wood is defined as wood, which is formed in the first years of tree growth and which is found around the pith. Main recourses of juvenile wood are plantations with fast-growing trees. In Slovakia approximately 50 000 m^3 of pine wood and 60 000 m^3 of poplar cultivars (hybrids) with rotation period from 17 to 35 years are obtained by this method.

The juvenile wood in hardwoods is characterized by (Juvenile and reaction wood): two times shorter cells than in the mature wood, narrower wood cells – lower density and strength, smaller amount of latewood cells, higher occurrence of spiral grains, higher longitudinal shrinkage, higher portion of lignin, lower portion of cellulose, higher compression and tensile strength, lower tearing strength.

Juvenile zone of *Populus tremula* L. was estimated to be 10 growth rings around the pith in breast height on the basis of visual method in combination with other measured physical and mechanical properties. The measured values of some physical and mechanical properties of *Populus tremula* L. are shown in Tab. 1 (Zobel and Sprague 1998).

Tab. 1: Overview of physical and mechanical properties – Populus tremula L.

Property	Juvenile wood	Mature wood
Tangential shrinkage [%]	5,5	6,2
Radial shrinkage [%]	5,1	4,7
Oven-dry density [$kg.m^{-3}$]	331	364
Specific gravity [$kg.m^{-3}$]	297	322
Modulus of elasticity [Mpa]	5776	7293
Modulus of rupture [Mpa]	17,95	21,91
Impact bending [$J.cm^{-2}$]	1,9	3,2

Much less has been found out on the effect of juvenile wood on solid woo products in the hardwoods. The low quality of juvenile wood is more marked in conifers than in hardwoods. The utilization of juvenile wood is increasing rapidly due to shorter harvesting rotations, more use of thinnings and better of top wood. The fast growing species can be harvested at young ages even when nearly all the wood is juvenile, without a serious loss of product quality (Zobel and Sprague 1998).

MATERIAL AND METHOD

In experimental tests were used the samples from poplar (*Populus tremula* L.), which comes from the region Kováčovská dolina, the cadastre School Forest Enterprise, 375 m above sea level, in age 45 years, with 27 % portion of juvenile wood.

There were gained radial experimental specimens with length 1 m by mechanical manipulation of log and after drying and air conditioning 12±1 % of moisture content.

The experimental tests were realized at spindle moulding machine with feeding device with stair-step change of feeding speed v_f = 2,5 and 15 m/min and cutting speed v_c = 30, 45 and 60 m/s. As tool was used shaper head with angular geometry – cutting edge angle β_f = 45º and cutting face angle γ_f = 15°. By using of miller with cutting edge angle 45° and face angle 15° was measured the lowest energy demand of cutting process. For this reason this milling cutter was used at evaluating of surface roughness.

Process of surface roughness measuring

Before measurement of surface roughness is determined the evaluation length on the basis of the maximum height of profile Ry and sampling length according to the standard STN EN ISO 4287 (1997). For our case the evaluation length is L = 40 mm.

The measurement of surface roughness was realized in Poznan University of Life Sciences. The stylus method was used to the evaluation of surface roughness. The device on measurement of roughness is grounded on inductive sensor Tesa TT 300. The parameters of device:

Compressive force ≈ 0,2 N,
Feed speed of probe 0,8 $m.s^{-1}$,
Radius of contact tip 100 µm,
Step of sampling 0,08 mm

The measurement of surface roughness was realized on specimens with dimensions 35 x 5 x 150 mm (width x thickness x length). The primary profile was determined in three longitudinal lines on specimens. From primary profile were evaluated the maximum height of profile and arithmetical mean deviation of profile.

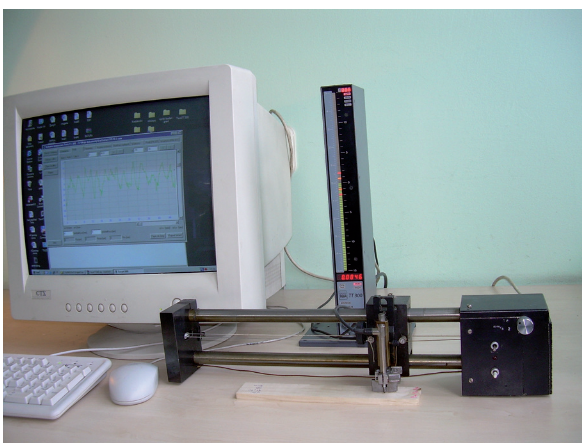

Fig. 1: The device on measurement of surface roughness

RESULTS AND DISCUSSION

The surface quality decreases when applying increasing feeding rate and rotation speed (Aguilera and Martin 2001). The other author state that the roughness will be reduced with a constant rotation speed and a small feeding rate (Lavery et al. 1995). Wood density has an influence on the surface roughness. If density is weak, then the roughness will be increased. The results of our measurements report:

Feeding speed

The surface quality decreases with increasing feeding speed. By feeding speed 15 $m.min^{-1}$ the surface roughness achieves the higher values in comparison of feeding speed 2,5 $m.min^{-1}$. These courses we can obvious see in Figs. 2 to 5. The reason of decline of surface quality with increasing feeding speed:

- The cutting tool removes a greater layer of material on one rotation.
- The greater tearing grains.
- The greater depth of wavelets.

Cutting speed

The influence of cutting speed on surface quality is not clear. At combination with feeding speed 2,5 $m.min^{-1}$ the influence of cutting speed is weak. The differences of roughness value among the particular values of cutting speed are not very significant. At combination with feeding speed 15 $m.min^{-1}$ it is much bigger affect of cutting speed on roughness. By feeding speed 15 $m.min^{-1}$ the surface quality improves with increasing cutting speed. The reason of improvement of surface quality with increasing feeding speed is caused by reverse characteristics as by the influence of feeding speed (present above).

The best value of surface roughness it was achieved by the combination of feeding speed 2,5 $m.min^{-1}$ and cutting speed 60 $m.s^{-1}$.

Wood properties

The arithmetical mean deviation of profile Ra and the maximum height of profile Rz achieve the lower values for the juvenile wood in comparison of the mature wood (for both feeding speed), as we can see in Figs. 2 to 5. So the juvenile wood is defined by better surface roughness.

The greatest difference between roughness of juvenile and mature wood is in combination of cutting parameters:

- feeding speed vf = 2,5 $m.min^{-1}$, cutting speed vc = 45 $m.s^{-1}$
- feeding speed vf = 15 $m.min^{-1}$, cutting speed vc = 30 $m.s^{-1}$

The difference between juvenile wood and mature wood is affected by the distinct anatomical, physical and mechanical properties of juvenile wood. The juvenile wood has shorter wood cells than the mature wood and then the unevenness after tearing grains is smaller. The lower strength characteristic of juvenile wood allows an easier dividing of wood elements, what it is evoked a lesser breaking of surface and herewith a better roughness.

In the most optimal combination of cutting parameters (v_f = 2,5 $m.min^{-1}$, v_c = 60 $m.s^{-1}$), the difference between roughness of juvenile and mature wood is not expressive.

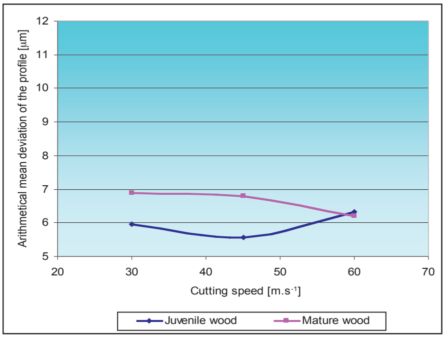

Fig. 2: Arithmetical mean deviation of profile Ra at v_f = 2,5 m.min^{-1}

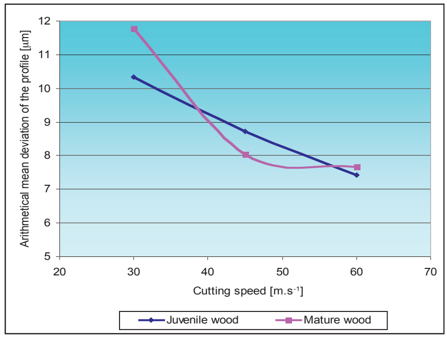

Fig. 3: Arithmetical mean deviation of profile Ra at v_f = 15 m.min^{-1}

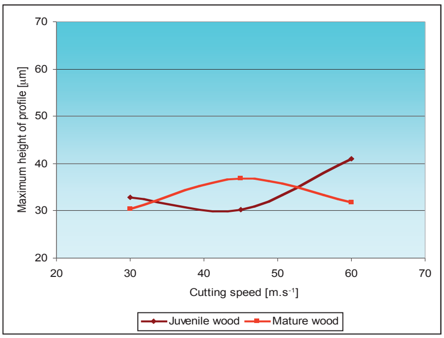

Fig. 4: Maximum height of profile Rz at v_f = 2,5 m.min^{-1}

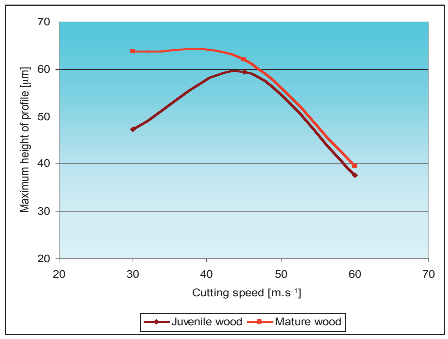

Fig. 5: Maximum height of profile Rz at v_f = 15 m.min^{-1}

CONCLUSION

The measured values of roughness of the juvenile wood are lower than the mature wood. The obtained surface quality of juvenile wood is better even though the juvenile wood has worse physical and mechanical properties in comparison of the mature wood. The following or final processing of juvenile wood is more and less identical than in mature wood. By using some combinations of cutting parameters the juvenile wood achieves even a better quality surface. The juvenile wood it not requires such a great stock removal in following woodworking operation. In final woodworking of juvenile wood we can achieve the lower energy demand and all costs of process.

Juvenile wood as a material starting to process in wood industry have their particularities, what are need to know and prepare on them. It is necessary to count with their different quality; therefore it can not be on every product. As well it is necessary to improve the primary application or to use the juvenile wood so that negative properties were eliminated.

The experimental measurements covered only the part of the problems. They do not represent the complex solved question of plane milling of juvenile wood at given conditions. In general they are basic and supplementary material for further continuing of experiments focused on observation of other interaction parameters of plane milling process of juvenile wood. The aim of these experiments should be creation of the milling techniques with minimal energy output and improved machined surface, as well as economic valuation of material, equipment and technology.

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