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Effect of technological parameters and wood properties on cutting power in plane milling of juvenile poplar wood

Utjecaj tehnoloških parametara obrade i svojstava drva na snagu rezanja pri blanjanju juvenilnog drva topole

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ABSTRACT • *This paper presents the results of experimental measurements aimed at observing the effect of technological parameters (cutting speed v_c and feed speed v_f), type of wood (juvenile wood and mature wood) and wood species (aspen Populus tremula, L. and hybrid poplar Populus × Euramericana „Serotina") on cutting power during plane milling of poplar wood.*
The results showed the reduction of cutting power with the decrease of cutting speed and feed speed. Lower cutting power was also measured in milling hybrid poplar than in milling aspen. The test also confirmed the effect of different anatomical and chemical structure of juvenile wood in relation to mature wood on different physical and mechanical properties of such wood and hence also on the cutting power in processing juvenile wood.

Keywords: *milling, poplar, cutting power, juvenile wood, fast-growing trees*

SAŽETAK • *U radu su izneseni rezultati eksperimentalnih mjerenja izvedenih radi ustanovljivanja utjecaja tehnoloških parametara obrade (brzine rezanja v_c i posmične brzine v_f), zrelosti drva (juvenilno drvo i zrelo drvo) i vrste drva (jasika - Populus tremula, L. i kanadska topola - Populus × Euramericana „Serotina") na snagu rezanja pri blanjanju.*
Rezultati eksperimenta pokazali su smanjenje snage rezanja sa smanjenjem brzine rezanja i posmične brzine. Manja snaga rezanja izmjerena je pri blanjanju drva kanadske topole nego pri blanjanju jasike. Eksperiment je potvrdio i utjecaj različite anatomske i kemijske građe juvenilnoga drva u odnosu prema zrelom drvu na fizikalna i mehanička svojstva takvoga drva, a time i na snagu rezanja pri mehaničkoj obradi juvenilnog drva.

Ključne riječi: *blanjanje, topola, snaga rezanja, juvenilno drvo, brzo rastuće drveće*

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1 INTRODUCTION
1. UVOD

In this millennium it is expected that utilization of wood plantation-cultivated fast growing wood species will represent the highest percentage of worldwide wood processing. Fast growing species have a high share of juvenile wood; therefore it is important to know its specific characteristics. Juvenile wood is characterized by different quality, to which wood processors will have to be adapted. Knowing its properties, it will be possible to eliminate its disadvantages or correctly utilize its positive properties.

The aim of the present study is to point out cutting power of processing juvenile poplar wood as well as differences between the processing of naturally growing and plantation-cultivated poplar under various technological conditions.

Juvenile wood is defined as wood formed in the first years of tree growth and found around the pith (Zobel and Sprague, 1998). Juvenile wood in deciduous trees is characterized by (Maeglin, 1987): two times shorter cells than in mature wood, narrower wood cells – lower density and strength, higher occurrence of spiral grains, higher longitudinal shrinkage, higher portion of lignin, lower portion of cellulose, higher tensile strength, lower tearing strength.

Juvenile zone of poplars was estimated to be 10 growth rings around the pith at breast height on the basis of the visual method in combination with other measured physical and mechanical properties. Before performing our experiments, some physical and mechanical properties were measured as the ground for understanding the difference between juvenile and mature wood and between poplars. Table 1 shows the average values of measured properties of aspen and hybrid poplar.

The low quality of juvenile wood is more marked in conifers than in deciduous trees. The utilization of juvenile wood is increasing rapidly due to shorter harvesting rotations, more use of thinnings and better quality of top wood (Zobel and Sprague, 1998).

The 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) are obtained by this method with the rotation period from 17 to 35 years (Bielik, 2006).

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).

Wood properties of hybrid poplar clones were lower than those of native aspen and cottonwood species (Peters *et al.*, 2002).

Hybrid poplars are primarily intended for paper raw material, but in twenty or thirty years a considerable volume of saw or veneer logs will also be obtained from those stands. These poplars are occasionally also used as construction lumber and as raw material of laminated veneer lumber (Junkkonen and Heräjärvi, 2006).

2 MATERIAL AND METHODS
2. MATERIJAL I METODE

In experimental tests, samples of aspen (*Populus tremula* L.) were used originating from the region of Kováčovská dolina, the cadastre School Forest Enterprise Zvolen, 375 m above sea level, 45 years of age, with 27 % portion of juvenile wood. The other used wood was hybrid poplar (*Populus × Euramericana „Serotina"*) originating from the region of Kráľová lúka (District of Gabčíkovo), 118 m above sea level, 37 years of age, with 30 % portion of juvenile wood.

One meter long radial specimens were made by mechanical processing of logs and with moisture content of 12±1 % after drying and air conditioning.

The experimental tests were carried out on a spindle moulding machine equipped with the feeding device with the possibility of stepping change of feed speed $v_f = 2.5$ and 15 $m \cdot min^{-1}$ and cutting speed $v_c = 30$, 45 and 60 $m \cdot s^{-1}$. The main tool was a shaper head with angular geometry – cutting edge angle $\beta_f = 55°$, cutting face angle $\gamma_f = 15°$ and with two knives (e.g. two cutting edges). For the purpose of the experiment, cut width was estimated to 35 mm and cut depth to 1 mm.

The principle was used of cutting power based on the alternating current of machine electromotor from the mains, Figure 1 (Barcík *et al.*, 2006).

The measured values of cutting power were evaluated in Statistics 6.0 program by means of analysis of variance (Scheer, 2007). Estimates were made of the

Table 1 Overview of physical and mechanical properties of examined wood samples
Tablica 1. Pregled fizikalnih i mehaničkih svojstava istraživanih vrsta drva

Property	***Populus tremula* L.**		***Populus × Euramericana „Serotina"***	
	Juvenile wood *Juvenilno drvo*	Mature wood *Zrelo drvo*	Juvenile wood *Juvenilno drvo*	Mature wood *Zrelo drvo*
Kiln-dry density, $kg \cdot m^{-3}$ *gustoća suhog drva*, $kg \cdot m^{-3}$	331	364	313	342
Modulus of elasticity, MPa *modul elastičnosti*, MPa	6620	7970	5650	7030
Modulus of rupture, MPa *modul loma*, MPa	61	65,7	46,1	51,8
Impact bending, $J \cdot cm^{-2}$ *otpornost na udarce*, $J \cdot cm^{-2}$	1,9	3,2	3,4	4,6

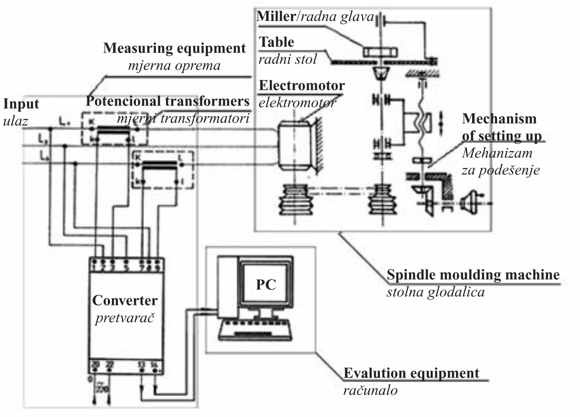

Figure 1 Scheme of experimental machine
Slika 1. Shematski prikaz stroja i mjernoga lanca

zero hypothesis H_0 that says that the mean squares of measured values of cutting power are equal and alternative hypothesis H_1 that says that the mean squares are not equal.

4 RESULTS
4. REZULTATI

The acquired values of cutting power were subjected to analysis of variance, which showed dependence of cutting power on feed speed, cutting speed and type of wood (juvenile wood, mature wood) for both wood species. The results are presented in Table 2 and 3.

It can be concluded from statistics results that the zero hypothesis H_0 was refused and thereby the alterna-

Table 2 Analysis of variance for aspen (*Populus tremula* L.)
Tablica 2. Analiza varijance izmjerenih vrijednosti snage rezanja za drvo jasike (*Populus tremula* L.)

	SS	*DF*	*MS*	*F*	*p*
feed speed - *posmična brzina*	202 109	1	202 109	2 557,1	0,000000
cutting speed - *brzina rezanja*	2 265 922	2	1 132 961	14 334,2	0,000000
wood type (juvenile/mature) *vrsta drva (juvenilno/zrelo)*	10 105	1	10 105	127,8	0,000000
feed speed * cutting speed *posmična brzina * brzina rezanja*	29 614	2	14 807	187,3	0,000000
feed speed * wood type *posmična brzina * vrsta drva (juvenilno/zrelo)*	190	1	190	2,4	0,122277
cutting speed * wood type *brzina rezanja * vrsta drva (juvenilno/zrelo)*	2 559	2	1 279	16,2	0,000000
feed speed * cutting speed * wood type - *posmična brzina * brzina rezanja * vrsta drva (juvenilno/zrelo)*	298	2	149	1,9	0,153541
Error - *pogreška*	27 506	348	79		

Table 3 Analysis of variance for hybrid poplar (*Populus × Euramericana „Serotina“*)
Tablica 3. Analiza varijance izmjerenih vrijednosti snage rezanja za drvo kanadske topole (*Populus × Euramericana „Serotina“*)

	SS	*DF*	*MS*	*F*	*p*
feed speed - *posmična brzina*	147 242	1	147 242	154,82	0,000000
cutting speed - *brzina rezanja*	1 912 509	2	956 255	1005,46	0,000000
wood type (juvenile/mature) *vrsta drva (juvenilno/zrelo)*	8 833	1	8 833	9,29	0,002484
feed speed * cutting speed *posmična brzina * brzina rezanja*	59 980	2	29 990	31,53	0,000000
feed speed * wood type *posmična brzina * vrsta drva (juvenilno/zrelo)*	82	1	82	0,09	0,768711
cutting speed * wood type *brzina rezanja * vrsta drva (juvenilno/zrelo)*	250	2	125	0,13	0,877099
feed speed * cutting speed * wood type - *posmična brzina * brzina rezanja * vrsta drva (juvenilno/zrelo)*	415	2	207	0,22	0,804180
Error - *pogreška*	330 970	348	951		

Legend for tables 2 and 3 (Scheer, 2007): *SS* – Summary of squares, *DF* – Degree of freedom, *MS* – Variance, *F* – Critical value of Fischer Test, *p* – Level of significance.
Legenda za tablice 2. i 3. (Scheer, 2007): SS – zbroj kvadrata, DF – stupanj slobode, MS – varijanca, F – kritična vrijednost Fischerova testa, p – razina signifikantnosti

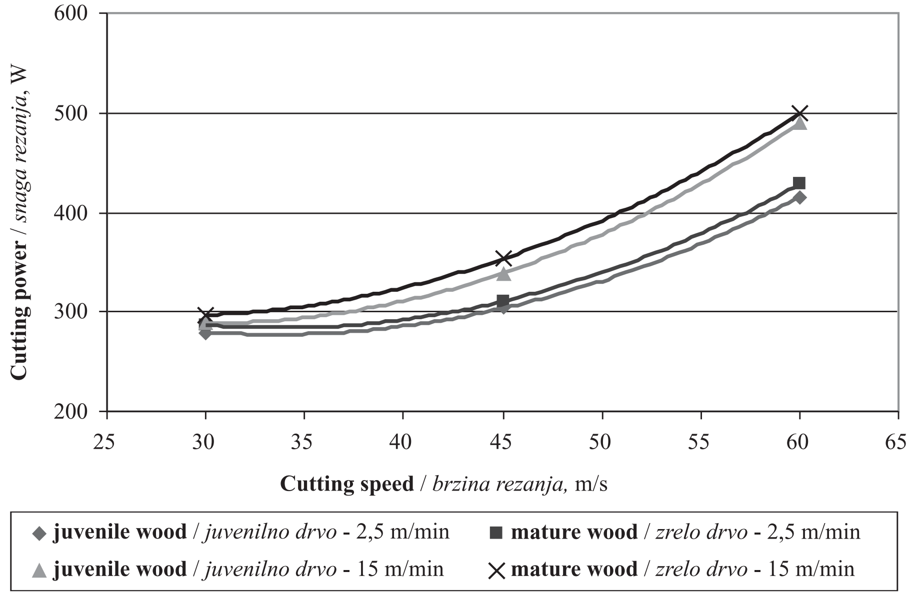

Figure 2 Dependence of cutting power on cutting speed for aspen (*Populus tremula* L.)
Slika 2. Ovisnost snage rezanja o brzini rezanja pri blanjanju drva jasike (*Populus tremula* L.)

tive hypothesis H_1 is valid. The cutting power is nonzero on average. The cutting speed and feed speed have a statistically significant effect with 100 % reliability at selected levels of cutting and feed speed. The type of wood has a statistically significant effect, too. It means that there is a considerable difference in cutting power between juvenile and mature wood. The cutting power of juvenile wood is lower than that of mature wood in all combinations of cutting and feed speed. The interactions among factors are null (nonexistent). All these factors act independently of one another.

We can say that the effect of feed speed, cutting speed and wood species is statistically important. It means that the observed factors markedly influence the cutting power.

The dependence of cutting power on cutting speed is obvious from the results presented in Fig 2 and 3. Cutting power increases with increasing cutting speed. The reason of increase of cutting power with increasing cutting speed is the decrease of feed per tooth and consequently the decrease of chip thickness. It is known from the literature that the cutting resistance has larger values for small chip thickness and as a result the cutting power is increased. More rapid increase of cutting power was recorded by cutting speed change from 45 to 60 $m \cdot s^{-1}$ than by change from 30 to 45 $m \cdot s^{-1}$. The results are similar to results of other authors (Kugel, 1958 and Kivimaa, 1959), who say that the cutting power increases more rapidly at cutting speed over 45 $m \cdot s^{-1}$. Pahlitzsch (1966) says that in term of cutting power the optimal cutting speed is from 30 to 45 $m \cdot s^{-1}$.

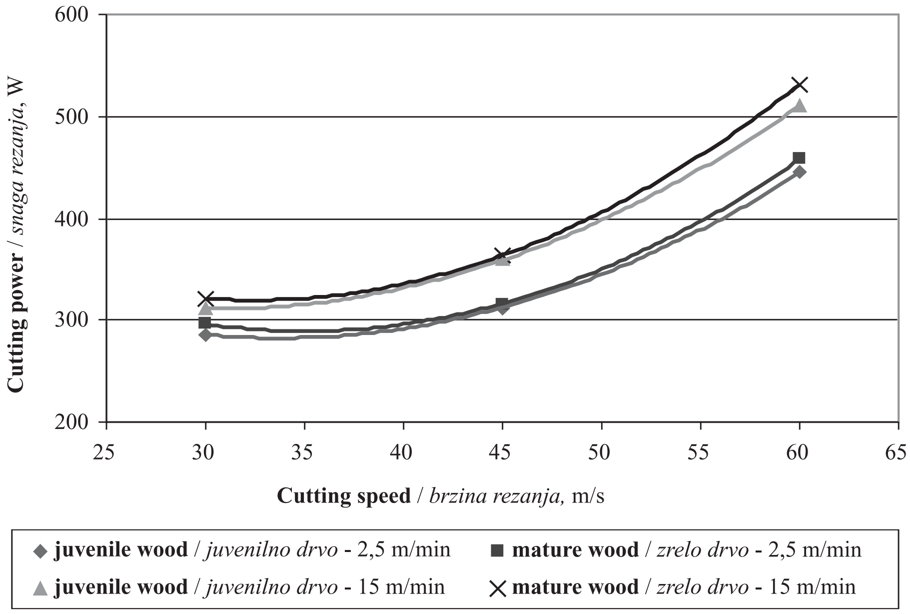

Figure 3 Dependence of cutting power on cutting speed for hybrid poplar (*Populus × Euramericana „Serotina“)*
Slika 3. Ovisnost snage rezanja o brzini rezanja pri blanjanju drva kanadske topole (*Populus × Euramericana „Serotina“)*

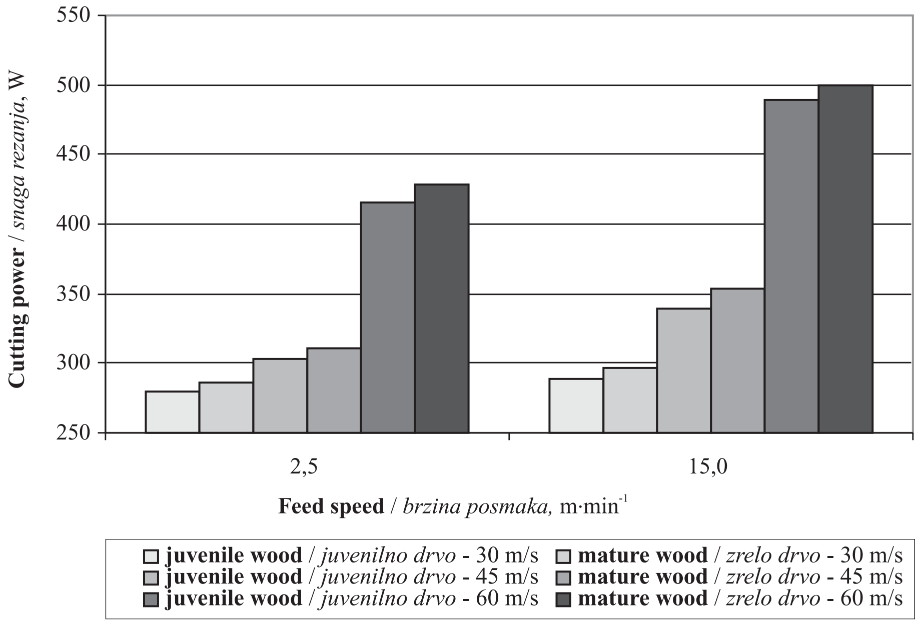

Figure 4 Dependence of cutting power on feed speed for aspen (*Populus tremula* L.)
Slika 4. Ovisnost snage rezanja o posmičnoj brzini pri blannjanju drva jasike (*Populus tremula* L.)

The graphs (Fig 4 and 5) show the dependence of cutting power on feed speed. The reason of the increase of cutting power with increasing feed speed is that within the same time a larger volume of wood is cut off. Kugel (1958) says that the cutting power has higher value with increase of feed speed, too. The effect of feed speed is not as expressive as the effect of cutting speed.

The graphs (Fig 2 through 5) also show that the cutting power is apparently lower in processing juvenile wood at all combinations of technological parameters and both wood species. It means that 2.8 % lower cutting power is achieved in processing juvenile wood. The reason lies in the fact that juvenile wood has worse physical and mechanical properties than mature wood (especially density).

The values of the obtained results of cutting power of both tree species confirm the fact that the replacement of naturally grown poplar wood (*Populus tremula* L.) with hybrid poplar wood (*Populus × Euramericana „Serotina“)* involves the decrease of cutting power by 4.7 %. Lower physical and mechanical properties of hybrid poplar probably influence the decrease of cutting power in its processing.

4 CONCLUSION
4. ZAKLJUČAK

It can be concluded from the obtained results that it is possible to achieve lower cutting power in plane milling:

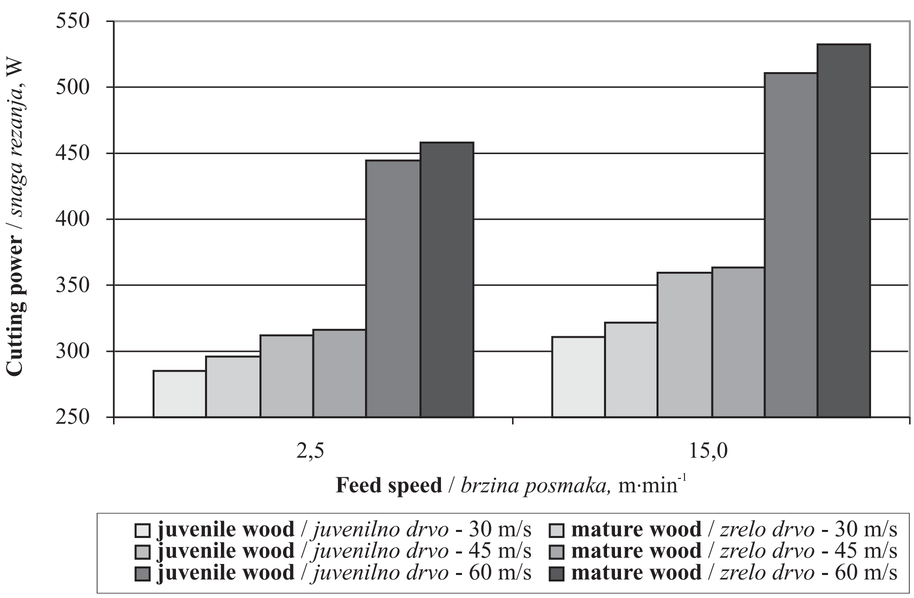

Figure 5 Dependence of cutting power on feed speed for hybrid poplar (*Populus × Euramericana „Serotina“)*
Slika 5. Ovisnost snage rezanja o posmičnoj brzini pri blanjanju drva kanadske topole (*Populus × Euramericana „Serotina“)*

- by milling juvenile wood compared to mature wood,
- by milling hybrid poplar compared to naturally grown poplar,
- by decrease of cutting speed,
- by decrease of feed speed.

The potential of juvenile wood does not only consist of resources that were ignored in Europe in the past but also in the possibility of its quick cultivation and thereby also its efficient processing. This state has lead to the formation of a certain barrier in the form of insufficient base of input information about the given material, which is nowadays needed for providing expansion and eliminating this barrier. The cutting power of juvenile wood processing is its strong point and taking into consideration the continuously increasing energy cost, it can become an important factor of its wide industrial use in the future.

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