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Influence of selected factors on granulometric composition of chips in plane milling of juvenile pine wood*

Utjecaj promatranih činitelja na granulometrijski sastav strugotine nastale pri glodanju juvenilne borovine*

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ABSTRACT • *The use of juvenile wood has become quite frequent today. Juvenile wood differs from mature wood in its physical, mechanical and technological properties. Different properties of juvenile wood can have a further effect on processing and manufacturing of products. Therefore it is important to investigate all aspects of processing juvenile wood. The aim of this paper was to establish the influence of physical, mechanical and technological properties on granulometric composition and dimension analysis of juvenile pine wood chips in plane milling.*

Key words: *pine wood, juvenile wood, mature wood, plane milling, granulometric analysis*

SAŽETAK • *Uporaba juvenilnog drva danas je vrlo česta. To se drvo svojim mehaničkim, fizikalnim i tehnološkim svojstvima razlikuje od adultnog drva. Različita svojstva juvenilnog drva mogu imati značajan utjecaj na preradu drva i proizvodnju drvnih proizvoda. Zato je vrlo važno ispitati sve aspekte prerade juvenilnog drva. Cilj je ovog rada istražiti utjecaj fizikalnih, mehaničkih i tehnoloških svojstava juvenilnog drva na granulometrijski sastav i dimenzije čestica nastalih pri glodanju.*

Ključne riječi*: borovina, juvenilno drvo, adultno drvo, glodanje, granulometrijska analiza*

1 INTRODUCTION
1. UVOD

It is taken for granted that juvenile wood will become much more significant in future by increasing the share of its processing. Changes can be expected in agricultural and forestry policy, mainly by afforestation of unused agricultural land by fast plantation growing tree species. Therefore different properties of juvenile wood, compared to mature wood, must be taken into account, mainly with respect to its further processing.

In the process of milling, chips are generated whose shape, dimensions and quantity depends not only on physical and mechanical properties of milled

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wood, but also on the shape, dimensions and sharpness of the cutting tool and technical and technological factors of the milling process.

In many studies, the properties of chips have been evaluated according to individual tree species and individual woodworking and cutting machines. No information can be found in the reference literature related exclusively to the properties of juvenile wood chips. Similarly, there is no comparison between juvenile wood and mature wood depending on specific technological conditions of cutting the wood.

In wood-processing industry, the transport of chips from the place of their origin is usually affected by an air-driven system. From the viewpoint of environmental criteria the air-driven system must be adapted to the changes of milled material as well as to the changes of technical and technological parameters. That is why it is important to specify the properties of disintegrated wood substance formed under particular conditions.

The paper aims at analysis of granularity of juvenile pine wood chips taken from the process of plane milling on conventional spindle moulding machine. The study also shows the differences between the chips generated from juvenile and mature pinewood. This analysis is followed by the experimental study of interactive relations between energy demands, wear of tool and quality of processing juvenile and mature pine wood in milling.

2 THEORETICAL ANALYSES
2. TEORIJSKE OSNOVE

2.1 Juvenile wood
2.1. Juvenilno drvo

Juvenile wood is defined as wood produced in the early growth of trees and found around the pith marked by physical, mechanical and technological properties, different from the properties of wood that is formed later.

2.1.1 Physical properties of juvenile wood
2.1.1. Fizikalna svojstva juvenilnog drva

The density of juvenile wood, compared to mature wood, is lower by approximately 5-15 %. Lower densities of juvenile wood were measured in the fast-growing pines grown in plantations whose density is lower by as much as 50 kg·m^{-3} (Thörnqvist, 1993).

Swelling and shrinking of wood is proportional to the orientation of cellulose fibrils in the cell wall. Considering the above mentioned prevailing orientation of fibrils in the cell wall of normal wood, under an angle of 5°-15° wood swelling in longitudinal direction is very low, this value is practically negligible. The angle of the cellulose fibril arrangement in juvenile wood is considerably higher, which is manifested in substantial increase of longitudinal swelling of this wood. That is why the values of longitudinal shrinkage of juvenile wood often exceed these values by more than 1 %. The sawn-wood from juvenile wood is as a result of changed shrinkage strained by drying stresses, which is often manifested by shape instability connected with longitudinal and also transversal deformation of the given sawn-wood assortment (Thörnqvist, 1993).

Wood moisture content of freshly cut raw material with high portion of juvenile wood (young trees, tree tops and branches) is higher as a result of physiologically active sapwood, which includes the entire portion of wood in young stems. High portion of spring, porous wood is not negligible either. This fact could affect the acceptance of wood by weight method in pulp mills.

Pivolusková and Kotlínová (2004) present the comparison of physical properties of juvenile wood and older pine wood with data found in reference literature (Table 1).

2.1.2 Mechanical properties of juvenile wood
2.1.2. Mehanička svojstva juvenilnog drva

Mechanical properties of juvenile wood are mainly influenced by lower density of wood, caused by its chemical, sub-microscopic and microscopic structure.

Table 1 Survey of physical properties of juvenile pinewood (Pivolusková and Kotlínová, 2004)
Tablica 1. Pregled fizikalnih svojstava juvenilnog drva borovine (Pivolusková and Kotlínová, 2004)

Property *Svojstvo*	**Measured values** *Mjerene vrijednosti*		**Požgaj et al. (1997)**	**Wagenführ (1985)**	**Wood-Processing Manual (1970)**
	Juvenile wood *Juvenilno drvo*	**Mature wood** *Adultno drvo*			
Tangential swelling, % *tangencijalno bubrenje,* %	4.5	6.9	10.2	8.1 – 8.7	7.7.
Radial swelling, % *radijalno bubrenje,* %	3.3	5.7	Not given *nije dano*	3.4 – 4.2	4.0
Longitudinal swelling, % *longitudinalno bubrenje,* %	0.5	0.2	Not given *nije dano*	0.4	0.4
Density in oven-dry state, kg·m^{-3} *gustoća u apsolutno suhom stanju, kg·m^{-3}*	460	530	500	300…490…860	490
Reduced density, kg·m^{-3} *smanjena gustoća*, kg·m^{-3}	403	470	440	Not given *nije dano*	440

Table 2 Survey of mechanical properties of juvenile pine wood (Pivolusková and Kotlínová, 2004)
Tablica 2. Pregled mehaničkih svojstava juvenilne borovine (Pivolusková and Kotlínová, 2004)

Property *Svojstvo*	**Measured values** *Mjerene vrijednosti*		**Požgaj at al. (1997)**	**Wagenführ (1985)**	**Wood-processing manual (1970)**
	Juvenile wood *Juvenilno drvo*	**Mature wood** *Adultno drvo*			
Modulus of elasticity in bending, MPa *modul elastičnosti savijanja,* MPa	7815	10341	10620	6900…12000…	12000
Ultimate bending strength, MPa *najveća čvrstoća savijanja*, MPa	60	81	100.1	41…100…205	100
Impact strength , $J \cdot cm^{-2}$ *čvrstoća na udarac,* $J \cdot cm^{-2}$	2.9	6.4	4.6	1.5…4…13	4
Front hardness, MPa *tvrdoća*, MPa	35	43	Not given *nije dano*	25…40…72	40

Mechanical properties are influenced by the amount of chemical substances such as lignin, cellulose of hemicelluloses and extractive matters. The tilt angle of the cellulose fibrils with respect to the walls of fibrous cells is also very important.

Mechanical properties of juvenile wood are practically changed in all tree species in comparison with mature, normal wood. It could not be generally said which properties of juvenile wood are worse and which ones are better for a manufacturer. Zobel&Spraque (1998) state the greatest decrease in tensile strength. The tensile strength in American pine decreased to approximately 70 % from the value of normal wood. The tensile strength in Douglas fir of juvenile wood decreased to as much as 50 %. Similarly, although not to such an extent, the modulus of elasticity in juvenile wood decreased to approximately 90 % in pinewood and to approximately 70 % in Douglas fir.

The decreased mechanical properties of juvenile pinewood are also presented by Pivolusková and Kotlínová, 2004 (Table 2).

2.2 Size and shape of chips
2.2. Veličina i oblik čestica

Size and shape of disintegrated particles of wood substance are the basic data characterizing loose wood substance. The above characteristics have an influence on physical properties of loose substance such as: apparent density, granulometric structure, angle of slip, angle of discharge. They also affect particles motion properties in the pipeline of the suction system and conditions of separation or filtration in the separation device.

The dimensions of particles are defined by dimensions of a rectangular parallelepiped circumscribed to a given particle, where length is the largest dimension of the particle, thickness is the smallest dimension of the particle, and width is the third dimension of the particle. The size of the particle is determined by the largest dimension of rectangular parallelepiped circumscribed around the particle i.e. length of a chip.

Dzurenda (2002) specifies that geometrical shapes of chips produced in cutting or wood processing are of various shapes. This is indirectly proved by the particles of disintegrated wood substance shown in Figure 2. In spite of this fact, effort has been made to classify the grains of loose substances into one of the three basic groups:

a) Isometric grains – chips having approximately the same dimension in all three directions (fine fraction of chips and very fine fractions of saw dust) Dzurenda (2002).
b) Flat grains (laminar) – the dimension of length and width in these grains are considerably larger than the third dimension, i.e. thickness of chips Dzurenda (2002).
c) Threadlike grains (fibrous) – chips with pronounced elongation in one dimension (fibre, medium coarse and coarse fractions of saw dust, needle-like chips, and medium coarse fractions of wood dust Dzurenda (2002).

2.3 Granulometric analysis
2.3. Granulometrijska analiza

Granularity (granulometric composition) is an information characterising representation of individual particles (group of particles) of certain size in the whole set of loose substance. The most common method for the determination of granulometric composition is sieving i.e. screening of the sample of loose substance through a sieve set with specific mesh sizes usually arranged from the largest to the smallest. The results of sieve analysis are presented in the form of a table or graphically in the form of a distribution curve D_a, or integral curve of granularity (the curve of oversizes P_a, or the curve of screen residue Z_a.).

The curve of screen residue Z_a (Figure 1) expresses the dependence of relative weight of grains bigger than the particle size in the analysed sample Z_i (%) on the particle size a (μm). The curve from screen residue is formed analogically as the curve of oversizes, i.e. by gradual plotting of dimensions of individual fractions f_i on the vertical axis. The difference in plotting screen residue curves compared with plotting oversizes curve is

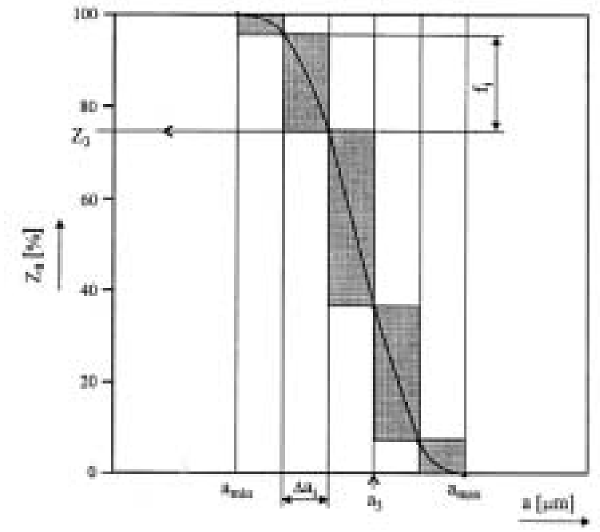


Figure 1 Curve of screen residue Za
Slika 1. Krivulja raspodjele veličina čestica Za

that the projection of fraction of values is made from the fraction of the biggest particles (Dzurenda, 2002).

The curve of screen residue or oversizes is often displayed in logarithmic-normal grid (Figure 2). In this grid the values of particle sizes a_i are projected on logarithmic scale (horizontal axis), and the quotients of fractions f_i are projected on linear scale. Considerable part of the curve of oversizes or the curve of screen residues is in this scale displayed by straight line, which is the main advantage of this form of screen analysis presentation.

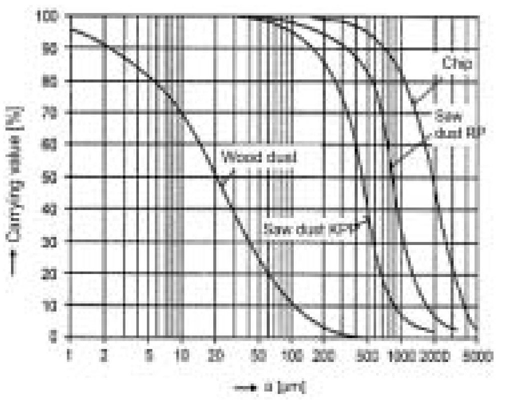


Figure 2 Curves of screen residue in logarithmic-normal grid
Slika 2. Krivulja raspodjele čestica (logaritamska skala)

3 MATERIAL AND METHODS
3. MATERIJAL I METODE

Experimental tests were carried out on samples of pine (*Pinus sylvestris*), coming from the region of Zubačková bučina, cadastral zone - Podzámčok (School Forest Enterprise), 450 m above sea level. Logs were used for cutting two quarter sawn boards, mostly consisting of juvenile wood. Subsequently they were both cut through the pith, cut to 1 m length, dried and air-conditioned at φ=65 % and t=20°C to w=12 % of moisture content, mechanically dried, and processed to the thickness of 35 mm. These samples contained a large number of defects, which could not be neglected, as these defects are a natural part of juvenile wood and hence, they cannot be ignored when determining its properties. Considered defects are mainly knots, which are the remnants of the first branches of a young tree.

All practical tests were carried out in VDL-TU (Development Workshops and Laboratories-Technical University Zvolen). The monitoring device consisted of a spindle moulding machine, feeding device, measuring apparatus and evaluation equipment designed for monitoring the cutting power. Individual samples (boards) were milled by standard milling under the following cutting conditions: feed rate v_f=2.5 m·min^{-1} and v_f=15 m·min^{-1}, cutting speed v_c=*20* m·s^{-1} and v_c=30 m·s^{-1}, angular geometry of the milling machine: β_f=55° (cutting edge angle), γ_f=15°, 20°, 25°,30° (cutting face angle). During the measurement of the cutting power, in the framework of individual interactive influences, chips were removed at the same time (cca 200 g), removal of 1 mm by one cutting edge of the tool.

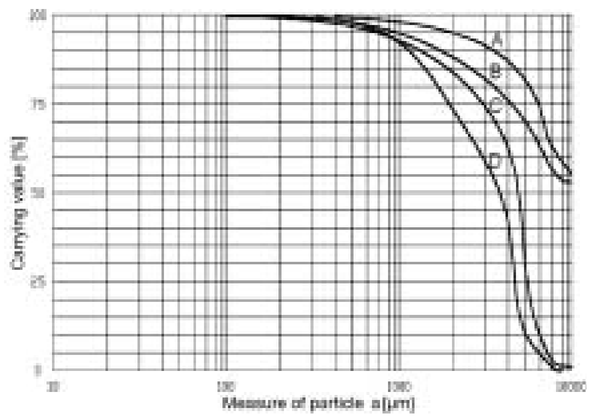
3.1 Process of granulometric analysis
3.1. Granulometrijska analiza

The screen analysis was carried out with the use of a Fritsch vibration screen machine by a testing sieve set in accordance with STN (Slovak Technical Norm) 15 3105 (STN ISO 3310-1). The standard does not define the exact time of sieving, nor the size or number of sieve meshes (Horák, 1996). On the basis of previous experiments, the sieves with the following mesh sizes were determined: 8; 6.3; 5; 4; 2 and 1 mm, as well as the time of sieving of 5 minutes. The measurements were carried out at average chips moisture of 12 %. The sieve set was mounted on the Fritsch vibration machine. The necessary amount of sample (100 g) was weighed on a laboratory scale and put to the upper sieve of the sieving machine. The set was then closed by a glass lid and continually sieved for 5 minutes. Upon sieving, individual sieving residues were weighed on a Bosch digital laboratory scale with the weighing accuracy to the nearest 0.001 g. After that the weight portions of individual sieves calculated in percentages were recorded in the form of a table and evaluated graphically. The procedure was repeated 3 times for each measured sample, to eliminate possible measurement error.

3.2 Process of dimensional analysis
3.2. Analiza veličine čestica

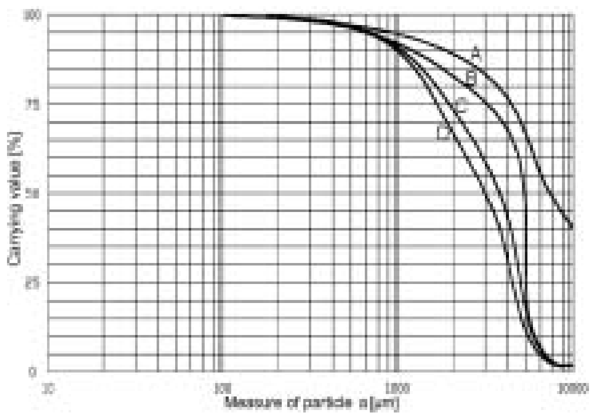
In order to carry out dimensional analysis, the evaluation was made of chips produced with angular parameters of the milling machine γ_f / β_f=15°/55° (cutting face angle/cutting edge angle) and both feeding speed (v_f =2.5 m·min^{-1} and v_f =15 m·min^{-1}) and cutting speed (v_c=20 m·s^{-1}) were derived from the cutting parameters.

The analysis of chip dimensions was carried out by the Department of Wood Sciences. The CCD Mitshubishi scanned each combination of chips ten times. In the analysis of the biggest fraction exceeding 8 mm, 4.5 x magnification was used, and in the analysis of the smallest fraction under 1 mm - 125 x magnification was used. By means of Lucia G/Comet programme, dimensional picture analysis was made of each photo, namely



A – Juvenile wood, v_f = 2.5 m·min^{-1} B – Mature wood, v_f = 2.5 m·min^{-1}
C – Juvenile wood v_f = 15 m·min^{-1} D – Mature wood, v_f = 15 m·min^{-1}
A – juvenilno drvo, v_f = 2,5 m·min^{-1} B – adultno drvo, v_f = 2,5 m·min^{-1}
C – juvenilno drvo v_f = 15 m·min^{-1} D – adultno drvo, v_f = 15 m·min^{-1}

Figure 3 Screen residue curves of pine chips at cutting speed v_c=20 m·s^{-1}
Slika 3. Krivulja raspodjele veličina čestica borove strugotine pri brzini rezanja v_c=30 m·s^{-1}



A – Juvenile wood, v_f = 2.5 m·min^{-1} B – Mature wood, v_f = 2.5 m·min^{-1}
C – Juvenile wood, v_f = 15 m·min^{-1} D – Mature wood, v_f = 15 m·min^{-1}
A – juvenilno drvo, v_f = 2,5 m·min^{-1} B – adultno drvo, v_f = 2,5 m·min^{-1}
C – juvenilno drvo, v_f = 15 m·min^{-1} D – adultno drvo, v_f = 15 m·min^{-1}

Figure 4 Screen residue curves of pine chips at cutting speed v_c=30 m·s^{-1}
Slika 4. Krivulja raspodjele veličina čestica borove strugotine pri brzini rezanja v_c=20 m·s^{-1}

the length and width in mm, and the obtained values were statistically processed.

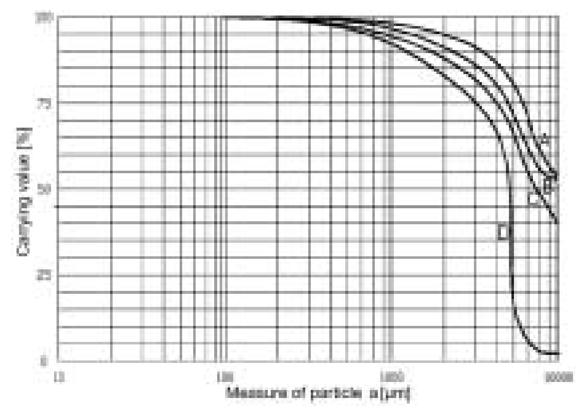
4 RESULTS AND DISCUSSIONS
4. REZULTATI I DISKUSIJA

4.1 Granulometric analysis
4.1. Granulometrijska analiza

The curves of granulometric composition of pine chips produced in plane milling with the combination of specific parameters and angular geometry γ_f /β_f = *15°/55°* are shown in Figures 3-6 by means of screen residue curves.

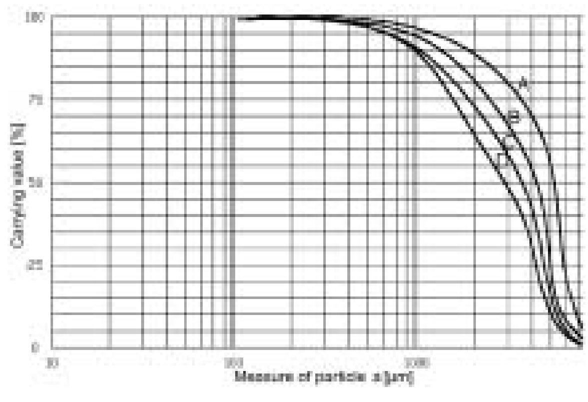
The results with combinations of angular geometry γ_f/β_f = 20°/55°°, 25°/55° and 30°/55 are not presented, because granulometric composition of chips is similar to all types of angular geometry both in juvenile and mature wood.

Significant difference in granulometric composition of pine chips was found by the change of feeding speed from v_f =2.5 m·min^{-1} to v_f =15 m·min^{-1}, as well as by the change of cutting speed from (v_c=20 m·s^{-1}) to v_c=30 m·s^{-1}*,* but only in combination with feeding speed v_f =2.5 m·min^{-1}. In combination with the feeding speed v_f =15 m·min^{-1} the influence of cutting speed was not significant. With regard to the percentage ratio of individual fractions, no significant difference was recorded between juvenile and mature wood. The only significant difference was recorded in the combination of cutting speed v_c=30 m·s^{-1} and feeding speed v_f =2.5 m·min^{-1}, where juvenile wood had the most numerous fraction over 8 mm and mature wood over 4 mm. Small differences (mainly various changes - increase or decrease with



A – Juvenile wood, v_c = 20 m·s^{-1} B – Mature wood, v_c = 20 m·s^{-1}
C – Juvenile wood, v_c = 30 m·s^{-1} D – Mature wood, v_c = 30 m·s^{-1}
A – juvenilno drvo, v_c = 20 m·s^{-1} B – adultno drvo, v_c = 20 m·s^{-1}
C – juvenilno drvo, v_c = 30 m·s^{-1} D – adultno drvo, v_c = 30 m·s^{-1}

Figure 5 Screen residue curves of pine chips at feeding speed v_f =2.5 m·min^{-1}
Slika 5. Krivulja raspodjele veličina čestica borove strugotine pri posmičnoj brzini v_f =2,5 m·min^{-1}



A – Juvenile wood, v_c = 20 m·s^{-1} B – Mature wood, v_c = 20 m·s^{-1}
C – Juvenile wood, v_c = 30 m·s^{-1} D – Mature wood, v_c = 30 m·s^{-1}
A – juvenilno drvo, v_c = 20 m·s^{-1} B – adultno drvo, v_c = 20 m·s^{-1}
C – juvenilno drvo, v_c = 30 m·s^{-1} D – adultno drvo, v_c = 30 m·s^{-1}

Figure 6 Screen residue curves of pine chips at feeding speed v_f =15 m·min^{-1}
Slika 6. Krivulja raspodjele veličina čestica borove strugotine pri posmičnoj brzini v_f =15 m·min^{-1}

different cutting parameters) in percentage ratio between juvenile and mature wood were probably caused by heterogeneity of juvenile wood, by numbers of knots, imperfect parallelism of wood fibres with regard to cutting line, inaccuracy of working, cutting conditions, and by intensity of blunting the cutting edge of the tool.

Based on all combinations of cutting parameters it can be concluded that the highest share of the smallest fraction of chips was created in using the highest cutting speed v_c=30 m·s^{-1} and the highest feeding speed v_f =15 m·min^{-1}. The reason lies in the fact that the contact between the cutting tool and working piece is shorter, by which smaller chips are produced. In this case, a lower proportion of the biggest fraction was also produced. The lower proportion of the smallest fraction of chips was produced by using the highest cutting speed v_c=30 m·s^{-1} and the lowest feeding speed v_f =2.5 m·min^{-1}, because the cutting tool rotates quickly, and the material moves slowly. As a result the cutting edge bites into the wood for the longest time, by which the longest chips are produced. So it means that in this combination of cutting and feeding speed, the highest share of the biggest fraction was produced. At lower cutting speed v_c=20 m·s^{-1} chips were produced in a similar process. However, in combination with a lower feeding speed, a lower proportion of the biggest fraction was produced.

The impact of the cutting speed was crucial in the percentage share of the largest fraction while the feeding speed was crucial in the percentage share of the smallest fraction.

4.2 Dimensional analysis
4.2. Analiza veličine čestica

Within dimensional analysis of particle sizes, the basic dimensions were determined of the biggest particles of the coarse fraction of pine chips exceeding 8 mm (Table 3-4), Figures 7 and 8, and the dimensions of the smallest particles of fraction with dimensions under 1 mm (Table 5-6), Figures 9 and 10.

Based on the results of dimensional analysis of individual particles it can be concluded that most of disintegrated wood substance produced in the process of plane milling of pine wood can be classified into the group of flat grains – where the dimension of length and width is markedly larger than the third dimension, i.e. the thickness of chip. A small percentage of produced chips can be classified into the group of fibrous loose materials of stick-shaped form with pronounced elongation in one direction (smaller fractions created mainly in feeding speed v_f =2.5 m·min^{-1}). Fine dust makes the last group (the smallest dust particles with dimensions 29.2 µm in length and 13.1 µm in width).

In dimensional analysis the difference of fractions between juvenile and mature wood is not pronounced. The maximum and minimum values of dimen-

Table 3 Basic dimensions of the biggest particles of pine chip wood fractions exceeding 8 mm in plane milling, angular geometry of milling machine γ_f / β_f =15°/55°and cutting parameters v_c=20 m·s^{-1}, v_f =2.5 m·min^{-1}
Tablica 3. Osnovne dimenzije najvećih čestica borove strugotine, frakcija čestica većih od 8 mm, nastalih pri glodanju drva (γ_f / β_f =15°/55°, v_c=20 m·s^{-1}, v_f =2,5 m·min^{-1})

		Average value *Prosječna vrijednost*	**Minimum value** *Najmanja vrijednost*	**Maximum value** *Najveća vrijednost*
Juvenile wood *juvenilno drvo*	Length of particle, mm *duljina čestice, mm*	24.72	13.51	36.77
	Width of particle, mm *širina čestice, mm*	3.56	1.82	5.24
Mature wood *adultno drvo*	Length of particle, mm *duljina čestice, mm*	24.74	8.94	39.18
	Width of particle, mm *širina čestice, mm*	2.21	1.25	4.55

Table 4 Basic dimensions of the biggest particles of pine chip wood fractions exceeding 8 mm in plane milling, angular geometry of milling machine γ_f / β_f =15°/55° and cutting parameters v_c=20 m·s^{-1}, v_f =15 m·min^{-1}
Tablica 4. Osnovne dimenzije najvećih čestica borove strugotine, frakcija čestica većih od 8 mm, nastalih pri glodanju drva (γ_f / β_f =15°/55°, v_c=20 m·s^{-1}, v_f =15 m·min^{-1})

		Average value *Prosječna vrijednost*	**Minimum value** *Najmanja vrijednost*	**Maximum value** *Najveća vrijednost*
Juvenile wood *juvenilno drvo*	Length of particle, mm *duljina čestice, mm*	21.54	9.37	38.13
	Width of particle, mm *širina čestice*, mm	7.17	2.33	10.11
Mature wood *adultno drvo*	Length of particle, mm *duljina čestice,* mm	21.14	9.57	37.13
	Width of particle, mm *širina čestice*, mm	6.28	2.19	9.87

Table 5 Basic dimensions of the smallest particles of pine wood fraction under 1 mm in plane milling, and angular geometry of the milling machine γ_f / β_f=15°/55° and cutting v_c=20 m·s^{-1}, v_f =2.5 m·min^{-1}
Tablica 5. Osnovne dimenzije najmanjih čestica borove strugotine, frakcija čestica manjih od 1 mm, nastalih pri glodanju drva (γ_f/β_f =15°/55°, v_c=20 m·s^{-1}, v_f =2,5 m·min^{-1})

		Average value *Prosječna vrijednost*	**Minimum value** *Najmanja vrijednost*	**Maximum value** *Najveća vrijednost*
Juvenile wood *juvenilno drvo*	Length of particle, μm *duljina čestice, μm*	216.5	29.2	1956.3
	Width of particle, μm *širina čestice*, μm	49.2	13.1	414.7
Mature wood *adultno drvo*	Length of particle, μm *duljina čestice*, μm	223.6	29,2	1781,3
	Width of particle, μm *širina čestice*, μm	42.1	13.1	350.4

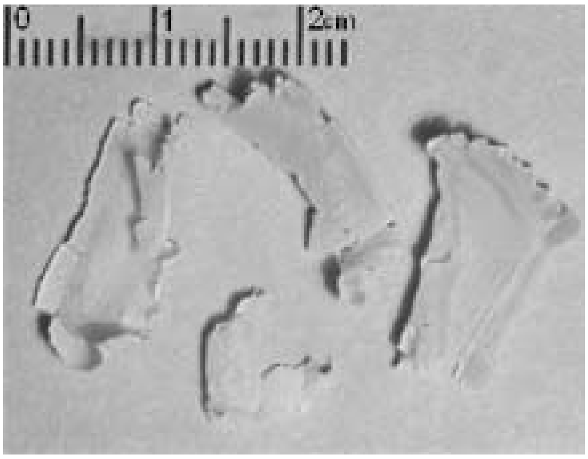


Figure 7 The biggest fraction (above 8 mm) of chips from juvenile pine wood with angular geometry of the milling machine γ_f/β_f =15°/55° and cutting parameters v_c=20 m·s^{-1}, v_f =2.5 m·min^{-1}
Slika 7. Prikaz čestica borovine većih od 8 mm nastalih pri glodanju juvenilnog drva (γ_f /β_f =15°/55°, v_c=20 m·s^{-1}, v_f =2,5 m·min^{-1})

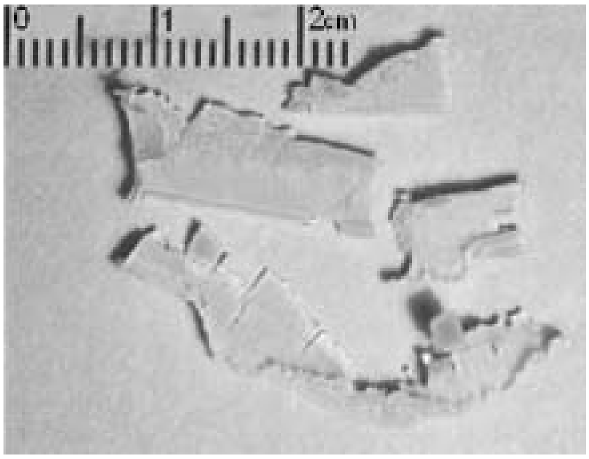


Figure 8 The biggest fraction (above 8 mm) of chips from mature pine wood with angular geometry of the milling machine γ_f /β_f =15°/55° and cutting parameters v_c=20 m·s^{-1}, v_f =2.5 m·min^{-1}
Slika 8. Prikaz čestica borovine većih od 8 mm nastalih pri glodanju adultnog drva (γ_f /β_f =15°/55°, v_c=20 m·s^{-1}, v_f =2,5 m·min^{-1})

Table 6 Basic dimensions of the smallest particles of pine wood fraction under 1 mm in plane milling, and angular geometry of the milling machine γ_f/β_f =15°/55° and cutting parameters v_c=20 m·s^{-1}, v_f =15 m·min^{-1}
Tablica 6. Osnovne dimenzije najmanjih čestica borove strugotine, frakcija čestica manjih od 1 mm nastalih pri glodanju drva (γ_f/β_f =15°/55°, v_c=20 m·s^{-1}, v_f =15 m·min^{-1})

		Average value *Prosječna vrijednost*	**Minimum value** *Najmanja vrijednost*	**Maximum value** *Najveća vrijednost*
Juvenile wood *juvenilno drvo*	Length of particle, μm *duljina čestice, μm*	97.5	29.2	1624.6
	Width of particle, µm *širina čestice*, μm	62.3	13.1	284.2
Mature wood *adultno drvo*	Length of particle, μm *duljina čestice*, μm	141.2	29.2	1755.3
	Width of particle, μm *širina čestice, μm*	53.4	13.1	303.9

sions (length, width) of juvenile and mature wood are similar. The difference between juvenile and mature wood is recorded in their average values of dimensions. With mature wood lower average values were measured of width in the biggest and smallest fraction. With regard to length, lower average values were recorded in juvenile wood (with the feeding speed v_f =15 m·min^{-1} and the smallest fraction – lower by 31 % compared to mature wood). It can be concluded that in milling juvenile wood, shorter and wider fractions are more frequent than in milling mature wood. This is caused by lower hardness and higher fragility of wood; regarding

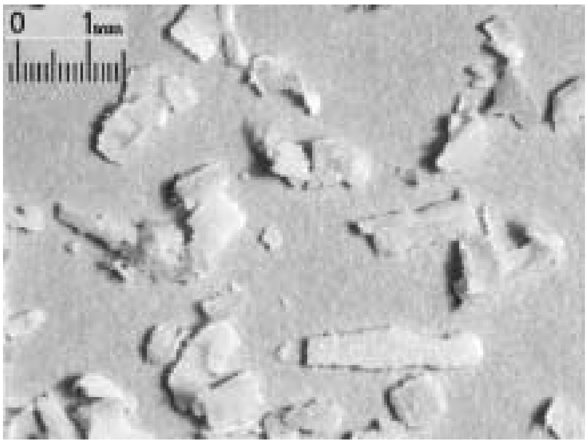


Figure 9 The smallest fraction (under 1 mm) of chips from juvenile pine wood with angular geometry of the milling machine γ_f/β_f =15°/55° and cutting parameters v_c=20 m·s^{-1}, v_f =2.5 m·min^{-1}

Slika 9. Prikaz čestica borovine manjih od 1 mm nastalih pri glodanju juvenilnog drva (γ_f/β_f =15°/55°, v_c=20 m·s^{-1}, v_f =2,5 m·min^{-1})

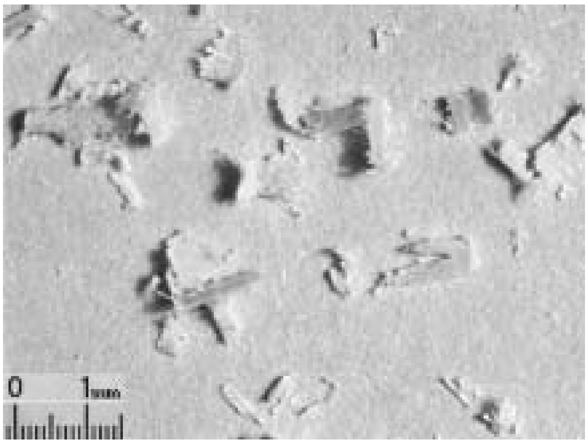


Figure 10 The smallest fraction (under 1 mm) of chips from mature pine wood with angular geometry of the milling machine γ_f/β_f =15°/55° and cutting parameters v_c=20 m·s^{-1}, v_f =2.5 m·min^{-1}

Slika 10. Prikaz čestica borovine manjih od 1 mm nastalih pri glodanju adultnog drva (γ_f/β_f =15°/55°, v_c=20 m·s^{-1}, v_f =2,5 m·min^{-1})

physical properties, density has the greatest influence on technological properties of wood. All these characteristics result from different anatomical and chemical structure of wood (thinner cell walls, shorter cells, lower proportion of summerwood and higher proportion of lignin, which increase the fragility of wood).

5 CONCLUSIONS
5. ZAKLJUČCI

The main aim of this paper was to research the influence of technological parameters (feeding speed, cutting speed, angular geometry of the milling machine) and the influence of wood (juvenile and mature wood) on the production of chips in plane milling; its granulometric composition and dimensions of the biggest particles (above 8 mm) and the smallest particles (under 1 mm). These data are important for designing the suction system and even more for adjusting the construction and type of the dust separator.

On the basis of the obtained results, it can be stated that the differences recorded between chips produced from juvenile and mature wood are not significant. Consequently there is no need to adapt the design of the sucking system and adjust the construction and type of the dust separator depending on the share and type of chip fractions, as the smallest and biggest chip fraction in juvenile and mature wood is similar. It means that it is not necessary to use another type of separating device in milling juvenile wood but the one commonly used in suction of chips produced in processing mature wood.

6 REFERENCES
6. LITERATURA

1. Dzurenda, L. 2002: Vzduchotechnická doprava a separácia dezintegrovanej drevnej hmoty. Zvolen: Vydavateľstvo TU vo Zvolene, p. 14 - 23, 65, 78.
2. Horák, M. 1996: Technika ochrany ovzdušia I. Bratislava: STU Bratislava, p. 170.
3. Pivolusková, E.; Kotlínová, M. 2004: Vybrané fyzikálne, mechanické a technologické vlastnosti borovicového juvenilného dreva. ŠVOČ, 2004, Zvolen.
4. Thörngvist, T. 1993: Juvenile wood in conifers. Swedish Council for Building Research Stockholm, 4 Edition, 1993, p. 110.
5. Zobel, B. J.; Sprague, J . R. 1998: Juvenile Wood in Forest Trees. Springer-Verlag, Berlin Heidelberg.

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