Alena Očkajová[1], Annamária Beljaková[2], Jana Luptáková[3]

Selected properties of spruce dust generated from sanding operations

Neka svojstva prašine smrekovine dobivene procesom brušenja

Original scientific paper · Izvorni znanstveni rad
Received – prispjelo: 8. 1. 2008.
Accepted – prihvaćeno: 5. 6. 2008.
*UDK: 630*832.17; 630*829*

ABSTRACT • *This paper presents the research of selected properties of spruce dust generated from experimental sanding by a hand belt sander with two sanding models - along the wood fibres and perpendicular to the wood fibres in the radial direction.*
The experiment was carried out for the purpose of obtaining the basic characteristics of wood sanding dust – granularity, size and shape of individually formed particles, and bulk properties (bulk density, bulk angle, and tilt angle) that are important for suction, which is connected with the quality of living and working environments. The particles smaller than 100 μm are unsuitable for both environments, since they do not sediment in space at all or only partly, and they are characterized as airborne dust. The most harmful particles for humans are those smaller than 2.5 μm as they reach the lung alveoli. When sanding wood the finest particles are formed and therefore it is important to know the basic characteristics of sanding dust in order to deal with these problems effectively.
On the basis of the mesh sieve analysis, we can state that in sanding perpendicular to the wood fibres the share of particles smaller than 100 μm is 76.94 % on average and along the wood fibres it is only 56.01 %.
The structure, shape and size of particles were investigated by microscope. When using the longitudinal model of sanding, the fibrous elements were formed for the most part. When using the perpendicular model, isometric particles were predominantly formed in smaller fractions and particles of fibrous shape in larger fractions.
The smallest particles were found in the following samples. When the perpendicular model of sanding was used, we have found the smallest particle in the investigated samples with the diameter of 1.68 μm, and when the longitudinal model of sanding was used, the particle with the diameter of 1.75 μm.
Bulk density of spruce dust from the longitudinal model of sanding is 77.77 kg · m^{-3}, while dust from the perpendicular model of sanding is 116.68 kg · m^{-3}.
Tilt angle of spruce dust in a longitudinal direction of sanding is 33.4°, and in a perpendicular direction it is 37.4°.
Bulk angle for the perpendicular model of sanding is 48.7°, and for longitudinal model of sanding it is 48.3°.
The obtained results have confirmed that the model of sanding at which wood dust was formed is a significant factor affecting properties of wood bulk material.

Key words: *sanding, spruce dust, granularity, bulk properties*

SAŽETAK • *U radu su istraživana neka svojstva prašine smrekovine dobivene ručnim eksperimentalnim brušenjem u dva smjera – u smjeru vlakanaca i okomito na njih, i to u radijalnom smjeru. Cilj istraživanja bio je odrediti osnovna obilježja čestica bruševine – granulaciju, veličinu čestica i oblike individualnih čestica, nasipna svojstva*

[1] The author is associate professor at the Faculty of Natural Sciences of Matej Bel University in Banská Bystrica, Slovak Republic. [2] The author is an external PhD Student at the Faculty of Wood Sciences and Technology of Technical University in Zvolen, Slovak Republic. [3] The author is assistant professor at the Institute of Foreign Languages of Technical University in Zvolen, Slovak Republic.

[1] Autorica je izvanredna profesorica na Fakultetu prirodnih znanosti Sveučilišta "Matej Bel", Banská Bystrica, Republika Slovačka. [2] Autorica je doktorantica na Fakultetu za znanost o drvu i tehnologiju Tehničkog sveučilišta u Zvolenu, Republika Slovačka. [3] Autorica je docentica na Institutu za strane jezike Tehničkog sveučilišta u Zvolenu, Republika Slovačka.

(nasipnu gustoću, nasipni kut i kut klizanja s kosine), koje su važne pri njihovu odsisavanju i za njihov utjecaj na kvalitetu općega i radnog okoliša. Za obje vrste okoliša štetno je postojanje čestica manjih od 100 μm, a s obzirom na to da se one teško talože ili se uopće ne talože, smatraju se lebdećim česticama. Najštetnije čestice za ljudski organizam jesu one manje od 2,5 μm jer dospijevaju do plućnih alveola. Uspješno rješavanje problema nastajanja najfinijih čestica bruševine moguće je uz poznavanje njihovih osnovnih obilježja. Granulometrijskom analizom bruševine nastale brušenjem okomito na drvna vlakanca izmjeren je udio od 76,94 % čestica manjih od 100 μm, a brušenjem u smjeru vlakanaca samo 56,01 %. Struktura, oblik i veličina čestica istražena je uz pomoć mikroskopa. Pri brušenju duž vlakanaca formirani su pretežno vlaknasti elementi. Pri brušenju okomito na vlakanca uglavnom su nastajale izometrične čestice u sitnijim frakcijama te čestice vlaknastog oblika u krupnijim frakcijama. Među česticama nastalim pri brušenju okomito na vlakanca izmjeren je najmanji promjer čestice od 1,68 μm, a pri brušenju uzdužno s vlakancima promjer 1,75 μm. Nasipna gustoća smrekove bruševine pri uzdužnom brušenju iznosi 77,77 kg/m³, odnosno 116,68 kg/m³ pri brušenju okomito na vlakanca. Kut klizanja s kosine bruševine nastale brušenjem u smjeru vlakanaca iznosi 33,4°, a kut klizanja bruševine nastale brušenjem okomito na vlakanca 37,4°. Nasipni kut za bruševinu nastalu brušenjem okomito na vlakanca iznosi 48,7°, a za bruševinu nastalu brušenjem uzdužno na vlakanca 48,3°. Dobiveni rezultati potvrdili su da smjer brušenja s obzirom na smjer vlakanaca ima značajan utjecaj na veličinu i svojstva usitnjenoga drvnog materijala.

Ključne riječi: *brušenje, prašina smrekovine, granulacija, nasipna svojstva*

1 INTRODUCTION
1. UVOD

In the technological processes of machine wood chipping, a by-product is also formed besides the main product. These are chips whose shape, dimensions and quantity dependent on physical and mechanical wood properties as well as on dimensions of the processed material, type of machine, tool and its geometry, and technical and technological conditions of the process (Lisičan et al., 1996). Particles of wood substance formed in individual processes of chipping and machining are called "bulk wood substance" (Dzurenda, 2007). The nature of the present production and conditions of chips require continual removal of chips from the place where they are formed. As far as sanding dust is concerned, it is removed by means of an air-technical device – suction. To develop an appropriate suction system, it is important to know the size and shape of bulk substance particles, which are the basic data for characterizing bulk material. The above characteristics affect physical and mechanical properties of bulk substance (bulk density, bulk angle, tilt angle, aerodynamic properties of particles in the piping of the suction system) and conditions of separation or filtration in the separating device (Dzurenda, 2007). The observed characteristics also affect service life of equipment in the workplace where dust is generated as well as transportation equipment and filtering elements, and last but not least safety of the working environment.

Hejma *et al.* (1981), define fractions smaller than 5 ìm as the fractions which do not sediment almost at all, they are airborne; the fraction from 5-100 μm sediment slowly and in quite wide surroundings of the place where they are generated; fractions whose size is over 100 μm sediment in the immediate surroundings of the place where they are grenerated. Particles whose dimension is smaller than 100 μm are unsuitable for the living and working environments (Hemmilä and Gottlőber, 2003) because they do not sediment in the space or sediment only partly, and they are characterized as airborne dust. The most harmful to humans are particles smaller than 2.5 μm as they get to lung alveoli and, according to government regulation, beech and oak wood dust is classified as carcinogen.

In many workplaces, research is focused on issues of solving the quality of living and working environments and the results of such research deal with granulometric composition of wood bulk substance generated from various processes of chipping and processing wood.

The sawing process was investigated from the viewpoint of risk factors - dustiness, by Dzurenda, *et al.* (2005), Očkajová *et al.* (2006), Banski *et al.* (2006), Beljo Lučić *et al.* (2005), Sandak *et al.* (2006).

Risk factors in the process of plane milling were studied by Kopecký and Pernica (2004), Barcík *et al.* (2007), Kos and Beljo Lučić (2004), Beljo Lučić *et al.* (2007), and in the process of wood turning by Wieloch and Osajda (2007).

Sanding process as the major source of generation of airborne dust was investigated by Rogozinski and Dolny (2004), Očkajová and Beljaková (2004), Beljaková and Očkajová (2007), Rončka and Očkajová (2007).

Wood-working enterprises, as sources of air pollution, emit in the air wood dust classified as solid pollutants. Clean Air for Europe is the initiative taken by the EU Commission, by which one of its main aims was set in 2002: "To reach such a quality of the environment where the level of pollutants coming from human activities does not cause any significant impacts and risks for human health".

Since detailed characteristics of wood sanding dust, such as physical and mechanical properties and information on size (primarily the smallest particles) and shape of generated particles, are still not known, the aim of this paper is to give more detailed information on wood sanding dust of spruce.

2 MATERIALS AND METHODS
2. MATERIJALI I METODE

2.1 Preparing the sample
2.1. Priprema uzoraka

The sample of desintegrated wood substance was prepared by sanding spruce 50x50x50 mm in size with the density of 446.35 kg · m^{-3} by two models of sanding: along the wood fibres (0°) and perpendicular to the wood fibres in the radial direction (90°), Figure 1.

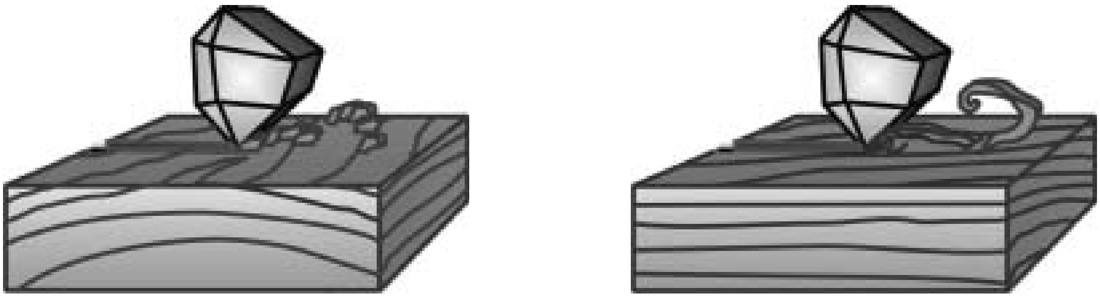

Figure 1 Process of chip creation: a) sanding model perpendicular to the wood fibres, b) sanding model along the wood fibres
Slika 1. Proces nastajanja usitnjene čestice: a) model brušenja okomito na smjer vlakanaca, b) model brušenja paralelno sa smjerom vlakanaca

2.2 Sanding process
2.1. Postupak brušenja

The experiments were carried out with the equipment for observing the contact phenomena (Siklienka *et al*., 1999) whose base was the GBS 100 AE hand belt sander by Bosch. The LS 309 XH sand belts by Klingspor were used for the experiments, 100x610 mm in size and grit size – 80. Sanding was carried out at cutting speed of 7.8 $m \cdot s^{-1}$ and specific pressure between the work piece and sand was1.04 $N \cdot cm^{-2}$.

Sanding dust was caught by the Rowenta vacuum cleaner in disposable filtering sacks Rowenta Original ZR 814 (the manufacturer provides no permeability). Dust sample was filled in plastic sacks, which were closed in order to keep the parameters unchanged. Moisture content of spruce dust for both models of sanding was 6.00%.

2.3 Granularity
2.3. Granulacija (veličina čestica)

To determine the shares of individual fractions, a sieving machine AS 200 by Retsch was used with the set of control stainless sieves with sieve mesh diameters of 0.032; 0.063; 0.08; 0.125; 0.250; 0.5; 1; 2 mm, and with the following sieving parameters: amplitude of 2 mm/“g“, interval of 10 s, sieving time of 20 min, and electronic laboratory scales Radwag WPS 510/C/2 (weighing precision up to 0.001g). Sieving was carried out three times for each model of sanding. Shares of individual fractions were determined as average values of measurements.

2.4 Shape of particles and size of the smallest particles
2.4. Oblik čestica i veličina najmanjih čestica

The shape and size of individual fraction particles were observed by microscope in order to specify the predominant shape in the given interval of particles. The picture was transferred from the microscope SM1 (maximum enlargement was 400x) directly to the PC by the camera MoticCam 1000 (1/2" CMOS,1.3 Mega pixels (1280x1024) by USB 2.0 PC output), where it was processed by the graphic software Motic Images Plus 2.0, parameters of the PC - Intel(R), Celeron(R), CPU 2.4 GHz, 504 MB RAM, the system Microsoft Windows XP Professional, the graphic adapter Intel (R) 82845G/GL/GE/PE/GV Graphic controller 64 MB, Figure 2.

Figure 2 Microscope SM 1 (maximum enlargement of 400x) with camera MoticCam 1000
Slika 2. Mikroskop SM1 (maksimalnog povećanja 400 puta) i kamera MoticCam1000

Ten photos were made for each fraction. To evaluate size and shape of particles, we used the Corel Draw 11 graphic programme in which the grid produced according to Vošahlík and the grid made by 125 μm and 250 μm distances were transformed. The shape of particles of each fraction was evaluated from 10 photos by individual description of particles by the Standard STN 260070.

The smallest particle size was found among particles observed in the bottom fraction. As the smallest particles have isometric shape – their two sizes being approximately equal, the sizes of these ones were evaluated as the diameter of circular outline of particle projection, Figure 3.

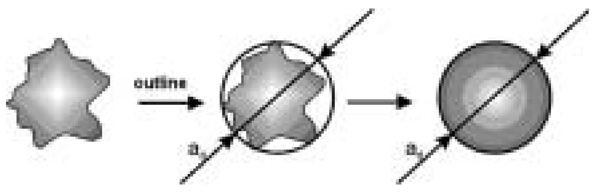

Figure 3 Equivalent diameter of particles as a circular outline of particle projection
Slika 3. Ekvivalentni promjer čestice projiciran s čestice sfernog oblika jednakog promjera

2.5 Bulk density
2.5. Nasipna gustoća

Bulk density of sanding wood dust was obtained by the following steps: the mass of the measuring cylinder was weighed. Then the sawdust sample was poured into a measuring cylinder 35 cm in height and filled to the volume of 1.000 ml. After filling 1.000 ml, the sample was again weighed. The above mentioned procedure was repeated 30 times. Based on mass and volume of the measured sawdust, bulk density was calculated. The result is an average value.

2.6 Tilt angle
2.6. Kut klizanja s kosine

The measured sample was evenly stratified on the whole area of the drop leaf (the area of 13.700 mm^2) so that its three raised rims (5 mm) were covered and levelled by the measured sample. The surplus sample was removed. We slowly tilted the drop leaf. At the moment when the sample started moving, we stopped tilting, and we subtracted the tilt angle on the scale in the range from 0° to 90°, Figure 4. Measurement by Longauer and Sujová (2000) was repeated 30 times for obtaining the average value.

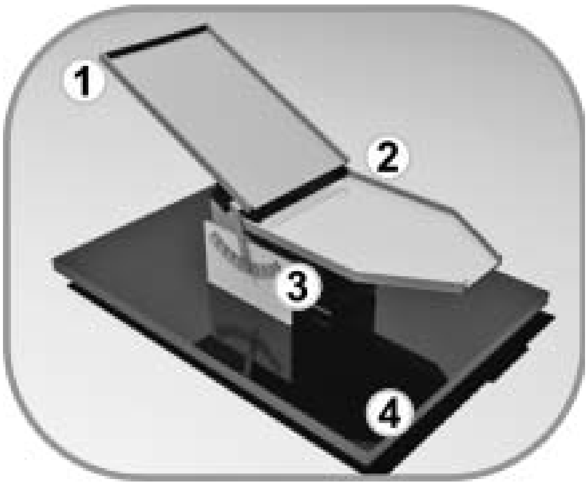

Figure 4 Equipment for measuring tilt angle: 1 – drop leaf, 2 – collecting place, 3 – angle gauge, 4 – stand
Slika 4. Uređaj za mjerenje kuta klizanja s kosine: 1 – produžetak za stol, 2 – mjesto stresanja, 3 – kutomjer, 4 – postolje

2.7 Bulk angle
2.7. Nasipni kut

The sample of the researched dust was slowly poured into the loading hopper from a certain height so that the sample could continually drop through the outlet tube of the loading hopper. The sample dropped through the outlet tube onto the circular plate (ø 50 mm) and gradually formed a cone there. Pouring was finished when the bottom of the formed cone had covered all the area of the circular plate. Having formed the cone on the circular plate, we carefully put the measuring rod down to the just formed cone and on the given scale we subtracted the angle, which was created by the formed cone and the circular plate, Figure 5. Measurement of the bulk angle by Longauer and Sujová (2000)

Figure 5 Langhaus equipment for measuring bulk angle
1 – loading hopper, 2 – screw for height adjustment, 3 – circular plate ϕ 50 mm, 4 – angle gauge, 5 – measuring rod, 6 – collecting vessel
Slika 5. Uređaj za mjerenje nasipnog kuta: 1 – lijevak za uzorak, 2 – vijak za podešavanje visine, 3 – kružno postolje, 4 – kutomjer, 5 – mjerni graničnik, 6 – posuda za skupljanje uzorka

for the given sample was carried out 30 times and the result is an average value.

3 RESULTS AND DISCUSSION
3. REZULTATI I DISKUSIJA

On the basis of mesh analysis we designed the curves of residues at the longitudinal and perpendicular models of spruce sanding, Figure 6. The curves of residues are of importance when designing the separation equipment. If the curve shifts more to the left side, then a greater demand is placed on the filtration equipment.

With the perpendicular sanding model, higher participation of the fraction smaller than 0.080 mm can be observed, the size of this fraction being under 100 ìm, which is airborne dust, and this is the most dangerous for the working environment. With the perpendicular sanding model, a share of 76.94% on average is recorded, whereas with the longitudinal sanding model only 56.01% is recorded. So, with the longitudinal sanding model, the share of the formed fraction is higher by 20.93%, with the size exceeding 80 μm, than with the perpendicular model. The percentage shares of particles smaller than 100 μm are very high in sanding compared to the results obtained for other woodworking processes. Our results are also confirmed by Beljo Lučić *et al.* (2005) who compared the particle size of chips generated by seven different wood machines (belt sander, hand belt sander, band saw, drilling machine, circular saw, multiple circular saw and four sided jointer). The percentage share of particles smaller than 0.5 mm is the highest for belt sander – 96% (beech) then followed hand belt sander – 80% (MDF) and for four sided jointer it is only 4%. The percentage share of particles smaller than 100 μm is 3.12% for spruce sawdust

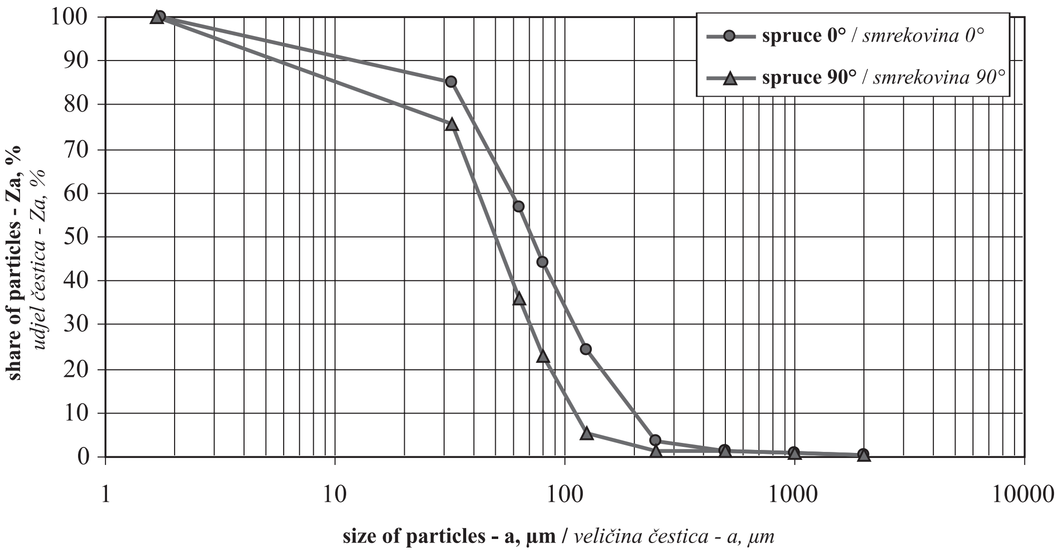

Figure 6 Curves obtained by granular analysis of spruce dust from sanding operations
Slika 6. Krivulje dobivene granulometrijskom analizom smrekove bruševine

and 3.16% for pine sawdust (Dzurenda *et al.* 2005). On the basis of these arguments we can say that particle size is influenced not only by the type of machine but also by wood species (spruce, beech, MDF).

If we are to account for the difference of the cutting model, we have to search for the main reason in wood structure. The predominant part of wood cell elements is oriented in the longitudinal direction. With the perpendicular sanding model, the particles are cut crosswise with respect to the longitudinal axis, the chip has low bending strength and is more spanned. With the longitudinal sanding model, sanding particles move in approximately the same straps of spring and summer wood along the whole length of the sample and ground particles also have a high bending strength despite small thickness, and therefore no more considerable breakdown occurs.

Shape and size of particles in individual sets were observed by microscope. We have made 10 photos, Figure 7 of each fraction which we visually assessed and described by the Standard STN 260070. These are the first results of our experiments related to the shape and size of sanding dust particles.

When the longitudinal sanding model was used, fibrous elements are predominantly formed with considerable elongation of one of their dimensions. The fibrous elements of bigger fractions were considerably curled and interlinked. With the perpendicular model, isometric particles were predominantly formed (with approximately equal length/width ratio) in smaller fractions, as well as particles of fibrous nature in bigger fractions. With both sanding models there are also larger fractions accompanied by a share of fine particles, which were attached to them or caught by electrostatic forces on individual sieves of relevant fractions.

The results are known of measurement of particle size, of circularity as a deviation of projection of a given chip shape from the projection of the shape of a circle (Dzurenda, Orlowski and Wasielewski, 2005) and of particle elongation as the length/width ratio μ, for fibrous particles $\mu > 3$ and for isometric particles $\mu < 3$ (Kopecký and Pernica, 2004; Beljo Lučić *et al.*, 2005; San-

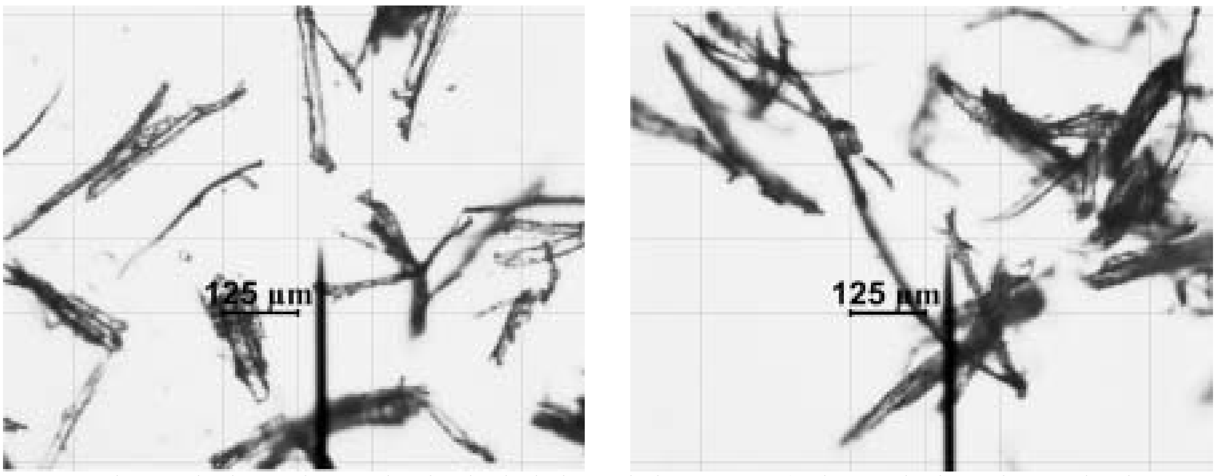

Figure 7 Microscopic photos of spruce dust fraction in the interval of 80 -125µm: a) microscopic photo of spruce dust from sanding perpendicular to the wood fibres, b) microscopic photo of spruce dust from sanding along the wood fibres
Slika 7. Mikroskopska fotografija smrekove bruševine veličine čestica od 80 do 125µm: a) mikroskopska fotografija smrekovih čestica nastalih brušenjem okomito na vlakanca, b) mikroskopska fotografija smrekovih čestica nastalih brušenjem u smjeru vlakanaca

dak *et al.* (2006)) but only for sawing and milling process. Beljo Lučić *et al.* (2005) established that the particles elongation was lower in larger particle fractions and in fractions of particle size under 0.2 mm. According to Dzurenda *ed al.* (2005) particles of fine fraction belong to the isometric ones, and according to Kopecký and Pernica, (2004) in the majority of particles the length/width ratio amounted to a mean value of μ = 1.63 for particles ≤ 100 μm. It is difficult to compare these results with our result because here we deal with particles incomparably bigger than sanding dust particles while percentage shares of the smallest particles under 100 μm are low. These are the processes with exactly defined tool geometry and cutting condition, the chips are bigger, regularly with recurring shapes, which is just the opposite of the sanding process where we deal with untypical tools whose geometry, shape and arrangement are not exactly identified and it is hence impossible to obtain chips with systematically repeated shape. In the sanding process the shape and size of single particles is influenced in advance by wood species and sanding model.

When assessing dimensions of the smallest particles we searched for the smallest particles whose dimension was assessed as the diameter of circular outline of particle projection, since they were isometric ones. With the perpendicular sanding model we have found out the smallest particle with the equivalent diameter of 1.68 μm in the observed sets of particles and with the longitudinal sanding model one of 1.75 μm, which are the particles that reach lung alveoli. For narrow kerf sawing machine the size of the smallest spruce particle is 85.38 x 78.31 μm, the size of the smallest pine particle is 84.71 x 78.89 μm (Dzurenda *et al.* 2005), for circular saw machine the size of the smallest beech particle is 0.0752 x 0.3485 mm (Beljo Lučić *et al.* 2005) and for milling the size of the smallest beech particle is 4 μm (Kopecký and Pernica, 2004). When we compare our results with others, we can say that these values are very different depending in advance on the type of machine, tool, wood species and working condition.

Regarding spruce wood dust we also found out some additional bulk properties, and namely how they are affected by the sanding model used when dust was generated, Table 1.

Bulk density of spruce dust generated from longitudinal sanding was 77.77 kg·m^{-3}, and dust from perpendicular sanding was 116.68 kg·m^{-3}.

With the longitudinal sanding model we have recorded a higher share of larger fraction, and therefore bulk density was lower than with the perpendicular sanding model. When bulking, the particles are put on each other determining the layer porosity, and therefore the anatomic direction in the sanding process from which dust was generated also has a fundamental impact on this property. Table 2 shows a significant difference between the results of bulk density of spruce sanding particles depending on the sanding model.

At the longitudinal direction, spruce dust had the total tilt angle of 33.4°, which is a lower value than for dust from perpendicular sanding of 37.4°. We can state that the heavier the particles are, the smaller the tilt angle. The smaller the particles, the higher adherence to the surface and the larger the tilt angles. The significant influence of sanding model on tilt angle is confirmed in Table 3.

Bulk angle is a certain measure of stability of the non-pressed layer of particles. Bulk angle for the perpendicular sanding model is 48.7° at the longitudinal

Table 1 Bulk properties of spruce wood dust
Tablica 1. Svojstva nasipane smrekove bruševine

Properties *Svojstva*	**Spruce 0°** / *Smrekovina 0°*		**Spruce 90°** / *Smrekovina 90°*	
	Mean value *Srednja vrijednost*	**Standard deviation** *Standardna devijacija*	**Mean value** *Srednja vrijednost*	**Standard deviation** *Standardna devijacija*
Bulk density, kg/m^3 *Nasipna gustoća*	77,775	3,703	116,681	3,049
Tilt angle, ° *Kut klizanja s kosine*	33,4	1,13	37,4	1,07
Bulk angle, ° *Nasipni kut*	48,3	3,00	48,7	1,63

Table 2 Analysis of variance for bulk density
Tablica 2. Analiza varijance za nasipnu gustoću

Significance level α=0,05 / *Razina signifikantnosti α=0,05*						
Source of variability	**Sum squares**	**Degree of freedom**	**Mean squares**	***F***	***p*-value**	***F* crit.**
Between groups *Između grupa*	22247,53	1	22247,53	2009,99	1,44E-45	4,012975
Within groups *Unutar grupa*	619,8349	56	11,06848			
Total – *Ukupno*	22867,36	57				

Table 3 Analysis of variance for tilt angle
Tablica 3. Analiza varijance za kut klizanja s kosine

Significance level α=0,05 / *Razina signifikantnosti α=0,05*						
Source of variability	**Sum squares**	**Degree of freedom**	**Mean squares**	***F***	***p-value***	***F crit.***
Between groups *Između grupa*	244,1552	1	244,1552	200,8652	3,59E-20	4,012975
Within groups *Unutar grupa*	68,06897	56	1,215517			
Total / *Ukupno*	312,2241	57				

Table 4 Analysis of variance for bulk angle
Tablica 4. Analiza varijance za nasipni kut

Significance level α=0,05 / *Razina signifikantnosti α=0,05*						
Source of variability	**Sum squares**	**Degree of freedom**	**Mean squares**	***F***	***p-value***	***F crit.***
Between groups *Između grupa*	0,155172	1	0,155172	0,028747	0,865975	4,012975
Within groups *Unutar grupa*	302,2759	56	5,397783			
Total – *Ukupno*	302,431	57				

sanding model it is 48.3°, which was the lowest average value of the bulk angle. There are not significant differences between the final values of found out bulk angles, Table 4.

4 CONCLUSION
4. ZAKLJUČAK

The experiments were carried out for the purpose of obtaining the basic information on the size and shape of formed particles (sanding dust), the granular composition of sanding dust as well as on physical characteristics of wood sanding dust, which are important for developing effective intercepting technology and dealing with quality of the living and working environments.

Regarding the measured results we can state that with the perpendicular sanding model of spruce a greater share of the fraction with the dimensions up to 80 μm is generated, this being air-borne (flying) dust. Particles generated from perpendicular sanding are isometric ones, and bigger fractions are of fibrous nature. With the longitudinal sanding model the generated particles are predominantly fibrous, strongly curled with the tendency to form clusters.

Among the observed particles we have found the smallest one with the equivalent diameter of 1.68 μm with the perpendicular sanding model, and with the longitudinal sanding model the diameter was of 1.75 μm, which are the particles very dangerous for the working environment.

Bulk density of spruce dust generated from longitudinal sanding was 77.77 kg·m^{-3}, which is a considerably lower value than bulk density of dust generated from perpendicular sanding of 116.68 kg·m^{-3}. At the longitudinal direction, spruce dust had the total tilt angle of 33.4°, which is a lower value than dust generated from perpendicular sanding of 37.4°. Bulk angle for spruce dust from longitudinal sanding is 48.3° and for perpendicular sanding it is 48.7°.

Our measurements confirmed that the model of sanding is a significant factor having impact on the granular composition of spruce wood dust. It affects the shape and size of formed particles, which are values that characterize the particles and have a significant impact on dust properties – bulk density and tilt angle.

5 REFERENCES
5. LITERATURA

1. Banski, A.; Vacek, V.; Kučerka, M. 2006: Stanovenie hmotnosti jemnej frakcie v suchej smrekovej piline – technickým výpočtom. Trieskové a beztrieskové obrábanie dreva 2006. Zvolen TU, 13-18.
2. Barcík, Š.; Pivolusková, E.; Kotlínová, M. 2007: Experimental observation of juvenile pine wood at plane milling. Proceedings of the 2nd ISC – Woodworking techniques, Zalesina. Zagreb: Faculty of Forestry, 189-199.
3. Beljaková, A.; Očkajová, A. 2007: Microscopic analyse of beech sanding dust. Proceedings of the 2nd ISC – Woodworking techniques, Zalesina. Zagreb: Faculty of Forestry, 201-206.
4. Beljo Lučić, R.; Čavlović, A.; Antonović, A.; Vujasinović, E.; Šimičić, I. 2005: Svojstva usitnjenog materijala nastaloga pri mehaničkoj obradi drva. Drvna industrija, 56 (1): 11-19.
5. Beljo Lučić, R.; Čavlović, A.; Ištvanić, J.; Đukić, I.; Kovačević, D. 2007: Granulometric analysis of chips generated from planing of different species of wood. Proceedings of the 2nd ISC – Woodworking techniques, Zalesina. Zagreb: Faculty of Forestry, 207-213.
6. Dzurenda, L. 2007: Sypká drevná hmota, vzduchotechnická doprava a odlučovanie. Zvolen: TU.
7. Dzurenda, L.; Orlowski, K.; Wasielewski, R. 2005: Granulometric analysys and separation options of dry saw-

dust exhausted from narrow – kerf frame sawing machines. Drvna industrija, 56 (2): 55-60.
8. Hejma, J.; Budinský, K.; Vavra, A.; Drkal, F. 1981: Vzduchotechnika v dřevozpracovávajícím průmyslu. Praha, SNTL – Nakladatelství technické literatury, p. 34, 36.
9. Hemmilä, P.; Gottlőber, Ch. 2003: Envicut – project how to reduce the amount of dust and noise in woodcutting. Proceedings of the 16th International wood machining seminar, Matsue, Japan, 712-723.
10. Kopecký, Z.; Pernica, J. 2004: Effects of the dimensional specification of dust on the quality of fair. In: Trieskové a beztrieskové obrábanie dreva 2004. Zvolen: TU, 125-130.
11. Kos, A.; Beljo Lučić, R. 2004: Wood dust emission of different woodworking machines. Part I. The growth and development in forestry and wood industry. Scientific book. Zagreb: ŠF, 121-127.
12. Lisičan, J. et al. 1996: Teória a technika spracovania dreva. Zvolen : MATCENTRUM.
13. Očkajová, A.; Beljaková, A. 2004: The chosen physical properties of sanding dust. Part I. The growth and development in forestry and wood industry. Scientific book. Zagreb: ŠF, 129-134.
14. Očkajová, A.; Beljo Lučić, R.; Čavlović, A.; Tereňová, J. 2006: Reduction of dustiness in sawing wood by universal circular saw. Drvna industrija, 57 (3): 119-126.
15. Rogozinski, T.; Dolny, S. 2004: Influence of moisture content on the apparent densities of dust from sanding of alder wood. Trieskové a beztrieskové obrábanie dreva 2004. Zvolen: TU, 205-208.
16. Rončka, J.; Očkajová, A. 2007: The influence of sanding machine type and grit size on granularity of sanding wood dust. Proceedings of the 2nd ISC – Woodworking techniques, Zalesina. Zagreb: Faculty of Forestry, 289-294.
17. Sandak, J.; Orlowski, K.; Negri, M. 2006: Divination from chips: Monitoring of the sawing process with chip geometry analyzes. Trieskové a beztrieskové obrábanie dreva 2006. Zvolen: TU, 253-258.
18. Siklienka, M.; Naščák, Ľ.; Banski, A. 1999: Monitorovacie zariadenie pre sledovanie kontaktných javov pri brúsení dreva. . Stroj – nástroj –obrobok . Zvolen: TU, 117-121.
19. STN 26 0070: 1995: Klasifikácia a označovanie sypkých hmôt dopravovaných na dopravných zariadeniach
20. Wieloch, G.; Osajda, M. 2007: Wymiary wiórów z drewna buka powstajacych przy toczeniu nožem samoobrotowym. Proceedings of the International Conference „Wood – machine – tool – workpiece“. Poznaň: AR, 53-54.

Corresponding address:

Assoc. Prof. ALENA OČKAJOVÁ, PhD

Faculty of Natural Sciences
Matej Bel University in Banská Bystrica
Tajovského 40
97401 Banská Bystrica
Slovak Republic
e-mail: ockajova@fpv.umb.sk