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MORPHOLOGY OF DUST PARTICLES FROM THE SANDING PROCESS OF THE CHOSEN TREE SPECIES

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ABSTRACT

The paper presents original results on granular analysis, shape and dimensions of dust particles from the process of sanding spruce, beech and oak wood. Granularity was determined by the sieve analysis. The results are aimed at the percentage of particles smaller than 0.08 mm. For oak dust, the percentage of this fraction is 87.26 %, for beech 93.34 %, for spruce 76.94 %. In investigated files occur also particles smaller than the fine respirable fraction $PM_{2,5}$ and $PM_{2,5\text{-}10}$. The diameter of the smallest dust particle recorded in oak dust had 1.19 μm, in beech dust 1.74 μm and in spruce dust 1.68 μm. An isometric shape of particles dominates in oak and beech dust in all examined fractions; in spruce dust in the interval (bottom; 0.063) mm, exclusively fibrous character of spruce particles dominates in greater fractions.

KEY WORDS: wood dust, granularity, shape, dimension, particles

INTRODUCTION

The processes of woodworking by cutting tools are always connected with forming of chips. Depending on the kind of technological operation the chips of various sizes, forms, and quantities are created. From working and living environment, as well as work safety point there are dangerous the particles below 100 μm, designated as the dust. Granular composition, i.e. grain size and the morphology of the dust particles themselves, belong to the basic characteristic of dust. They are the data about their shape conditions and character of their surface, which is important information for separation or filtration of dust exhausted from woodworking machines, for fire safety (determination of limit of explosiveness, inflammability) as well as for the health of operating staff.

Sawing process from the viewpoint of risk factors – dustiness was followed by Dzurenda et al. (2005), Očkajová et al. (2006), Banski et al. (2006), Beljo-Lučič et al. (2005), Sandak et al. (2006), risk factors in the process of plane milling solved Kopecký and Pernica (2004), Barcík et al. (2007), Kos and Beljo Lučič (2004), Beljo-Lučič et al. (2007) and the process of wood turning Wieloch and Osajda (2007). For these particles there are known granularity, shape of particles (with mostly of isometric shape) and dimensions of the smallest particles.

Sanding process as the biggest source of airborne dust particles creation was followed by Rogozinski and Dolny (2004), Očkajová and Beljaková (2004), Beljaková and Očkajová (2007), Rončka and Očkajová (2007) from the viewpoint of granularity of wood sanding dust.

Whereas the particles greater than 10 μm (PM_{10}) can cause only irritation of upper respiratory organs with cough and sneeze or irritation of eye conjunctivae, smaller particles get further to lower respiratory organs, and the particles with dimensions below 2.5 μm ($PM_{2.5}$) can interpenetrate into pulmonary alveoli and either settle in the lungs or penetrate into blood circulation.

There has been very little inquiry into the morphology of dust particles from the process of wood sanding. Ljubimov (1976 a,b) from the viewpoint of chips forming process presents that chips at sanding widely differ either by their size or shape. In the given process there are not obtained systematically repeated chips, partly due to anisotropy of wood and by specific kind of cutting tool.

The aim of presented paper is to characterize granularity and on the basis of microscopic analysis the size and morphology of dust particles from the sanding process of our most significant industrially processed tree species – spruce, beech, and oak.

The shape and size belong among the most significant properties of particles characterization. From the viewpoint of morphology, dust shows a great diversity, so we can say that it assumes all possible formations. A whole range of characteristic equivalent dimensions is used for determining their sizes according to measurement method used. Laminar and fibrous particles are called non-isometric. Their behaviour in flow aerodynamic of gaseous environment cannot be defined exactly, as their movement depends on particle positions to direction of their relative movement regarding surrounding environment. In theoretical solutions of particle movements in the flow aerodynamic, from the above given reasons, we issue from isometric shapes of particles represented by a particle of spherical shape. In their real shapes particles acquire non-spherical shapes. It is useful to express the particle size by one dimension, so called equivalent diameter, namely by a full-sphere diameter, which has some characteristics in common with the real particle (Longauer and Sujová, 2000).

An equivalent diameter of the particle can be considered the simplest way of expressing the particle size. An equivalent diameter of the particle a_A is such diameter of the particle A, whose circular surface equals projection surface of the real particle S in direction of its thickness:

$$a_A = \sqrt{\frac{4.S}{\pi}} \tag{1}$$

MATERIAL AND METHODS

The sample was prepared by sanding of spruce *(Picea abies)*, beech *(Fagus silvatica)* and oak *(Quercus robur)* samples with dimensions of 50 x 50 x 50 mm, perpendicular to the wood fibres in the radial direction.

The experiments were realised with the equipment for observing the contact phenomena (Siklienka et al. 1999) whose base was the GBS 100 AE hand belt sander from the Bosch company. For the experiments were used the LS 309 XH sand belts from the Klingspor company, with dimension of 100 x 610 mm and grit size – 80. Sanding was carried out with cutting speed

– 7.8 $m.s^{-1}$ and specific pressure between the work piece and sand means – 1.04 $N.cm^{-2}$.

Sanding dust was caught by the Rowenta vacuum cleaner in disposable filtering sacks Rowenta Original ZR 814 (the manufacturer does not give permeability). Dust sample was filled in plastic sacks which were closed in order the parameters were not changed. Moisture content of dust was approximately 6.00 %.

To determine proportions of individual fractions, there was used the sieving machine AS 200 control from the Retsch company 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 parameters of sieving: amplitude of 2 mm/g, time interval at interrupted sieving of 10 seconds, sieving time of 20 minutes, and electronic laboratory scales Radwag WPS 510/C/2 (precision of weighing 0.001g). Sieving for each wood species was carried out three times. Proportions of individual fractions were determined as average values of measurements.

Since sieve analysis does not give us sufficient picture about shape and dimensions of individual particles, neither about form and dimensions of the smallest particles, the methods of investigation into these properties by means of microscope was created, which enables more precise specification of their prevailing forms and dimensions in the given interval of particles.

Vošahlík's grid was applied to the pictures for inquiry into sizes and forms of pictures, which also serves as a pattern for evaluation of dimensions of the smallest particles studied on the dust samples taken from the fraction on the bottom.

The picture was transferred from the microscope SM1, Fig. 1 (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. There were made 10 photos for each fraction of three wood species – oak, beech and spruce.

Fig. 1: Microscope SM1 with the installed MoticCam 1000 camera

To evaluate dimensions 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 methods of evaluation can be seen in Fig. 2. The shape of particles of each fraction was evaluated from 10 photos by individual description of particles by the STN 260070.

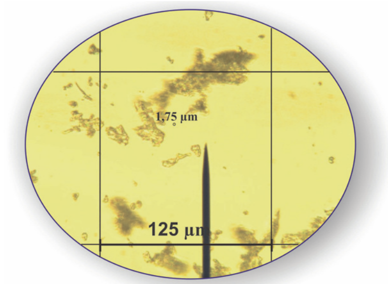


Fig. 2: Evaluation of dimensions and shape of particles

As two-dimensional pictures of particles were created by means of microscope, for determining of the smallest particle sizes that appeared as noticeable isometric, a modification of the method of equivalent particle diameter determination according to its projection surface, was used.

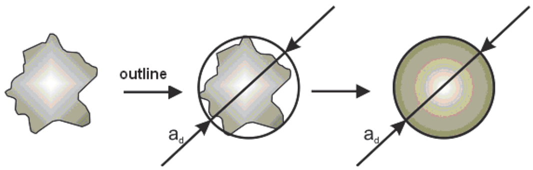


Fig. 3: Equivalent particle size (the smallest particle) according to the circle circumscribed through the contours of the particle projection

The dimension of particles was determined in simplified way as a diameter of the circle circumscribed through the contours of the particle, since determination of projection surface of small particles in direction of their thickness would be fairly difficult (Fig. 3).

RESULTS AND DISCUSSION

The results of sieve analysis are shown by means of integral curves of the dust sample sieve residues in the Fig. 4.

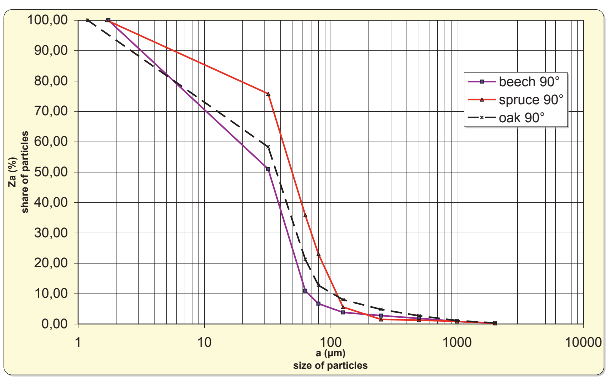


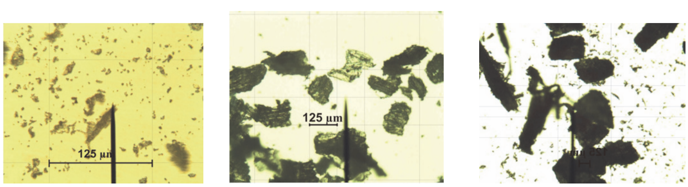
Fig. 4: The curves of residues from granular analysis of spruce, beech and oak dust from sanding process

As from the safety viewpoint and occupational hygiene, the particles sizes below 100 µm are the most dangerous for working environment; we have determined the share of particles below 80 µm. The highest share of particles with dimensions below 80 µm was recorded with the beech dust samples – 93.34 %. With the oak dust the share of this fraction was 87.26 %, and with the spruce dust it was 76.94 %. We can follow a significant influence of wood species on granular composition of sanding wood dust. The percentage shares of particles smaller than 100 µm are very high at sanding in comparing these ones with results for other woodworking processes. Beljo Lučič et al. (2005) are comparing particle size analysis of chip generated on seven different wood machines. 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 for spruce sawdust 3.12 % and for pine sawdust 3.16 % (Dzurenda et al. 2005). On the basis of these arguments we can say that particle size is influenced not only by type of machine but also by wood species (spruce, beech, MDF) too.

Integral curves give us also the picture about approximate percentage of the coarse $PM_{2.5-10}$, and the fine respirable particles $PM_{2.5}$. The value of particles $PM_{2.5-10}$ for beech is about 30 %, for oak it is 28 %, and for spruce it is 14 %. The values of fine fraction of respirable particles $PM_{2.5}$, i.e. the particles penetrating up to pulmonary alveoli are for spruce app. 4 %, for beech app. 7 %, and for oak nearly 10 %. The share of these particles, smaller than $PM_{2.5}$ is quite high, considering the fact that oak and beech dust, according to government decrees No. 356/2006 ranks among the substances with carcinogenic effect on human organism. At sawing and milling of wood neither fine respirable fraction $PM_{2.5}$ nor coarse respirable fraction $PM_{2.5-10}$ with aerodynamic diameter below 10 µm are formed (Dzurenda and Kučerka 2006, Očkajová et al. 2006). Bulk wooden mass from these processes is not a source of smog creating solid particles outlet into the atmosphere.

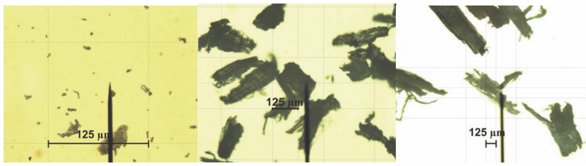
The occurrence of the smallest particles among inquired files was recorded with oak; the smallest particle had the diameter 1.19 µm. In the files of beech dust particles the equivalent diameter of the smallest particle was 1.74 µm. The smallest particle with the size 1.68 µm was found with the spruce particles. All particles had distinguished isometric shape with rounded edges. In comparing our results with the same known for other woodworking processes we can see the big differences. For narrow kerf sawing machine the smallest spruce particle is with dimensions 85.38 x 78.31 µm, the smallest pine particle is with dimensions 84.71 x 78.89 µm (Dzurenda et al. 2005), for circular saw machine the smallest beech particle is with dimensions 0.0752 x 0.3485 mm (Beljo Lučič et al. 2005) and for milling the smallest beech particles are with dimension 4 µm (Kopecký and Pernica 2004).

The results from evaluation of shape and dimensions of particles are recorded in Fig. 5, 6, 7. For better imagination we feature the chosen pictures of particles in certain dimensional intervals. The shape of particle was judged in accordance with STN 260070.



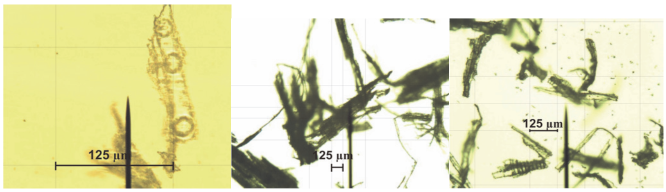
oak (0.032;0.063)mm oak (0.080;0.125)mm oak (0.250;0.500)mm

Fig. 5: Morphology of dust particles from sanding process of oak



beech (0.032;0.063)mm beech (0.080;0.125)mm beech (0.250;0.500)mm

Fig. 6 Morphology of dust particles from sanding process of beech



spruce (0.032;0.063)m spruce (0.250;0.500)mm spruce (0.080;0.125)mm

Fig. 7: Morphology of dust particles from sanding process of spruce

With oak dust, in all investigated fractions the isometric shape of particles with sharp edges and rounded corners dominates, which is more typical for fraction in the interval (bottom; 0.08) mm. With beech dust, similar to oak dust we encounter mostly isometric particles with sharp corners in the interval (bottom; 0.125), with particles of greater dimensions they are of prismatic shape, there were recorded even the particles of fibrous character. With the spruce dust in the interval (bottom; 0.063) mm there were recorded mainly the particle of isometric shape. In greater fractions exclusively fibrous character of particles dominated. On the basis of experiments, which have already been carried out and the obtained results, we can state that the chips of the dust fraction from the process of chip-forming processing and cutting of wood are mostly of isometric shape (Dzurenda et al. 2005, Longauer and Dzurenda 2006, Beljo Lučič et al. 2005).

Higher share of finer particles can be observed with oak and beech samples than spruce as the tree species with good mechanical and strength properties are more resistant to penetration of cutting tool into wood and chip removal. They are characteristic by higher hardness and density in compact state. Beech and oak posses more specialized cell tissues with various functions, shapes and sizes, and various thicknesses of cell walls. Therefore, produced dust is very fine-grained with prevailingly isometric particles. Spruce has anatomically simpler structure, lower density, and the worse mechanical properties of wood. Its chip removes easier, its dimensions are larger, and in bigger fractions has fibrous character. The difference between beech and oak dust in the shares of particles smaller than 0.08 mm we can search is microscopic or even sub-microscopic structure, in connection with chemical structure of wood (Požgaj et al. 1997). Beech has thicker-walled wooden grains in comparison with oak and also higher density of wood, but lower hardness of wood. But in comparison with oak, the occurrence of woody (libriform) fibres of beech is lower. Therefore at perpendicular model of beech sanding, when fibres are cut crosswise regarding their longitudinal axis, despite the fact that beech fibres are more thicker-walled than in the case of oak, the share of its very fine particles is much higher. It is probably due to fact that beech has a high share of vessels, though they have smaller lumens than oak, but these are the thin-walled cell elements. So if a smaller thickness cell wall is cut, the higher fraction of arising particles is of small dimensions and isometric shape. That is why the results of granular analysis have shown the highest portion of particles with dimensions below 80 μm in the dust from a perpendicular model of beech sanding. Oak is characterized by greater hardness, which is also influenced by chemical composition of oak wood. Due to it, the penetration of abrasive grains into sanded surface is more difficult and, the created particles are in increase amount small-sized (the smallest recorded particle), and prevailingly of isometric shape.

CONCLUSION

From the viewpoint of performed experiments we can claim that we have obtained original results mainly in the field of morphology of dust particles from the wood sanding process of our most significant commercial tree species, as well as the results concerning the determination of percentage and dimensions of the smallest dust particles.

With oak dust in all investigated fractions dominates an isometric shape of particles with sharp corners and a rounded shape of particles with round corners that is more typical for fractions in the interval (bottom; 0.08) mm. With beech dust, we have mostly encounter with isometric particles with sharp corners in the interval (bottom; 0.125) mm. With spruce dust, in the interval (bottom; 0.063) mm we have recorded the particles mainly of isometric shape, with greater fractions an exclusively fibrous character of particles has dominated.

From the results of microscopic analysis follows that in investigated files of particles are also particles of very small dimensions, which are smaller than the respirable fractions $PM_{2.5}$, and their share is about 4 % for spruce, 7 % for beech, and as much as 10 % for oak. The smallest recorded particle was in oak dust and its size was only 1.19 μm, in beech dust it was 1. 74 μm, and in spruce dust it was 1.68 μm.

The percentage share of dust particle is also very different depending on the kind of tree species. In comparison of particles below 0.08 mm we can state that in oak dust, the occurrence of this fraction represents 87.26 %, in beech dust it is in average 93.34 %, and in spruce dust it is in average 76.94 %.

The results have shown that the kind of tree species is a significant factor influencing the shape, dimensions and also the share of arising particles in individual fractions.

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REFERENCES

1. Banski, A., Vacek, V., Kučerka, M., 2006: Stanovenie hmotnosti jemnej frakcie v suchej smrekovej piline – technickým výpočtom. In: Trieskové a beztrieskové obrábanie dreva 2006. TU Zvolen. Pp. 13-18
2. Barcík, Š., Pivolusková, E., Kotlínová, M., 2007: Experimental observation of juvenile

pine wood at plane milling. In: Proceedings of the 2nd ISC – Woodworking techniques. Zagreb: Faculty of Forestry. Pp. 189-199

3. Beljaková, A., Očkajová, A., 2007: Microscopic analyse of beech sanding dust. In: Proceedings of the 2nd ISC – Woodworking techniques. Zagreb: Faculty of Forestry. Pp. 201-206
4. Beljo Lučič, R., Čavlovič, A., Antonovič, A., Vujasinovic, E., Šimičič, I., 2005: Svojstva usitnjenog materijala nastaloga pri mehaničkoj obradi drva. Drvna industrija 56(1): 11-19
5. Beljo Lučič, R., Čavlovič, A., Ištvanič, J., Dukič, I., Kovačevič, D., 2007: Granulometric analysis of chips generated from planing of different species of wood. In: Proceedings of the 2nd ISC – Woodworking techniques. Zagreb: Faculty of Forestry. Pp. 207-213
6. Dzurenda, L., Kučerka, M., 2006: Effectiveness of Separation of wet pine sawdust in mechanical separators of type SEB with elements T4/630. In: Manufacturing engineering in time of information society. Gdansk. Pp. 99-104
7. Dzurenda, L., Orlowski, K., Wasielewski, R., 2005: Granulometric analysys and separation options of dry sawdust exhausted from narrow – kerf frame sawing machines. Drvna industrija 56(2): 55-60
8. Kopecký, Z., Pernica, J., 2004: Effects of the dimensional specification of dust on the quality of fair. In: Trieskové a beztrieskové obrábanie dreva 2004. TU Zvolen. Pp. 125-130
9. Kos, A., Beljo Lučič, R., 2004: Wood dust emission of different woodworking machines. In: Part I. The growth and development in forestry and wood industry. Scientific book. Zagreb: Faculty of Forestry. Pp. 121-127
10. Longauer, J., Dzurenda, L., 2006: Granulometrická analýza suchej smrekovej piliny odsávanej od rámovej píly Clasic 150/200 a možnosti jej efektívnej separácie. In: Trieskové a beztrieskové obrábanie dreva 2006. TU Zvolen. Pp. 185-190
11. Longauer, J., Sujová, E., 2000: Vybrané vlastnosti tuhých častíc. Vedecké štúdie. TU Zvolen. Pp. 10-35,
12. Ljubimov, V.C., 1976a: O stružkoobrazovanii pri šlifovanii DSP-V. Lesnoj žurnal (2): 71-77
13. Ljubimov, V.C., 1976b: O tolščine sloja srezaemogo abrazívnym zernom šlifovaľnogo kruga. Lesnoj žurnal (6): 97-101
14. Nariadenie vlády SR 356/2006 Z.z. o ochrane zdravia zamestnancov pred rizikami súvisiacimi s expozíciou karcinogénnym a mutagénnym faktorom pri práci
15. 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: Faculty of Forestry. Pp. 129-134
16. Očkajová, A., Beljo Lučič, R., Čavlovič, A., Tereňová, J., 2006: Reduction of dustiness in sawing wood by universal circular saw. Drvna industrija 57(3): 119-126
17. Požgaj, A., Chovanec, D., Kurjatko, S., Babiak, M., 1997: Štruktúra a vlastnosti dreva. Bratislava, Príroda, 485 pp.
18. Rogozinski, T., Dolny, S., 2004: Influence of moisture content on the apparent densities of dust from sanding of alder wood. In: Trieskové a beztrieskové obrábanie dreva 2004. TU Zvolen, Pp. 205-208
19 Rončka, J., Očkajová, A., 2007: The influence of sanding machine type and grit size on granularity of sanding wood dust. In: Proceedings of the 2nd ISC – Woodworking techniques. Zagreb: Faculty of Forestry. Pp. 289-294

20. Sandak, J., Orlowski, K., Negri, M., 2006: Divination from chips: Monitoring of the sawing process with chip geometry analyzes. In: Trieskové a beztrieskové obrábanie dreva 2006,TU Zvolen. Pp. 253-258
21. Siklienka, M., Naščák, Ľ., Banski, A., 1999: Monitorovacie zariadenie pre sledovanie kontaktných javov pri brúsení dreva. In: Stroj – nástroj –obrobok. TU Zvolen. Pp. 117-121
22. STN 26 0070: 1995: Klasifikácia a označovanie sypkých hmôt dopravovaných na dopravných zariadeniach
23. Wieloch, G., Osajda, M, 2007: Wymiary wiórów z drewna buka powstajacych przy toczeniu nožem samoobrotowym. In: Wood-Machine-Tool- Workpiece. Poznaň. AR Pp. 53-54

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