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Effect of Twist Drill Bit and Feeding Speed on Air Dust During Boring Process of Solid Wood and Wood-Based Composite Panels

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A study was carried out to analyze the particles produced during drilling process with twist drills with one and two spirals (length 70 mm, diameter 8 mm) with different feeding speeds, executed in beech (*Fagus sylvatica*), pine (*Pinus sylvestris*) and oak (*Quercus petraea*) woods, and also, medium density fiberboard (MDF), particleboard and poplar plywood panels. Drilling of solid woods was performed by following its longitudinal and transversal directions. The measurement and counting of wood dust particles was performed with a Particle Scan Pro instrument that measures the concentration of wood dust particles (milligrams per cubic meter or particles/l) present in the air. This instrument is able to count particles with diameter equal to and larger than 0.3 μm . A total of 281 tests were made with an average number of repetitions of eight for each material. The larger quantity of particles was produced by the wood-based panels, followed by hardwoods and finally, softwood. All drilled woods produced more particles on the longitudinal direction than on the transversal direction. For lower feeding speed, the number of particles increased with the increase of the number of bit's spirals. In general, the bits with one spiral produced a smaller number of pending particles than two spirals bits. Most of produced particles were registered in small sized categories ($\leq 1 \mu\text{m}$ Ø), where most of them were occupied by micro fines particles with 0.3 to 0.5 μm diameter, which were produced massively during V_22_b work regime.

Key words: Twist drill bit, feeding speed, drilling process, dust particles, solid wood, wood composite panels.

INTRODUCTION

Wood dust appears as a serious problem, taking into consideration the number of people exposed continuously to it and the pathological effects caused from it. Furniture manufacturing industry represents the highest values of exposure, where only in EU countries 32 to 54% of workers are exposed to a level that reaches the value of 2 mg/m^3 and more (Kauppinen et al., 2006). This fact becomes even more troubling considering the fact that this industry employs millions of people

worldwide (Lebedys, 2004) and the facts show that exposure to 1 mg/m^3 causes irritation of mucous membrane (Borm et al., 2002), whereas, an exposure to over 1.5 mg/m^3 cause damage to the clearance of the mucous membranes (Black et al., 1974; Wilhelmsson et al., 1984). Allergic symptoms to nasal region and sneezing are common to woodworkers especially to those who work with oak, beech, pine and some exotic species (Enarson and Chan-Yeung, 1990; Bohadana et al., 2000; Schlunssen, 2001). Symptoms that are related to the impairment of lung functions, to asthma, chronic bronchitis and cough, and also eye discomfort are significantly common among carpenters (Priha, 2004;

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Table 1. Properties of used materials.

Materials	ρ (kg m ⁻³)	Moisture content (%)
Poplar plywood	442	10.3
Particleboard	658	9.9
MDF	745	10.4
Beech	654	11.9
Pine	427	12.4
Oak	700	12.0

Schlunssen, 2001).

The link between exposure to wood dust and sino-nasal cancer in wood processing industry workers was identified in 1968 (Acheson et al., 1968) and many later subsequent studies and reports have reconfirmed this fact (Demers et al., 1995; Scientific Committee on Occupational Exposure Limits, 2003). However, now there is no doubt that wood dust is also able to cause DNA damage (U.S. Department of Health and Human Services, 2000; Lange, 2008). Based on this reality, International Agency for Research on Cancer (IARC) has made this classification of dust particles:

1. Group 1 (carcinogenic to man) – furniture manufacturing and cabinet making;
2. Group 2B (Possibly carcinogenic to man) – operations in wood processing enterprises and carpentry;
3. Group 3 (not classified as carcinogenic to man) – production of lumber and sawn timber.

The amount of dust inhaled and deposited throughout the respiratory ways depends on the size, shape, solubility, chemical properties of surface, and density of dust particles, as well as from the strength (turbulence and velocity) of the air flow in the respiratory system (U.S. Environmental Protection Agency, 2004). Particles with diameter greater than 5 μm ("inspirable" particles) are deposited almost completely in the nose, whereas those with diameter from 0.5 to 5 μm ("respirable" particles) are deposited in the lower respiratory ways (U.S. Department of Health and Human Services, 2004) up to the lungs (fine particles) (Schlunssen et al., 2004). In fact, it is still unknown what the exact amount of dust that penetrates into the lower respiratory ways, but based on some measurements, some authors think that is about 10% of the total dust (Innocenti, 2008).

The total amount of wood dust produced and its particle sizes varies, depending on the type of machine (working operation) (Thorpe and Brown, 1994). In the quantity and characteristics of the dust, there are several factors combined together, such as, wood species (density and its anatomical structure) or the structure of processed wood-based composite panels [particleboard, medium density fiberboard (MDF), plywood, oriented strand board etc.], humidity of the material, direction of work in relation

to wood's grain and also the processing machines. There are some elements that are included in the processing machine, such as, the type of cutting tool and the cutting-tool geometry, feeding speed and its cutting rate and depth of elaboration. Currently, the literature does not provide much information on the impact of these elements in the wood dust amount and its size.

This study presents the quantitative analysis (total assessment) and the size distribution (classification according to the diameter) of wood dust emitted during the drilling process in a working place environment. Analysis is performed in function of four factors: the cutting instrument (twist drills with 1 and 2 spirals), the feeding speed (two speeds are applied), the processed material (some types of wood and wood-based panels) and the operation's direction according the anatomic structure of wood. Boring is one of the main technological operations in furniture manufacturing, where the possibility to use cutting instruments (bits) with different technological parameters by the same machine is significant. For technical reasons, the study was focused on particles with diameter from 0.3 to 30 μm , classified in 6 size categories, three of which belong to the ultra fine particles with diameter <1 μm .

MATERIALS AND METHODS

Materials

The study was carried out on materials (Table 1), which are commonly used as raw materials in the wood processing industry. Determination of moisture content (MC) and density for all materials were performed at the moment of testing.

The tests were carried out on boring machine "BORING SYSTEM 23" of "Maggi Engenharia" Company. This machine is designed to drill different wood materials like solid woods, MDF, particleboard, plywood panels etc., with different types of boring bits and different feeding rates. The holes were drilled by the twist drills with one and two canals, with a length of 70 mm and a diameter of 8 mm.

The measurement of sawdust particles was carried out through a device called Particle Scan Pro, which measures the concentration of airborne particles, present in the air in [mg/m³]. This device is able to count the particles from 0.3 to 30 μm and divides them into 6 following diametric categories ($\varnothing = m \cdot 10^{-6}$):

- 1) $0,3 \leq \varnothing \leq 0,5$
- 2) $0,5 \leq \varnothing \leq 0,7$
- 3) $0,7 \leq \varnothing \leq 1$
- 4) $1 \leq \varnothing \leq 2$

Table 2. Tests data variables.

	Description	Abbreviation
Feed Rate	Feeding speed 1 m min ⁻¹	V ₁
	Feeding speed 2 m min ⁻¹	V ₂
Twist drill bits' type	Diameter 8 mm, length 70 mm, one bit	1 _b
	Diameter 8 mm, length 70 mm, two bits	2 _b
Materials	Beech longitudinal direction	Beech-L
	Beech transversal direction	Beech-T
	Pine (<i>P. sylvestris</i>) longitudinal direction	Pine-L
	Pine (<i>P. sylvestris</i>) transversal direction	Pine-T
	Oak longitudinal direction	Oak-L
	Oak transversal direction	Oak-T
	Medium Density Fiberboard	MDF
	Particleboard	Particleboard
	Poplar Plywood	Plywood
Constant variables		
Holes depth	18 mm	
Nr. rot/min of twist drill	2800 RPM	
Drilling machine	Boring 23	

5) $2 \leq \emptyset \leq 5$

5) $5 \leq \emptyset \leq 30$

Method of tests performing

Non through-holes were bored applying two feeding rates $V_1=1$ m/min and $V_2=2$ m/min. These velocities were calculated by the formula $V=L/t$, where L the length of the way generated by the twist drill from the initial cutting, up to the depth of the hole and t the needed time to cover this way. The depth of the holes had to be 18 mm, which was controlled by the caliper. The holes of solid wood were bored following the longitudinal and transversal anatomical directions. The boring machine was leveled and the compressor was recharged to 7.5 Bar, before the work started. This pressure was controlled after each boring, in order for the pressure to be the same for each measurement (the machine works from 6 to 8 Bars). The defining of the data tests was carried out, in order to compare the boring processes and the essential parameters that affected in sawdust particles formation (Table 2).

Procedures of test performance

Before every test started, 10 air measurements were done with Particle Scan, in order to know the quantity of particles presented in the air. After getting all the tests results for all the samples of one material, from their maximum results, the average value of the first ten measurements of Particle Scan instrument was deducted. The difference is the true value of wood dust particles that the boring process gives in this case. This procedure is repeated for all executed tests. The Particle Scan instrument was positioned in the area where the operator usually stays. In this manner, the amount of particles that reaches up to him can be investigated. However, the obtained data appeared not homogeneous and not repetitive, because of microclimatic conditions effects (ascending air currents, operator's movements etc.). To make the environment less influential in the executed tests, it was decided that the instrument should be placed closer to the source of particles (Figure 1). In this case, the data obtained were much more homogeneous and

repetitive, although not representing the numbers of particles that reach the operator, it offered the possibility to freely compare the different drilling instruments, materials and parameters of the processing. The Particle Scan's probe was positioned in the center of the four twist drills, of the boring machine (Figure 1).

In this study, 281 tests were carried out with an average number of repetitions of approximately 8 times (Table 3).

The data obtained from the measurements were processed in an MS Excel spreadsheet and the graphs were built according to the fractions of particles. These graphs provide data on the performance of the quantities of particles divided by fractions from the beginning of the tests up to the moment that the level of particles in the air reaches the initial state.

RESULTS AND DISCUSSION

The total dust particles and their percentage of size distribution produced by each wood-based composite panel during four boring regimes are summarized as follows (Tables 4, 5 and 6).

The six tables below summarize the results obtained during the four boring regimes of three studied wood species, taking into consideration their anatomical direction (Tables 7, 8, 9, 10, 11 and 12).

The studied materials, although worked with the same machine and the same work regime, produced different amounts of dust both in total as well as in size. This is confirmed the information given in literature (Thorpe and Brown, 1995).

From the obtained results, a classification for materials based on the number of particles produced for each work regime cannot be made. A classification, results only for the $V_1 2_b$ and $V_2 2_b$ work regimes where the multi-ply gives the most amount of produced particles, followed by MDF and particleboard and then by beech, oak and pine. It



Figure 1. Placement of the particle measuring instrument closer to the source of particles, avoiding the environmental impacts.

Table 3. The number of tests performed for each material.

V_{11b}		V_{12b}		V_{21b}		V_{22b}	
Material	Nr. tests	Material	Nr. tests	Material	Nr. tests	Material	Nr. tests
MDF	8	MDF	8	MDF	7	MDF	7
Particle-board	8	Particle-board	8	Particle-board	9	Particle-board	8
Beech-L	7	Beech-L	7	Beech-L	8	Beech-L	8
Beech-T	8	Beech-T	8	Beech-T	8	Beech-T	8
Pine-L	8	Pine-L	8	Pine-L	8	Pine-L	8
Pine-T	9	Pine-T	9	Pine-T	8	Pine-T	8
Oak-L	8	Oak-L	7	Oak-L	7	Oak-L	7
Oak-T	8	Oak-T	7	Oak-T	8	Oak-T	7
Plywood	8	Plywood	8	Plywood	8	Plywood	7

Table 4. Total of dust particles and their size distribution during boring process of MDF.

Boring regime	Total of particles	Size distributions											
		0.3 - 0.5		0.5 - 0.7		0.7 - 1		1.0 - 2.0		2.0 - 5.0		>5	
		%	St. Dev.	%	St. Dev.	%	St. Dev.	%	St. Dev.	%	St. Dev.	%	St. Dev.
V_{11b}	302706	32.5	60615	8.9	10440	9.6	11072	6.0	6998	5.2	5959	37.8	44807
V_{12b}	1581435	76.3	264082	10.3	47993	3.8	12721	1.4	997	1.1	2765	7.1	10914
V_{21b}	72858	37.4	22642	10.3	6806	10.3	8637	5.3	4515	4.6	3619	32.0	25954
V_{22b}	110173	79.6	56520	13.3	8960	2.5	880	1.0	448	0.8	471	2.6	972

was noted that plywood panels MDF and particleboard drilled with V_1 feeding speed, with 2 spiral twist drills produced much more particles compared to the other three work regimes, as well as, woods studied.

If we refer only to wood-based panels, they are classified in three different variants for the four work regimes (V_{11b} -Plywood, Particleboard, MDF;

V_{21b} -Particleboard, MDF, Plywood; V_{12b} & V_{22b} -Plywood, MDF, Particleboard).

On the other side, the classification of woods is presented in a different way, where we have the same classification (beech, oak and pine) for three work regimes, while in work regime V_{21b} the pine wood produces more particles than oak. For all regimes, the

Table 5. Total of dust particles and their size distribution during boring process of particleboard.

Boring regime	Total of particles	Size distributions											
		0.3 - 0.5		0.5 - 0.7		0.7 - 1		1.0 - 2.0		2.0 - 5.0		>5	
		%	St. Dev.	%	St. Dev.	%	St. Dev.	%	St. Dev.	%	St. Dev.	%	St. Dev.
V ₁ 1 _b	625430	25.1	49593	19.2	29762	19.8	34790	10.0	15911	7.0	10177	19.0	26009
V ₁ 2 _b	1455172	27.3	212541	17.9	105274	20.1	93142	9.9	32750	6.9	23290	17.9	51015
V ₂ 1 _b	330327	30.8	109626	19.1	69460	18.0	76578	8.7	38645	6.0	26227	17.4	72452
V ₂ 2 _b	86534	41.2	25584	23.7	13243	12.6	6346	5.0	2386	4.1	1491	13.4	5232

Table 6. Total of dust particles and their size distribution during boring process of poplar plywood.

Boring regime	Total of particles	Size distributions											
		0.3 - 0.5		0.5 - 0.7		0.7 - 1		1.0 - 2.0		2.0 - 5.0		>5	
		%	St. Dev.	%	St. Dev.	%	St. Dev.	%	St. Dev.	%	St. Dev.	%	St. Dev.
V ₁ 1 _b	1037911	30.9	115555	22.2	81164	20.3	66650	8.4	25069	5.1	14209	13.1	32502
V ₁ 2 _b	1597329	32.4	224032	19.2	113315	20.0	83358	8.8	35190	5.6	17838	13.9	42342
V ₂ 1 _b	65466	43.0	19440	28.5	13414	14.2	5556	4.2	2379	3.1	1350	7.0	3474
V ₂ 2 _b	125357	45.3	14072	26.9	7419	12.3	3345	4.6	1468	3.0	900	7.9	2217

Table 7. Total of particles and their size distribution during boring process of Beech, longitudinal direction.

Boring regime	Total of particles	Size distributions											
		0.3 - 0.5		0.5 - 0.7		0.7 - 1		1.0 - 2.0		2.0 - 5.0		>5	
		%	St. Dev.	%	St. Dev.	%	St. Dev.	%	St. Dev.	%	St. Dev.	%	St. Dev.
V ₁ 1 _b	730420	62.2	158595	12.1	17038	9.5	14977	4.4	8588	3.1	7617	8.7	21101
V ₁ 2 _b	755326	29.8	66236	14.2	16469	16.9	22533	9.3	14445	7.0	12982	22.8	46312
V ₂ 1 _b	288422	72.7	481319	11.7	81134	6.1	55525	2.9	24713	1.8	16521	4.8	39920
V ₂ 2 _b	60659	77.6	22833	11.5	1898	4.5	719	1.8	361	1.3	300	3.4	667

Table 8. Total of particles and their size distribution during boring process of Beech, transversal direction.

Boring regime	Total of particles	Size distributions											
		0.3 - 0.5		0.5 - 0.7		0.7 - 1		1.0 - 2.0		2.0 - 5.0		>5	
		%	St. Dev.	%	St. Dev.	%	St. Dev.	%	St. Dev.	%	St. Dev.	%	St. Dev.
V ₁ 1 _b	673853	21.9	66165	17.7	34883	22.2	41444	11.0	20706	6.9	13397	20.3	45915
V ₁ 2 _b	736553	23.0	28700	17.0	27897	21.3	34854	10.7	17139	7.2	8871	20.8	23200
V ₂ 1 _b	181612	27.9	54233	18.7	49195	18.2	57031	9.7	31863	6.7	21410	18.7	56324
V ₂ 2 _b	33931	43.6	7419	20.5	972	11.0	732	5.8	933	4.6	799	14.5	1491

three species of woods produce more particles in the longitudinal boring than in the transversal one. Referring to the total particles for the four work regimes taken together, the largest quantity of particles is produced by the wood-based panels, followed by hardwoods and at the end by the softwood (pine) (Table 13).

Regarding to the type of bit, it was noticed that for the

V₁ feed rate, the twist drill bits with two spirals produce more particles than that with one spiral regardless of material and direction of boring. Whereas, for the V₂ feed rate this relationship does not exist. So, for the small feed rate, the greater the number of spirals, the greater the number of particles produced is. It was noticed that despite the feeding rate, MDF, multiply and drilled oak

Table 9. Total of particles and their size distribution during boring process of Oak, longitudinal direction.

Boring regime	Total of particles	Size distributions											
		0.3 - 0.5		0.5 - 0.7		0.7 - 1		1.0 - 2.0		2.0 - 5.0		>5	
		%	St. Dev.	%	St. Dev.	%	St. Dev.	%	St. Dev.	%	St. Dev.	%	St. Dev.
V ₁ 1 _b	405781	55.2	305341	19.8	61505	11.2	34330	4.1	11519	2.6	7037	7.1	19621
V ₁ 2 _b	448008	43.0	128283	17.1	36810	12.8	25718	6.3	8935	4.4	6669	16.4	20882
V ₂ 1 _b	17197	46.9	2919	30.1	1894	9.4	459	3.6	217	2.1	51	7.9	300
V ₂ 2 _b	32482	63.2	14697	18.9	2993	6.9	378	2.0	499	2.9	511	6.1	1028

Table 10. Total of particles and their size distribution during boring process of Oak, transversal direction.

Boring regime	Total of particles	Size distributions											
		0.3 - 0.5		0.5 - 0.7		0.7 - 1		1.0 - 2.0		2.0 - 5.0		>5	
		%	St. Dev.	%	St. Dev.	%	St. Dev.	%	St. Dev.	%	St. Dev.	%	St. Dev.
V ₁ 1 _b	228593	21.0	8013	23.6	13517	23.0	17413	10.5	10285	6.5	8125	15.4	15414
V ₁ 2 _b	343281	26.3	39387	21.8	21965	21.5	26345	9.5	9900	6.0	7865	14.9	19882
V ₂ 1 _b	15016	45.0	4898	25.6	2278	10.6	1032	4.7	529	3.4	240	10.7	691
V ₂ 2 _b	22646	49.8	10103	24.9	1357	8.3	1127	4.2	582	3.6	471	9.3	728

Table 11. Total of particles and their size distribution during boring process of Pine, longitudinal direction.

Boring regime	Total of particles	Size distributions											
		0.3 - 0.5		0.5 - 0.7		0.7 - 1		1.0 - 2.0		2.0 - 5.0		>5	
		%	St. Dev.	%	St. Dev.	%	St. Dev.	%	St. Dev.	%	St. Dev.	%	St. Dev.
V ₁ 1 _b	60483	39.5	8697	26.1	9645	15.3	6236	6.0	2194	3.5	1119	9.6	2480
V ₁ 2 _b	67757	52.0	19630	16.6	2076	12.3	2943	5.9	802	3.2	734	10.0	2180
V ₂ 1 _b	30988	36.7	6349	23.4	5510	12.2	3229	6.4	1641	3.9	982	17.4	4578
V ₂ 2 _b	9392	60.4	1225	24.6	254	8.9	261	2.3	96	1.3	67	2.5	86

Table 12. Total of particles and their size distribution during boring process of Pine, transversal direction.

Boring regime	Total of particles	Size distributions											
		0.3 - 0.5		0.5 - 0.7		0.7 - 1		1.0 - 2.0		2.0 - 5.0		>5	
		%	St. Dev.	%	St. Dev.	%	St. Dev.	%	St. Dev.	%	St. Dev.	%	St. Dev.
V ₁ 1 _b	30074	43.5	8013	22.4	13517	11.0	17413	4.5	10285	3.1	8125	15.5	15414
V ₁ 2 _b	57907	59.6	39387	18.0	21965	7.3	26345	3.8	9900	2.6	7865	8.8	19882
V ₂ 1 _b	18649	46.7	4898	20.7	2278	11.6	1032	5.8	529	4.2	240	10.9	691
V ₂ 2 _b	8479	57.6	10103	23.6	1357	8.1	1127	3.7	582	2.9	471	4.1	728

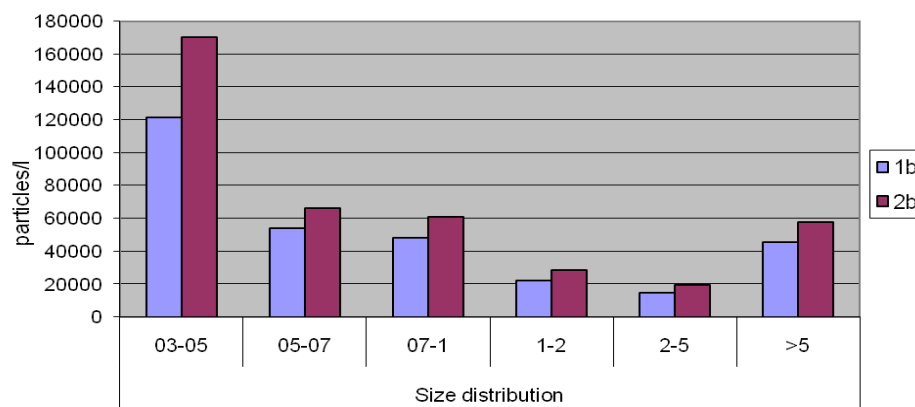
according to both its anatomical directions, produce more particles with the increasing number of bit's spirals. This is not observed in particleboard and the other two drilled woods according to both their anatomical directions, which for the V₂ feeding rate produce more particles with one spiral. By considering the general average of particles produced with the V₁ and V₂ feeding rate, it was

noted that the 1 spiral twist drill bit produces a smaller number of pending particles than the two spirals twist drill bit (Figure 2). This bit produces 40% of the overall total particles.

Regardless of material type, number of bit's spirals and direction of boring, the largest amount of particles is produced by the V₁ feeding rate, and also for small feed

Table 13. The total quantity of particles produced by the materials.

No.	Material	Total particles produced for the four works regimes
1	Poplar multi-ply	2826063
2	Particleboard	2497463
3	MDF	2067172
4	Beech longitudinal	1634827
5	Beech transversal	1625949
6	Oak longitudinal	903468
7	Oak transversal	609536
8	Pine longitudinal	148620
9	Pine transversal	115109

**Figure 2.** Particle size distribution referring to number of bits.**Table 14.** Ratio of particles diametric classes produced by drilling with V_1 and V_2 feeding rate.

Rapport	Size distribution					
	0.3 – 0.5	0.5 – 0.7	0.7 – 1	1 – 2	2 – 5	>5
V_1/V_2	5.9	6.8	10.1	10.3	9.8	9.5

speeds. The amount of particles produced during the boring of the V_1 feeding rate represents 88% of the total number of particles generated, versus only 12% of the V_2 feeding rate. The ratio of diametric classes for particles produced at V_1 and V_2 feeding rate results from 5.9 up to 10.3 (Table 14).

For all materials considered in this study, the variant which produces more particles is $V_1 2_b$. This is particularly noticed in wood-based panels and especially in MDF, which for this work regimen produces 76% of the total amount of particles. This regime produces 52% of the total number of particles for all size classes, followed by $V_1 1_b$ with 34%, $V_2 1_b$ with 9% and finally $V_2 2_b$ by 5%. Low feeding rate causes decrease in the chip's thickness, which brings a greater fragmentation of it and therefore

an increase in generated particles. Chips fragmentation increases with the increase of the number of bits' cutting edges because the particles produced go easily through two spirals compare to one spiral twist drill bits. So, we can say that for low feeding rate and a large number of spirals of twist drill, more particles are produced. The average distribution of size particles calculated on the sum of the results obtained for all materials and boring regimes shows that the majority of particles is registered for the small size distribution ($\leq 1 \mu\text{m } \varnothing$) (Figure 3). Standard deviations (shown by error bars) show the overall performance of frequencies for size distribution, apart from high variability of data.

With the increasing diameter of particles, their percentage for the diametric classes decreases

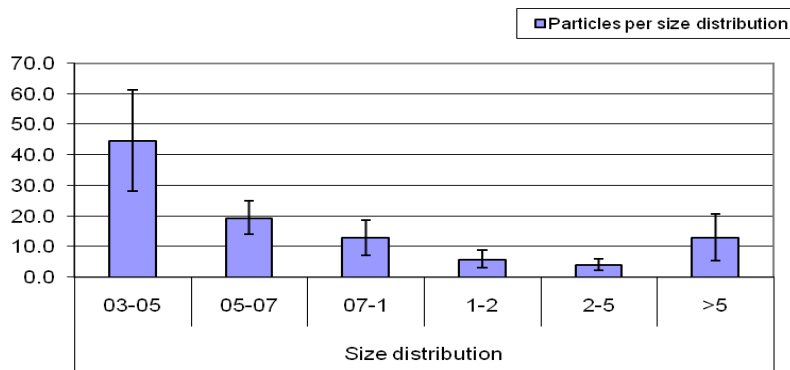


Figure 3. The average size distribution of dust particles referring to all tests.

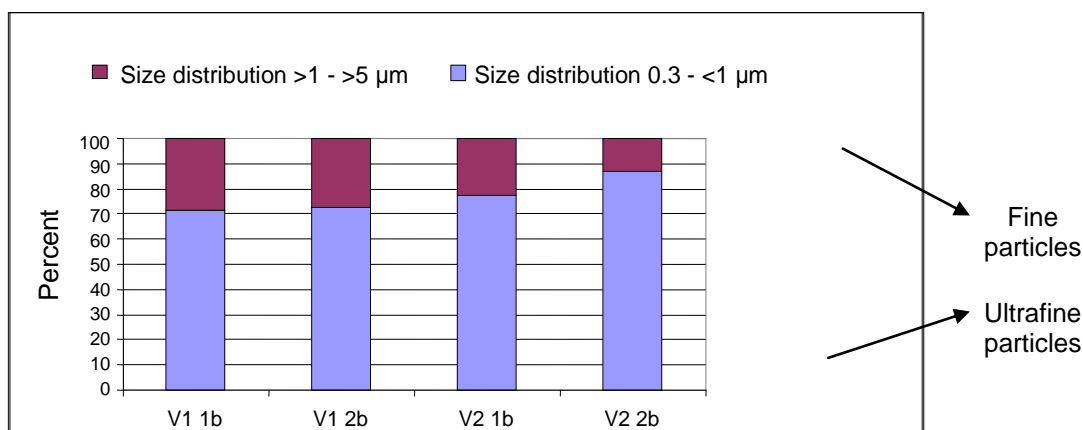


Figure 4. Distribution into fine and ultrafine particles referring to boring regimens.

continuously up to 2 to 5 μm class, and increase again to $> 5 \mu\text{m}$ class. One such phenomenon is related to the fact that the instrument is able to measure up to a maximum diameter of 30 μm , and thus, the grouping made for the 5 to 30 μm class turns out to be large enough. The highest percentage of particles for all boring regimens is for particles with 0.3 to 0.5 μm diameter. Referring to this diametric group, the largest amount was given by V_{2b} regimen for all materials, except of pine in transversal direction, where V_{2b} regimen produces 2% less particles than V_{1b} regimen. For other diametric classes, there is no functional relationship as regard the boring regime. The maximum concentration of particles was from fine diametric classes and this was noticed for the four boring regimen (Figure 4). Ultra fine particles with diameter less than 1 μm , which penetrate in the lungs (Schlünssen et al., 2004), occupy 77% of the overall total, and those other ones with diameter greater than 1 μm are only 23%. This result differs from previous literature data, which the particles of 1 to 5 μm diametric groups was placed at the level of 61 to 65% (International Agency for Research on Cancer, 1995).

For the four boring regimes, the size distribution curves are more or less the same, so the relationship between the size classes can be considered approximately the same (Figure 5).

Regarding the pending times of particles in air, it was noticed that in all cases, the amount of particles in the air returned into initial values before the boring process, indicating that the particles produced were deposited quickly or they were moved into space by moving away. The average periods in which these quantities of particles returned to the initial state of the evidence, were very fast (11 seconds) and more homogeneous (standard deviation 2.2 s).

Conclusion

The executed tests provide only a part of the necessary information to assess the levels of wood particles during the manufacturing of wood furniture. It was observed that different materials gave different amounts of dust in total; and in the size distributions, during the boring, within the

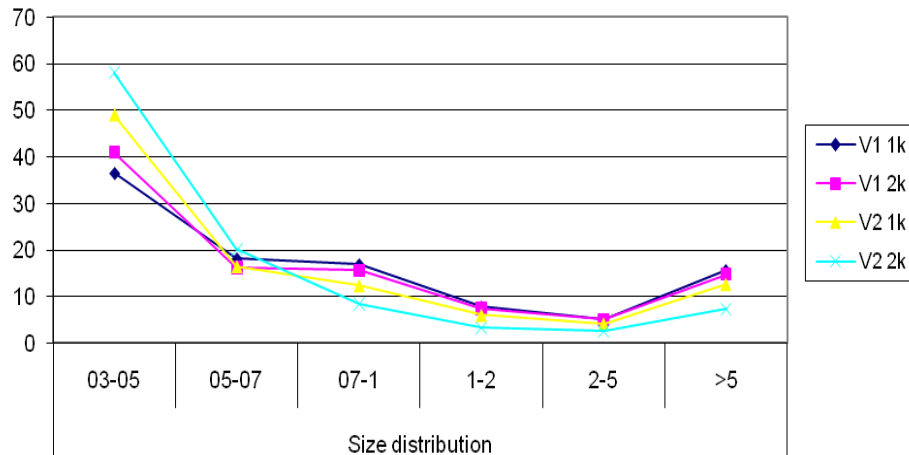


Figure 5. Size distribution of dust particles referring to boring regimens.

same regimen of process. The largest amounts of particles are produced by the wood-based panels, followed by hardwoods and by softwood at the end. Average periods in which the amount of pending particles returns to the initial state of tests are more rapid and more homogeneous. Woods produce more particles in longitudinal boring rather than in transversal boring direction. For the lower the feeding rate, the greater the number of bits' spiral, the greater the number of particles that is produced too. In general, the bit with one spiral produces a smaller number of pending particles than two spiral bits. Regardless of type of material, number of bits' spirals and boring direction, the largest amount of particles is produced by low feeding rate. For all studied materials, the variant that produces more particles is V_{12b}, especially for wood-based panels. Most of the particles produced are registered in small sized classes ($\leq 1 \mu\text{m } \varnothing$), where most of them fall between the range of 0.3 to 0.5 μm diameter, which were produced massively in V_{22b} regimen.

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