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DUST EMISSIONS DURING SANDING OF THERMALLY MODIFIED BEECH WOOD

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Abstract
The aim of the paper is determination of dust emission during sanding of native and modified beech. The analysis concerns the characteristics and composition of this dust. The issue of danger for human health exposed to the wood dust is also addressed and impact of dust particles on the working environment hygiene. The experimental part was carried out on a test stand to simulate standard sanding. For our experiment three samples were selected, namely a modified beech at 180 °C, 200 °C and a native beech. In order to evaluate the incidence of wood dust, a methodology was designed to determine the representation of individual fractions of wood particles. Very fine particles (particles smaller than 100 μm) were subjected to microscopic analysis and then mathematical and statistical evaluation.

Key words: *wood dust, sanding, proportion of particles, size of particles, thermally modified wood, beech*

INTRODUCTION

Together with the main product also chips and sawdust are produced during wood machining. Wood dust is an assembly of individual particles which shape and size depends on properties of the worked wood material and working parameters (Prokeš, 1978; Goglia, 1994; Lisičan, 1996; Dzurenda, 2007). The sawdust created during woodworking is dispersed in the air and presents a serious health risk of woodworkers (Hubbard et al., 1996; Beljo-Lučić et al., 2011; Čavlović et al., 2013). Protection against the wood dust should be based on the detailed knowledge on the sources of dustiness of the air around woodworking machines. Thus it is necessary to determine the mass rate of generated dust and its particle-size distribution for evaluation of the health hazard created at working of different wood materials by dust particles dispersed in the air. Different working operations and properties of wood materials are the reason of changeability of total dust created. Beech wood is moreover one of the most hazardous materials worked in wood products and furniture manufacturing. Recently modification technology makes it possible to obtain new materials based on solid wood for manufacturing of such products. The thermal treatment process is aimed at suppression of wood properties that are detrimental for its use, such as water

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absorption, swelling, shrinkage and resistivity against biologic pest (Gaff et al., 2010; Kopecký et al., 2007). It influences on the working parameters of these materials and on the properties of generated wood dust. Dolný et al. (2011) have found that the smaller dimensions dust particles are generated during the sanding of thermally modified oak wood than of natural oak wood. Similarly conclusion gave Dzurenda and Orłowski (2011) according the sawdust generated during sawing of the thermal treated oak and native oak wood on sash gang saw.

MATERIAL AND METHODS

To obtain samples of wood dust, a stand was used which was manufactured directly for the purpose of this measurement. Samples were cut in the transverse and longitudinal direction. In order to maintain the constant conditions for all samples, a new abrasive belt was used for each individual sample. The cut sample was pressed towards the abrasive belt with a constant compressive force by the lever mechanism - the specific pressure was maintained at 0.40 $N\cdot cm^{-2}$. The abrasive belt has a length of 610 mm, a width of 100 mm and a grain size of 80. To determine the dust emission during sanding, a method of dust collection has been proposed from the inside of the box with the grinder. Prior to each measurement, there was carried out a precise cleaning of the area around the grinder and of the grinder itself. Subsequently, the box was sealed with a flexible seal. Then, a layer of workpiece was sanded off so that the amount of wood dust was at least 50 g. After the dust had settled (about 30 minutes), the wood dust was manually removed and prepared for granulometric analysis.
Thermall modified beech at 180°C and 200°C was selected as experimental material and native beech. Samples were modified in a laboratory (Katres s.r.o.) for 3 hours in a steamy environment.

Tab. 1: Properties of experimental samples

Wood	Process	Density [$kg\cdot m^3$]		Weight loss [%]	Equilibrium moisture [%]
		untreated	treated		
BK native		723.6	-	-	12.9
Thermo – 180 °C	process I = 180 °C	719.0	694.4	3.42	6.8
Thermo – 200 °C	process II = 200 °C	742.3	677.4	8.73	4.9

For the granulometric analysis, a sieving method was chosen to determine the particle size. The granulometric analysis was performed using the Retsch AS 200 digit instrument with the option of continuously amplitude adjusting of the vibrations in the three-axis network. The device is equipped with 5 mm, 1 mm, 500 μm, 250 μm and 100 μm sieves according to ISO 565 (DIN ISO 3310-1), vibration amplitude A = 1 mm, sieving time t = 10 min. At precise digital scales Vibra AJ - 420 - CE with an accuracy of ± 0.001 g, the particles were weighed, which were sieved through individual sieves.
For particles smaller than 100 μm, microscopic analysis was used. Microscopic images were evaluated for a fraction less than 100 μm. Regards to inhalation, the most dangerous dust particles are 0.25 to 5 μm (Koncz, 1970). For each sample, approximately 20000 dust particles were put to the probability analysis. Using an analysis system and a Keyence VHX – 5000 microscope image processing that measures the shape of a subject using Focus

Variation, the particle samples have been examined, which have fallen to the bottom of the sieving device (particle size below 100 µm).
To assess the behaviour of dust from various aspects, such as its ability to separate in different types of separators, its health effects, its settling capability, its explosive capability, its probable occurrence in a given dust emission must be known. For a probability analysis of fine dust up to 100 µm, it is possible to use a two-parameter Weibull model, which complies for most cases of occurrence of a random variable. Weibull model data is obtained from image analysis. Since the Weibull model parameters - the shape parameter and the scale parameter are movable, ie dependent on the statistical distribution of the particles, the Weibull model can pass e.g. in Gauss, log-normal, exponential and other probability models (Kopecký, Mazal, 2005).

RESULTS

The granulometric analysis shows that for the longitudinal sanding model (Figure 1a), the particle size is below 100 µm for native beech (60%) and THERMO beech for 180°C (52%). At THERMO 200°C, the largest representation is in the range of 100-250 µm (60%).

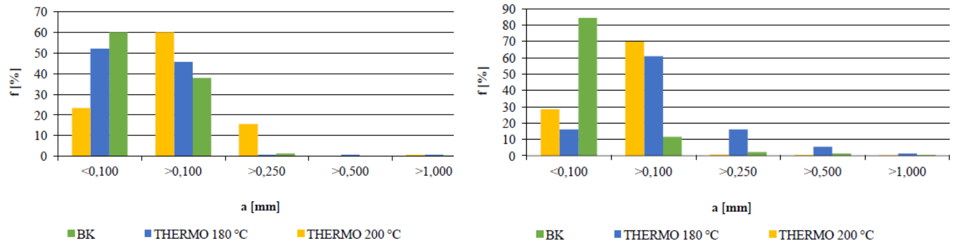

Fig. 1: Histograms of the sawdust particle-size distribution for a) longitudinal direction of sanding, b) transverse direction of sanding

From the fractional representation in the beech dust histogram from the transverse sanding model (Figure 1b), it is clear that the largest representation of particles below 100 µm is for native beech (83%). In the range of 100-250 µm, the largest proportion is for the THERMO 200°C (70%) and THERMO 180°C (62%).
In order to better illustrate and compare the effect of the modification on the fractional composition of wood dust, we created a cumulative particle-size distribution curve (Figures 2a and 2b). A log-normal or log-log coordinate are used to display this chart appropriately. The results show, that with the increasing temperature of the modification, the proportion of dust particles smaller than 100 µm decreases, especially in cross-sanding. In the THERMO200°C longitudinal sanding model (Figure 2a) 38% less fine dust up to 100 µm is produced than for the native beech, for the THERMO 180°C is a 30% difference.
In the transverse sanding model (Figure 2b), the differences are more apparent than in the longitudinal sanding model. THERMO 180°C has a 53% lower proportion of fine dust particles up to 100 µm than the native beech, THERMO 200°C makes this difference even more noticeable, up to 67%. The dropout curve is important when designing separating devices. If the curve is deflected to the left side, there is a higher demand on the filter device.

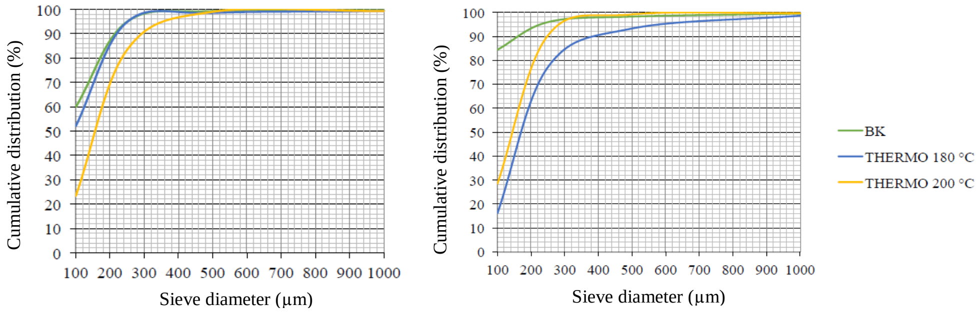

Fig. 2: The cumulative particle-size distribution for a) the longitudinal direction of sanding, b) transverse direction of sanding

The particle-size distribution probability density graph for the longitudinal sanding model (Figure 3) results in a significant occurrence of dust particles in dimensions smaller than 30 µm. The probability density exponentially increases in the range of x = 2 to 30 µm. With the increasing temperature of the modification, the probability density of occurrence of small dust particles decreases in the range of x = 5 to 40 µm. In the range of x = 2 to 5 µm, the opposite impact occurred, and the THERMO 200°C dust has the highest probability density of occurrence.

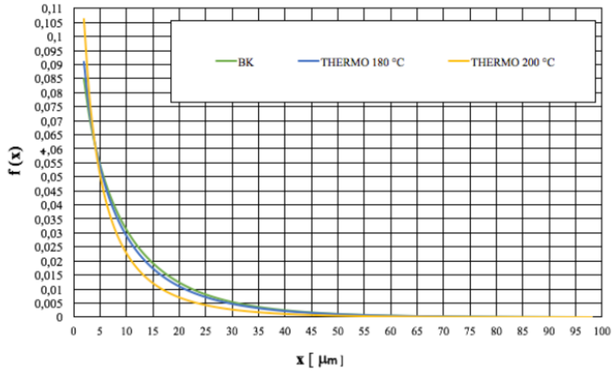

Fig. 3: Particle-size distribution – longitudinal direction of sanding

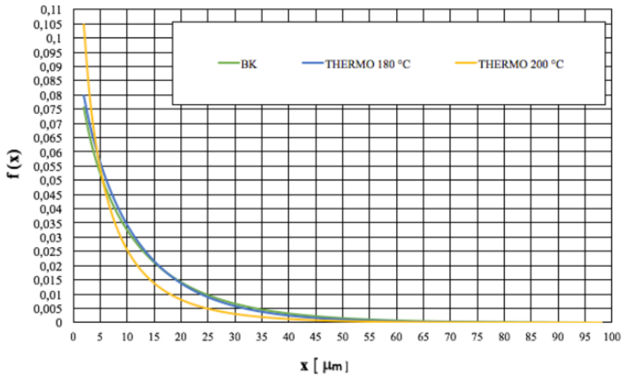

Fig. 4: Particle-size distribution – transverse direction of sanding

The probability density in the transverse sanding model (Figure 4) exponentially increases in the range of x = 2 to 45 μm. From the course of values it is clear that the difference between native beech and THERMO 180°C is negligible. In the range of x = 5 to 40 μm the probability density of THERMO 200°C relative to the native beech and THERMO 180°C decreases. In the range of x = 2 to 5 μm the opposite effect occurred and THERMO 200°C has the highest probability of occurrence probability.

DISCUSSION

Granulometric analysis results for particulates smaller than 100 μm (airborne particles) that with the increasing temperature of the modification in longitudinal sanding, the percentage of finest dust particles decreases by up to 37% at THERMO 200°C compared to native beech. In the transverse sanding model, the smallest percentage of fine particles was for THERMO 180°C, 52% less than the native beech. The measured results clearly showed that the modified beech has a smaller percentage of fine particles than native beech. It is also clear from the results that the temperature of the modification and the sanding model have had a major influence on the granulometric composition of the individual fractions of wood dust in all the samples examined. Jobbágyová (2008) monitored the granulometric composition of wood dust, depending on the type of wood and the sanding model, and recorded a particle size under 0.08 mm in average percentage of 93.34% and in the longitudinal sanding 83.34% in the transverse sanding model of a native beech. These values are comparable with the results of our native beech analysis. Similar results are published by Očkajová, Rončka and Banski (2006).

Longitudinal sanding has larger particles than a transverse sanding, due to the microscopic structure of the wood, because most of the cellular elements are located in the longitudinal direction and have a fibrillar structure, resulting in less cutting of the wood elements. Boonstra et al. (2006b) studied the microscopic structure of heat-treated hardwood and concluded that the treated beech and birch had radial cracks near the wood rays. Broken cell walls perpendicular to the fibre direction can cause transverse cracks creation.

In addition, a microscopic analysis of wood dust with dimensions less than 100 μm was carried out in order to determine the probable occurrence of hazardous inhalable particles which are the most dangerous in terms of hygiene and labour safety. The probability analysis showed that in the fraction up to 100 μm, most of the samples contained particles smaller than 40 μm. For a range of 5-40 μm, it has been found that the modified beech has a smaller percentage of fine particles than native beech. The highest probability density of fine dust was for THERMO 200°C both in the longitudinal and transverse direction, namely 2 μm. From a medical point of view, according to Bean (1996), these particles with dimensions smaller than 10 μm can reach the bronchial system depending on their size in different sections of the tract (bronchoalveolar, tracheobronchial). According to Standfest (2008), the hardness according to Brinell of modified beech increased approximately by 10 $N \cdot mm^{-2}$. This factor probably affected the total sanding time of the individual samples the most, which was up to three times longer for the modified beech compared to the native beech. Also, Očkajová, Rončka and Banski (2006) examined the dependence of the density of the sanded material on the granulometric composition of wood dust. They came to the conclusion that with increasing density of native wood, the proportion of wood particles below 80 μm increased, by about 10%. The decrease of density for the modified beech was probably one of the main reasons for reducing the number of wood particles to 100 μm.

CONCLUSION

According to the measurement results, we found that thermal modification of wood as well as the sanding model have significant effect on the resulting particle size and on the shape and proportion of particles in individual fractions. In practice, it is preferable to select the model of longitudinal direction of sanding in order to reduce the emission of dust. Today as in the future, it is necessary to focus on reducing or eliminating hazardous substances in the workplace. It is therefore necessary in all industry sectors, including in woodworking to seek out ways how to eliminate pollution. Thanks to the knowledge of the dust properties we are able to influence positively the development of separation techniques and technologies leading to the emission reduction in the working environment.

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