EFFECT OF SELECTED FACTORS ON MASS CONCENTRATION OF AIRBORNE DUST DURING WOOD SANDING

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Sanding with handheld powered tools has been recognized as one of the most significant factor in personal exposure to wood dust in the woodworking industry. The aim of this study was to investigate the effects of wood species and grain size of abrasive on wood removal and mass concentration of wood dust emitted by a random orbit sander. Experimental study was designed as 4x4 full factorial experiments. The mass concentration of emitted wood dust was measured using aerosol monitor DustTrak DRX 8533. The results of this study confirm that softwood species generated higher dust concentrations than hardwood species due to difference in abrasion durability. Compared to sanding disc with P40 grit size, approximately 48% higher dust concentration was generated when the sanding disc with P240 grit size was used.

KEYWORDS

safety, aerosol, concentration, real-time measurement, workplace air, photometer

1 INTRODUCTION

The sanding process is an important value-addition task in the wood products manufacturing industry. Inevitably, the sanding process results in the production of wood dust that is injurious to the health of the workers [Ratnasingam et al. 2011]. Sanding has been shown to produce the highest exposure among typical wood machining processes. Sanding with both stationary and hand-held powered tools has proved to be the most significant factor in personal exposure to wood dust in small woodworking shops even when appropriate local ventilation was used [Welling et al., 2009]. Exposure to wood particles and specific health effects are based on many factors, including the type of wood, occupational setting, intensity, duration, and frequency of exposure. Health effects of occupational exposure to wood dust can be summarized under five headings:

- toxicity (including dermatitis and allergic respiratory effects),
- non-allergic respiratory effects,
- sinonasal effects other than cancer (nasal mucociliary clearance and mucostasis),
- nasal and other types of cancer,
- lung fibrosis [Alonso-Sardón et al. 2015].

In inflammatory diseases induced by wood dust, e.g., allergic rhinitis, chronic bronchitis, and asthma, the dust particle diameter is a crucial factor in exposure evaluation as it determines the deposition mechanism in the human respiratory system [Wiggans et al. 2016].

Random orbit sander is sander equipped with a plate positioned eccentrically on the driving spindle which can rotate freely around its axis parallel to the work surface [EN 50632-2-4 2016]. Despite the fact that random orbit sander has to meet the basic safety requirements related to the health hazards caused by the emission of dust according to Machinery Directive 2006/42/EC, in contrast with noise or vibration, suppliers and manufacturers of hand-held sanders are not currently obliged to notify the users of the dust emission levels. Standard EN 50632-1:2015 specifies a procedure to measure dust concentrations (inhalable and/or respirable) produced during the use of random orbit sander under standardized conditions. Whilst the airborne dust concentration during actual use of the tool will differ, the test procedure does allow comparison of dust concentrations produced by tools of the same type. In addition, the test can be carried out on tools with and without dust extraction so the effectiveness of control measures can be evaluated and optimised [Saunders 2016]. Recently, a laboratory methodology has been developed, with the aim of classifying the different power tools tested in terms of dust emission [Keller 2018].

Traditional exposure control measures include dust extraction unit integrated into sander, mobile local exhaust ventilation, downdraft table and respiratory protection equipment. The most effective way of reducing dust exposure is to reduce the emission of wood dust at the source. The experiments testing the efficacy of several intervention options showed that use of the filter bag attachment to hand tools was ineffective in reducing emissions to inhalable particles [Douwes et al. 2017].

Several studies have been conducted on the influence of the various factors on wood dust emission during sanding process.

One of the first studies reported on this topic was made by Thorpe and Brown [1995]. They investigated the effect of wood density and hardness, sandpaper grade, and contact pressure on the production of dust during the sanding of wood. They found that harder woods produced a lower rate of dust production and finer dust, but the quotient of the mass of dust produced and the mass of wood removed varied little with wood type. Furthermore, they reported that fine and coarse sandpaper produced similar concentrations of airborne dust, but coarse sandpaper produced less dust per unit mass of wood removed. A study of the factors that influence dust-generation during the sanding process of Malaysian hardwoods was undertaken by Ratnasingam et al. [2011]. They found that the amount of wood removed during the sanding process predetermined dust generation, although the wood density and abrasive grit used also played a role. Ojima [2016] observed by laboratory experiments the generation rate and the particle size distribution of the wood dust produced by handheld sanding operation. He reported that respirable wood dust is able to be controlled by general ventilation with more than 0.7-4.2 m^3/min ventilation rate. Očkajová et al. [2018] compared the granulometric compositions of sanding wood. They determined statistical significance of individual factors (type of sander, wood species, grain size of sander, sanding direction) affecting the percentage of fraction ≤ 80μm.

The aim of this study was to investigate the effects of wood species and grain size of abrasive on wood removal and mass concentration of wood dust emitted by a random orbit sander.

2 MATERIALS AND METHODS

Wood removal and mass concentration of airborne wood dust were investigated in sanding operation as function of wood species and abrasive grain size. The experimental set-up is illustrated in Fig. 1.

The input material for the production of the test specimens were cuts of oak *(Quercus petraea)*, beech *(Fagus sylvatica)*, spruce *(Picea abies)* and pine *(Pinus sylvestris).* Test specimens were cut to the required dimension of 500 mm x 250 mm x 50 mm (length x width x thickness) by longitudinal cutting using band saw (Mebor, model HZT 1000) and following by the cross cutting using cross cut saw (TOS Svitavy, model KRU). Planks were subsequently conditioned to a final moisture content of 12% before experimentation. The humidity of the test specimens was determined gravimetrically using universal lab oven (Memmert, model UF 30 Plus). The mobile workbench (Bosch Power Tools, model PWB 600) was used for clamping the test specimens.

Sanding was performed using a commercially available handheld random orbit sander (Bosch, model PEX 300 AE) without dust box. Sander was adjusted to maximum orbital stroke rate. Aluminum oxide abrasives of four different sanding grits, i.e., 40, 80, 120, 240, were used in this study. Abrasive disc (Klingspor, PS 22 K), which had an orbit diameter 125 mm, was replaced after each trial. To ensure consistent sanding operation, monitoring the pressure force was performed by the load cell capacity sensor (Hoggan Scientific, model Ergopak FSR). The pressure force 50 N ± 5 N was applied on the sander.

In order to evaluate the wood removal, quantity of dust removed from the planks during the 3 minutes of sanding was determined by weighting the planks before and after the sanding operation. The weighting procedure was performed using an analytical balance (Sartorius AG, model BP 3100P).

The mass concentration of emitted wood dust was measured using aerosol monitor (TSI Inc., model DustTrak DRX 8533). An aerosol monitor combines a light scattering photometer and an optical particle counter. Zero-point calibration of the device was completed prior to each sampling event, as recommended by the manufacturer. The airborne wood dust was sampled in the breathing zone of the sander operator. Conventionally, the breathing zone is defined as the zone within a 0.3 m radius of operator's nose and mouth, and it has been generally assumed that a contaminant in the breathing zone is homogeneous and its concentration is equivalent to the concentration inhaled by the operator [Ojima 2012]. Sampling period (3 minutes) was determined following the time required for sanding one test specimen. Five repetitions were performed in each trial.

The experimental study was conducted in a test room that fulfils requirements according to standard EN 50631-1. The temperature and relative ambient humidity was monitored using microclimatic conditions monitor (Testo, model Testo 480). All tests were done at an ambient temperature of 20 °C ± 1°C and at a relative ambient humidity of 36 % ± 1 %. The average speed of air flow rate at sampling point was measured using anemometer (Testo, model Testo 415) and ranged from 0,23 $m.s^{-1}$ to 0,27 $m.s^{-1}$. In order to verify adequate cleaning and ventilation after each sampling event, the background concentration in test room was monitored using a photometer (Casella CEL Inc., model MicroDust). Prior to making measurements the aerosol monitor was zeroed by purging measurement chambers with particle-free air. Optical reference element was used to perform a single point check to ensure that the photometer was adjusted to the factory-set calibration.

An analysis of variance (ANOVA) was used to determine the influence of wood species and abrasive grain size on the magnitude of the generated wood dust mass concentration. The significance level was set up at p = 0,05. The data analysis was performed using the statistical software (StatSoft Inc., Statistica v. 10).

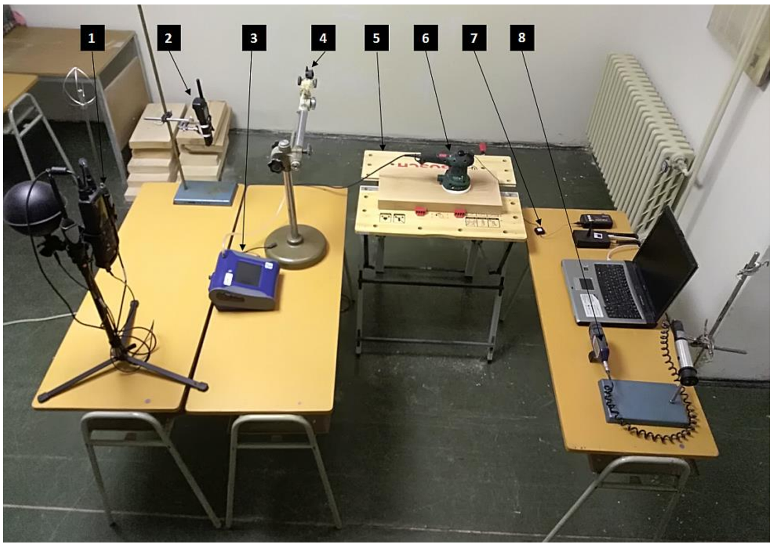

Figure 1. Experimental set-up: 1-microclimatic condition monitor, 2-anemometer, 3-aerosol monitor, 4-sampler, 5-workbench, 6-random orbit sander, 7-pressure force monitor, 8-photometer

3 RESULTS

Influence of the type of wood and grain size of the abrasive on the mass of removed wood is shown in Fig. 2. Two-way ANOVA showed that the mass of removed wood significantly varied with different wood species ($F(3,64) = 291.6$, $p < 0.05$) and grain sizes of the abrasive ($F(3,64) = 584.4$, $p < 0.05$) as well as interaction between the two factors ($F(9,64) = 36.1$, $p < 0.05$).

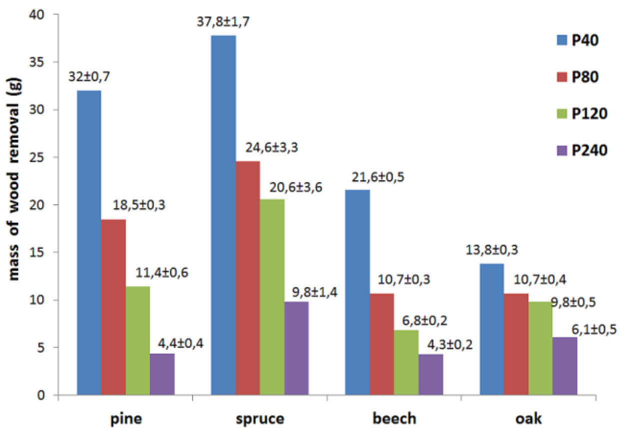

Figure 2. Wood removal as function of wood species and abrasive grain size (arithmetic mean ± standard deviation, n=5)

Influence of the type of wood and grain size of the abrasive on the mass concentration of respirable fraction of wood dust emitted by random orbit sander is shown in Fig. 3. Two-way ANOVA showed that the mass concentration significantly varied with different wood species ($F(3,64) = 2226.5$, $p < 0.05$) and grain sizes of the abrasive ($F(3,64) = 1682.9$, $p < 0.05$) as well as interaction between the two factors ($F(9,64) = 428.8$, $p < 0.05$).

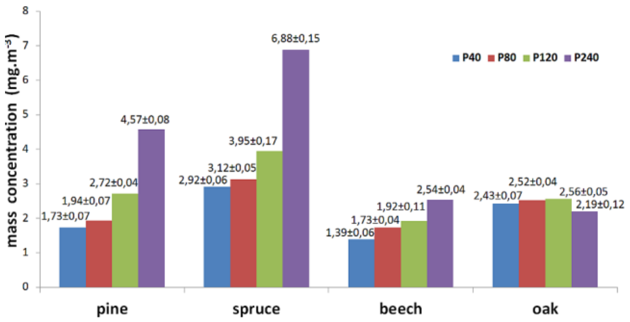

Figure 3. Mass concentration of respirable fraction as function of wood species and abrasive grain size (arithmetic mean ± standard deviation, n=5)

The relationship between mass of wood removed and respirable mass concentration is depicted on Fig. 4.

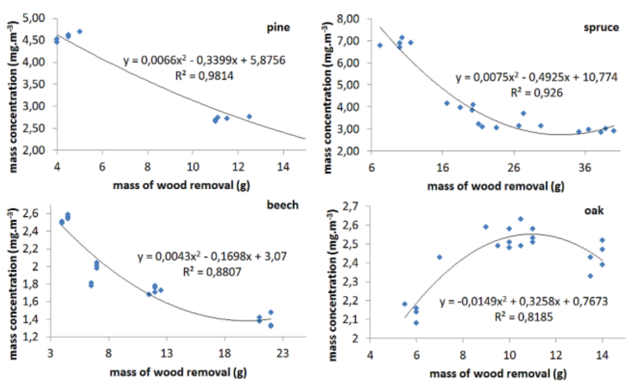

Figure 4. Wood removal-mass concentration relationship

4 DISCUSSION AND CONCLUSIONS

This study investigated the generation of wood dust during sanding four different wood species with four different grit sizes of the sanding paper by hand-held random orbit sander. For this study well-know and often used wood species – two coniferous and two hardwood species have been chosen.

The results of this study confirm that the total amount of airborne dust produced is a function of the total amount of wood removed during the sanding process. Although the coarsest paper removed almost eight times as much pine wood as the finest, the airborne dust concentration resulting from the sanding differs by only about 62%. For comparison, in case of oak wood coarsest paper removed more than two times as much wood as the finest and the airborne dust concentration resulting from the sanding differs by only about 10%.

Real-time measurements demonstrated that softwood species generated higher dust concentrations than hardwood species due to difference in abrasion durability. Compared to the hardwood specimens, approximately 38% higher dust concentration was generated when the coniferous specimens was sanded.

Influence of grit size did seem to have a significant impact on the generation of wood dust. As expected, sanding disc with P240 grit size produced higher dust concentrations than sanding disc with P40 grit size due to enhanced production of small particles, regardless on the type of wood species with one exception. Compared to sanding disc with P40 grit size, approximately 48% higher dust concentration was generated when the sanding disc with P240 grit size was used. Exception was just oak wood – lowest dust concentration was generated when sanding disc with P240 grit size was used.

Comparing results of wood dust concentration evaluation from different experimental setups and field measurements reported in the literature is very difficult. However, results of this study are in agreement with previous studies [Očkajová et al. 2008, Ratnasingam et al. 2011, Ojima 2016] which similarly found that harder woods and coarsest abrasive grit produced a lower rate of dust production.

One limitation to this study need to be considered. Correct calibration of the aerosol monitor is a basic prerequisite for obtaining meaningful data. DustTrak DRX has two calibration modes. First, zero calibration mode serves as compensation of zero drift. In order to zeroing instrument zero filter was attached to the inlet port of aerosol monitor. Zero calibration procedure was performed according to manufacturer instructions and it took approximately 70 seconds. Second, user calibration mode serves for determination of photometric and size correction calibration factors. Due to the fact that for the purpose of the study, it was sufficient to know the relative mass concentration values and at the same time we assuming that the optical properties of pine, spruce, beach and oak wood aerosols are not diametrically different, the corresponding calibration factors were not determined.

As observed in this study, it is clear that use of random orbital sander without appropriate engineering control increases exposure potential to inhaled particles that could have a negative health effect on operators. Results of this study showed that during sanding, most wood dust generated is breathable, and, if sander is not equipped with particle removal system, the level of dust particle concentration in the air becomes higher than the threshold set under the regulations. It is more difficult to find solutions for capturing dust particles from the working area than to reduce particle emissions at the source. In order to reduce particle emissions at the source, it is necessary not only to understand how dust particles are formed, but also to be able to predict their emission. The predictive modeling of wood dust particle emission is required in finding strategies to reduce such emissions at the source while remaining competitive. Our further research efforts will be focused on developing and validating prediction model for wood dust emission during sanding.

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