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Pilot-scale study on the influence of wood dust type on pressure drop during filtration in a pulse-jet baghouse

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ABSTRACT

Experimental filtration processes were carried out to investigate the air flow resistance during separation of three types of wood dusts in a pilot-scale pulse-jet filter. Three types of dust were compared: dust from sanding pine wood, dust from sanding beech wood and dust from working particl,eboard. These dusts are characterized by different particle-size distribution. The resistance coefficient K_1 was determined for the filter fabric used in tests. Basing on the results of pressure drop across the filter measured during the experimental processes in condition of three levels of filtration velocity V_f (0.0405; 0.0484 and 0.0583 m s^{-1}) the specific dust cake resistance coefficient K_2 was calculated. It value depends on the dust type and filtration velocity used. The lowest K_2 (20,085 s^{-1}) has pine wood dust at filtration velocity 0.0484 m s^{-1}. While the highest value (28,925 s^{-1}) was calculated at V_f = 0.0583 m s^{-1} for dust from working of particleboards.

1. Introduction

Fine particles created during milling of wood and wood composites are continuously discarded from the working space area. Dust extraction installations are used in for this purpose. They can be equipped with recirculation system. In winter, when there is a difference in temperatures between the dedusted and the outside air can save heating energy. However, using recirculation implies specific limitations. It is necessary to provide an adequate level of air cleanliness which in recirculation cycle is directed back to the machining zone where employees work. Otherwise, when the dust extraction system is inefficient or when the air in recirculation cycle is not properly cleaned, this can lead to excessive air dustiness in the working area which results in putting employees at risk of diseases connected with breathing in dusty air polluted by wood dust (Baran and Teul, 2007; Beljo-Lučić et al., 2011; Čavlović et al., 2013; Jug et al., 2016).

Requirements regarding the degree of air cleanliness can only be met with the use of filtering dust separators, the efficiency of which ensures proper cleanliness of air returning to the interiors of production workshops. Therefore, pulse-jet filter baghouses came into use in wood industry as effective separators of fine dust particles (Simon et al., 2014; Mračková et al., 2015). Since the operation of the dust separators is characterized by two opposite values: separating efficiency and flow resistance, the right choice, project and construction of a dust separator in accordance with particular industrial conditions should include all the factors which might influence filter operation. The choice of filtering material, the method and conditions of its regeneration as well as the parameters of filter's operation - gas and dust load, are of fundamental and decisive importance to the efficient work of the filter. However, these actions must be taken with the consideration of the characteristic of dust that reaches the dust separator with the air flow (Mukhopadhyay, 2009, 2010).

Wood dust is a general and imprecise term because chipped wood as production waste can be characterized by considerable variability depending on the species of wood being machined or the type of wood material along with shape and size variations of particles as a result of different methods and parameters of machining. Dust from sanding hardwood (oak and beech) is different from waste coming from sawing or milling of softwood. Dolny and Rogozinski, 2011; Očkajová et al., 2008; Očkajová et al., 2010, 2014). One should add to these species the wood which is exotic in European conditions (e.g. mahogany) and other plant-based materials (bamboo), different kinds of wood composites commonly used in furniture industry and modified wood which recently is also often processed, and non-wood furniture materials (Ratnasingam et al., 2015; Dzurenda et al., 2010; Dzurenda and Orlowski, 2011). The result of machining of these materials is waste including chips of different forms shapes and size, and among them fine dust particles. Lack of knowledge concerning the influence of the type of wood dust on filter operation may cause mistakes in choosing the right

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Table 1
Properties of nonwoven filter fabric used in experiments.

Properties	KYS – PROGRES series nonwoven filter fabric
fiber material	polyester
thinness of fibers	1.5 dtex
diameter of fibers	13 μm
filter fabric finish	heat setting, singeing, calendering
basic weight	500 g m^{-2}
thickness	2.1 mm
air permeability	240 dm^{3} dm^{-2} min^{-1}
the highest tension force:	140 daN
longitudinal	220 daN
transverse	
retracility at 140 °C	<1%
maximum temperature:	140 °C
continuous	150 °C
intermittent	

filter parameters and may result in inefficient work and increased energy consumption.

The aim of this paper was to assess the influence of the type of wood dust on the operation of pulse-jet filter basing on pressure losses during filtration. The comparison of effect of different wood dusts on the value of pressure drop was conducted with the use of calculated from empirical data values of the coefficient of dust resistance.

Due to the fact that specialist literature lacks sufficient data on the subject of pulse-jet filters' operation in wood dusts separation, the present work shall constitute a starting contribution to research on this problem.

2. Material and method

2.1. Wood dust

Wood dust used in this research was obtained from furniture factories. Beech and pine dust was a by-product of sanding and are characterized by bulk density adequately 192 and 184.7 kg/m^3. The dust from chipboards was a by-product of sawing and milling with bulk density 299.2 kg/m^3. After delivery to the laboratory, it was air conditioned in order to balance the humidity on the level of 9%. Then it was sifted through a sieve with the mesh size of 300 μm in order to get rid of bigger size waste that might disrupt safe course of experiments. However, due to expected different size distribution of particles which went through the sieve, it was submitted to size distribution analysis with the sieving method.

A sieve shaker AS 200 DIGT (Retsch Germany) with a set of sieves of aperture sizes 0.063, 0.125, 0.250, 0.500, 1 and 2 mm was used for this purpose. Analysis time amounted to 10 min. The mass of dust in every size class was determined by weighing of the rests remaining on each sieve after sieving on the laboratory scales WPS 510/C/2 (precision of weighing 0.001 g) (Radwag Poland). Three trials were performed and the average value was accepted as the result and approximation error was calculated with use of EXCEL Microsoft Software. The arithmetic mean particle diameter of a mass distribution was also calculated.

2.2. Filter medium

A polyester nonwoven filter fabric named KYS – PROGRES series (REMARK-KAYSER Poland) was used to make bags. Properties of this filter fabric supplied by the manufacturer were listed in Table 1.

2.3. Pressure drop theory

General theory to estimate pressure drop of fabric filters described in many previous papers (Cheng and Tsai, 1998; Leith and Ellenbecker, 1980; Koehler and David, 1983; Mukhopadhyay, 2009) assumes that the total pressure drop across the filter equals the pressure drop across the filter fabric ΔP_f and across the dust cake ΔP_c deposited on the surface of the filter fabric:

$$\Delta P = \Delta P_f + \Delta P_c \quad (1)$$

ΔP_f depends on filtration velocity V_f and specific characteristic of a filter medium represented by the constant K_1, which can be described as the filter fabric resistance coefficient:

$$\Delta P_f = V_f \cdot K_1 \quad (2)$$

The pressure drop across the deposited dust cake ΔP_c depends also on the filtration velocity V_f as well as on the mass of dust deposited on a unit of the filter area. The properties of the dust deposit are represented by the specific dust cake resistance coefficient K_2. This dependency can be written as follows:

$$\Delta P_c = V_f \cdot W \cdot K_2 \quad (3)$$

where:
W – dust deposit areal density, kg/m^2.
It can be calculated as:

$$W = C \cdot T \cdot V_f \quad (4)$$

Where:
C – dust concentration at filter inlet, kg/m^3,
T – filtration cycle time, s.
V_f – filtration velocity m/s.

2.4. The test rig (experimental setup)

The tests were done using an experimental setup shown in Fig. 1. The principal parts of the test rig are:

- the filtering chamber (1) with a filtering bag (2) inside. The tested bags were of 150 mm in diameter and operational length of 1485 mm, so the total filtering area was of 0.7 m^2. The bag was supported with a metal cage (3) with a Venturi tube on the top,
- the clean air chamber (4) with the air relative humidity and temperature sensor (5) and the cleaning nozzle (6) connected with the compressed air installation by means of a surge tank (7), an electromagnetic valve (8) and a controlling device (9).

The dust-laden air is delivered to the chamber by the dust inlet tube (10) connected with the screw dust feeder (11) DSK-I-04p (HYDRAPRESS, Poland) with output range 0–14 kg/h. The air flow through the filter is driven by the fan (12). The flow rate of the air is adjusted by the gate valve (13). The air flow rate which determines the air-to-cloth ratio is measured by the inclined-tube manometer (14) type MPR-1 (ZAM Kęty Poland) operating at scale factor 1:5 with measuring range 0–320 Pa and precision 0.5% cooperating with a Prandtl tube (15) placed into the outflow pipe (16). Another differential manometer type CMR-10 A (ZAM Kęty Poland) (17) with the measuring range 0−1500 Pa and maximal measurement uncertainty ± (0005 | Δp | +0,5) Pa measures the air flow resistance across the filtering bag during the filtering process. Numbers in the text are identical with those in Fig. 1.

2.5. Experimental filtration process

Measurements of the pressure drop across the clean filter fabric provided the basis for the determination of the resistance coefficient K_1 used later during computational evaluation of the specific dust cake resistance coefficient K_2. The measurements were done using the differential manometer CMR-10 A while the air flow rate of the fan was subsequently increased and decreased in the usable range. It resulted in changes of the air-to-cloth ratio and in consequence in filtration velocity. The dust supply system was