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THE ANALYSIS OF PARTICLES EMISSION DURING THE PROCESS OF GRINDING OF STEEL EN 90MnV8

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Metal grinding is a one of the manufacturing technologies that is greatly connected to particles emission. Particles generated during the grinding process are dangerous in terms of its potential penetration deeply into the lungs of an operator. The level of risk for human respiratory system is related to nature, shape and size of the particles, and for this reason it is important to have a quality characterization of emitted particles. This paper focuses on particles characterization on the bases of image analysis from scanning electron microscopy (SEM). The research was conducted during the process of grinding of steel EN 90MnV8, using personal sampler. Results of image analysis, consisted of Feret's diameter and circularity, showed quite a wide range of sizes and signiﬁcant deviation of particles from regular shape.

Key words: particles emission, grinding, image analysis, particle shape, particle size distribution

INTRODUCTION

Occupational exposure to particles generated during material processing by grinding, is one of the most important industrial hazards that workers are exposed to and that have to be monitored. Grinding belongs to a group of technologies which are characterized by high levels of particle pollution. The main classification of grinding technologies, in conjunction with the particles emission, is on the wet and dry grinding. One of the main reasons for the application of cutting fluid during grinding is to reduce the emissions of particles. However, although the application of fluid helps to reduce the level of emitted particles, it is still on high level in the working environment. Operators are exposed to the particles' contamination during the entire working time [1], while processing different materials that are associated with chronic diseases, such as respiratory diseases, allergies, as well as dermatological diseases [2]. During the metal processing, dust particles appear in a different range of sizes. For professional medical purposes, powder contamination can be, on the basis of size, classified into three categories: inhalational, respiratory and thoracal fraction. According to the standard [3,4], inhalational particles (aerodynamic diameter $d_{ae} < 100$ μm) penetrate the upper airways (nose and mouth), while the thoracal fractions ($d_{ae} < 30$ μm) can penetrate into the lungs. Respiratory fractions ($d_{ae} < 10$ μm) can reach the lower respiratory tract (alveolus and bronchioles), where gas exchange takes place. Also, smaller particles are better dispersed in the air, making it easier to breathe in and therefore are even more dangerous [5].

Determination of shares of the aforementioned fractions of particles is an important basis for understanding the relationship between exposure to emitted particles and adverse health effects. In other words, measuring the size, i.e. dimensions, and size distribution are fundamental for the characterization of particles emissions. However, the characterization of particles emissions is not only of interest in relation to health [6]. Many physical characteristics of particles, as well as their behavior in different technologies depend on its shape and morphology - e.g. flowability and abrasion efficiency [7].

For an accurate evaluation of the risk of grinding technology, in terms of occupational exposure, identification of dispersed particulate matter is a major issue. This goal can be complex, since the workers are often at the same time exposed not only to a variety of materials in the process of grinding, but also to particles of different concentrations, size and morphology. Since the emitted particles in the working environment are unisometric with irregular shapes, in order of its complete characterization it is necessary to determine the size and shape factor [8,9]. In this sense, the aim of this research study is to determine the size and size distribution of particles, as well as their shape over the circularity (roundness) parameter, generated during the processing of the material by wet grinding. Experimental investigation included sampling by using personal sampler, generating microphotography of sampling filters by scanning electron microscope (SEM), and image analysis of the generated microphotography.

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MATERIALS AND METHODS

Sampling

Sampling was carried out within the indoor workplace, during the wet grinding processing operation of the steel EN 90MnV8, on grinding machine tool for flat grinding LK 750. Sampling was conducted by the personal sampler EGO PLUS TT, with tapered extension adapted for collecting of inhalational particles fraction. Intake manifold of the personal sampler is positioned on the upper chest, near the collarbone in a technician's breathing zone. Breathing zone covers the breathing area around the face of the workers, and a general recommendation is that it should not be extended to more than 30 cm from the mouth. Sampling time was 30 minutes.

Applied were filters of mixed cellulose esters, with pore size of 0,8 um and a diameter of 25 mm. Before and after the sampling, filters were held in standard microclimate conditions at 25 °C and 38 % of relative humidity. This type of filter is selected as suitable for the analysis of light microscopy and SEM for it is because of the texture characterized by lower static repulsion of particles, and less vulnerability to change in weight due to moisture absorption [10-12]. The main technical data related to the sampler and the filter are given in Table 1.

Table 1 **The main technical data related to the sampler and the filter**

	Flow rate / l/m	Sampled volume / l	Normalised volume / l	Filter diameter / mm
Ego Plus TT	3,5	420	407,9	25
	Effective filter diameter / mm	Effective filter surface / mm^2	Filter weight / g	Sampling time / min
Ego Plus TT	22	380	0,022	30

SEM microphotographing

SEM microphotographing required the preparation of a filter in the form of its coating with a thin layer of gold, with the aim of increasing conductivity for generating microphotography. This is realized by steaming process with the help of the device Sputter Coater Balzers SCD 050. Generating microphotography was carried out using scanning electron microscope Jeol JSM - 5610, working at 20 kV, equipped with the SEI and BEI detectors and EDX analyzer [13]. For purposes of particulates analysis magnifications of 200 x, 500 x and 1 000 x were applied. Field of resolution of 640 x 480 pixels, at 200 x magnification corresponds to an area of 307 200 μm^2, at 500 x magnification corresponds to the area of 49 152 μm^2, while at 1 000 x magnification corresponds to the area of 12 288 μm^2 of the filter surface. In BEI microphotographing, in addition to images of average contrast and brightness, generated were the images of high contrast and maximum brightness to enhance the visibility of the particles, since in this case the particles are completely white, and the filter completely black (Figure 1).

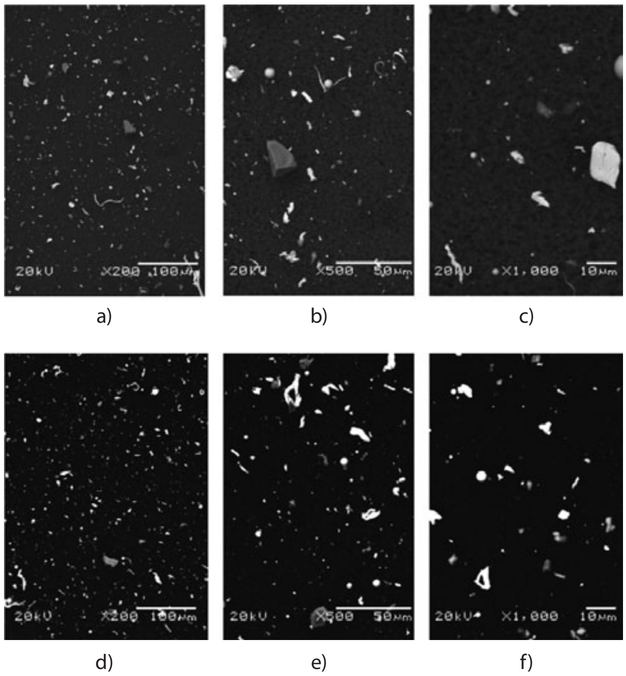

Figure 1 BEI micrographs of particles with: average contrast and brightness (a-c) and high contrast and maximum brightness (d-f)

Image analysis

Microphotographs generated on the SEM, were processed using specialized software ImageJ v1.47t. In this research study, a large number of microphotographs was generated in different zones of the filter, whereby in all cases an identical procedure was implemented: (i) calibration (ii) normalized contrast enhancement, (iii) the application of the median-filter (radius 0) to reduce background noise, and (iv) border settings related to particle extraction from the background. Parameters in focus of this research were Feret's diameter and the circularity. Feret's diameter is measured by the software as the distance between two tangents on opposite sides of the particle, parallel to some fixed direction. The circularity is a measure of the ratio of the actual circumference of the particle and circumference of a circle of the same rank. An ideal circle has a circularity value of 1, while the circularity of very irregular shape is close to 0. Hence, in this analysis circularity represents a measure of irregularity, i.e. level of deviation from a perfect circle.

RESULTS AND DISSCUSION

Results included the distribution of particle size, particle size frequency analysis and the analysis of particles circularity as the shape factor. Figure 2 shows the distribution of particle sizes, which allows evaluation of the degree of particles dispersion through the dimensional range. As mentioned in the previous section, this research study comprised analyses of microphotographs with three degrees of magnification: 200 x, 500 x and 1 000 x. To determine the Feret's diameter, the mean values of Feret's (MaxFeret) and MinFeret were used. The

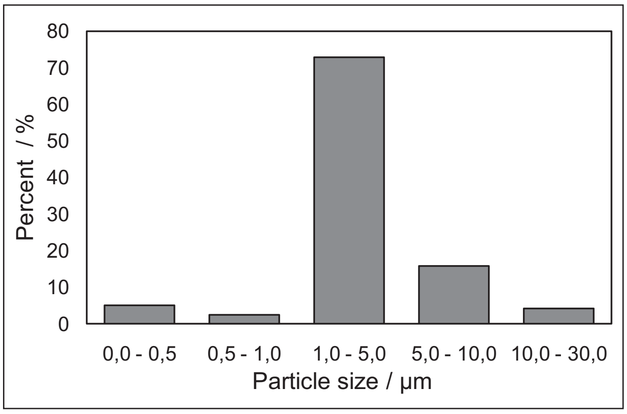

Figure 2 Distribution of particle sizes (based on Feret's diameter)

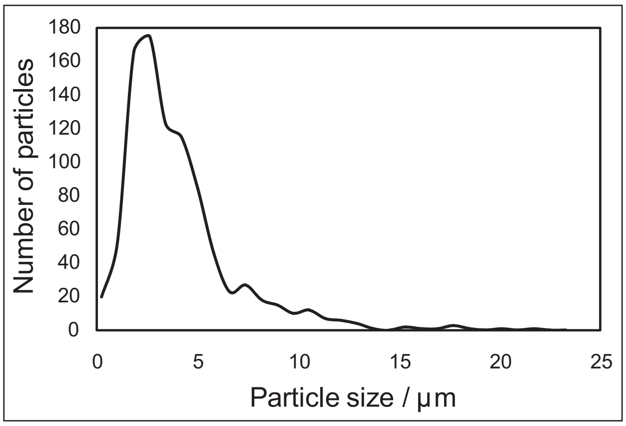

Figure 3 The frequency of occurrence of a certain particle sizes

result is displayed over the percentage shares of the particles, in the ranges of 0 – 0,5 µm, 0,5 – 1,0 µm, 1,0 – 5,0 µm, 5,0 – 10,0 µm and 10,0 – 30,0 µm. The ranks were defined in this way in order to better understand the degree of risk to the health of exposed workers. The analysis showed that more than 95 % of the particles belong to the respiratory dust fractions. The largest percentage, 72 % is in the range of 1,0 – 5,0 µm, which is displayed by the frequency of occurrence of a certain particle sizes within the sample (Figure 3).

The main descriptive statistical parameters related to distribution (mean, median, standard deviation, minimum, maximum, and number of analysed particles) are given in Table 2.

Table 2 **The main descriptive statistical parameters of particle sizes**

Mean	3,646
Median	2,880
Standard Deviation	2,902
Minimum	0,241
Maximum	24 079
Count	912

While the particle size distribution enables to assess the degree of dispersion over the range of particles size, shape distribution provides information about the ag gregation of

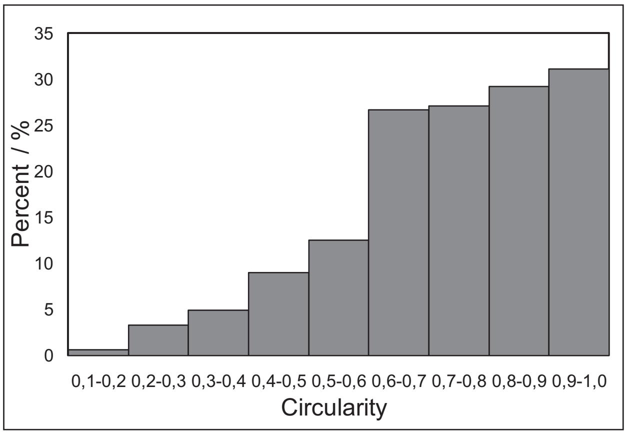

Figure 4 Shape distribution of particles through the circularity factor

particles. The results of the distribution shape factor indicates a relatively slight increase in the value of circularity (Figure 4). Since only circularity factor values over 0,8 ensure that analysis did not include aggregates, i.e. stucked or accumulated particles [14], here around 60 % of the particles showed the proper form and exclude the possibility that the analysis included overlapped particles or aggregates.

Since the method of image analysis is relatively subjective, therefore the measurement was performed several times in order to avoid incorrect dimensioning of smallest particles by the software for image analysis. It is important to note that, within the analysis of images, was utilized the opportunity to isolate individual particles while performing measurements and checking the degree of consistency with the real image, which significantly increases the precision of the method.

CONCLUSIONS

The presented research showed thatanalysis of particles' emissions, based on SEM microphotography and image analysis, enable obtaining of accurate results related to the characterization of particles in terms of morphological and dimensional distribution, which may contribute to better understanding of the causes of certain occupational respiratory diseases as well as of their prevention.

Based on the analysis of particles emitted during processing of steel EN 90MnV8 by wet grinding, it can be concluded relatively broad size distribution of emitted particles, but also the presence of particles of dif ferent and complex shapes. Particularly alarming is that the analysis showed that more than 95 % of the particles belonging to the respiratory dust fractions, that can arrive to the lower parts of the lungs, and therefore are the most dangerous to the health of workers. Considering this, future research will be focused on the inclusion of some other materials and technologies, which are characterized by intensive emission of particle pollution.

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