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The use of an electronic particle size analyzer in the study of the brittle material grinding process

***Abstract**. The subject the paper are the results of grinding brittle materials. The effect of the grinding process can be measured by several parameters. One of the most important parameters is the particle size distribution of a product. The paper presents the results of using an electronic particle size analyzer for determining of the grinding process.*

Streszczenie.** Praca zawiera wyniki badań rozdrabniania materiałów kruchych. Efekt procesu rozdrabniania można mierzyć wieloma parametrami. Jednym z najbardziej istotnych jest skład ziarnowy produktu. W pracy przedstawiono wyniki wykorzystania elektronicznego analizatora wielkości ziaren do oceny procesu rozdrabniania. (**Wykorzystanie elektronicznego analizatora wielkości ziaren w badaniach procesu rozdrabniania materiałów kruchych).

Keywords: electronic particle size analyzer, particle, grinding.
Słowa kluczowe: elektroniczny analizator wielkości ziaren, ziarno, rozdrabnianie.

Introduction

An increase in the interest in modern mechanical material processing technologies has been observed recently. This is partially due to the need for assuring ecologically safe processing of substances of both organic and mineral origin, industrial engineering materials and waste raw materials.

The effect of the grinding process depends primarily on the correct selection of operating machinery and equipment, on the physico-mechanical properties of a substance subjected to grinding and the design and operational parameters of the machines. Generally, the effect of the grinding process is difficult to be described in a rigorous theoretical manner.

The grinding effect can be referred to quantities, such as mill efficiency, the relationship relating the grinding energy with the increase in the surface area of the obtained product, and the particle size distribution of the grinding product. Of these quantities, the particle size distribution is worthy of special attention. This is the basic quality criterion of the grinding process. The further use of grinding products is in many cases dependent on their particle size. The presence of particle larger that the limiting size disqualifies the product.

For determining the particle size distribution, a wide range of devices can be used. They operate based on different principles and are characterized by different features. Very often, there is a need for a very large amount of information describing the particle size distribution and, what is more, the time in which that information has to be acquired is very short. In such cases, an inestimable role is played by electronic particle size analyzers, which allow a huge amount of information to be obtained in a short time.

Grinding materials in jet mills

There are various methods of grinding. They differ in energy demand, as well as in product particle size distribution. Among many grinding methods, jet grinding deserves special consideration. In spite of the fairly large costs, it enables a pure final product to be obtained, which in the case of a process involving intermediary elements (e.g. balls, rolls, etc.) is not possible. This type of grinding results in fine particles that are distinguished by a larger specific area.

Jet mills take advantage of the energy of a gaseous medium flowing at a high velocity, which propels the granular material. The input material undergoes high accelerations and, as a result of, *inter alia*, collisions of its particles with one another or with the immovable bed, it breaks up. The main element of these devices are jet pumps, whose job is to suck in and accelerate the particles of a brittle material. The driving medium in these devices is compressed air at a pressure normally in the range of 0.2 – 1 MPa. The material to be ground is poured by gravity or sucked in to the capture chamber of the jet pump, and then it is guided to the jet pump's acceleration tube, where it is accelerated and, together with the gaseous medium, sent to the grinding chamber. [1, 2, 3]

Among jet mills, super-fine grinding mills can be distinguished, which have the acceleration tube outlet oriented tangentially to the grinding chamber walls. As a result of the vortex motion, the particles rub against the grinding chamber walls and lose their kinetic energy. At the cost of the energy lost, an increase in the specific area and degradation of the particle size of the material being ground will result. The second group include fine milling mills, known also as separated-classifier or opposite jet-pump jet mills. Breaking up of particles in these mills takes place in chambers, where particles inflowing from two opposite jet pumps collide with one another. There are also mills that combine these two technologies, i.e. they grind on the principle of both the friction and free collisions of particles [4, 5].

The testing stand

Laboratory tests were carried out on a testing stand consisting of a multi-jet mill incorporating twenty jet pumps and auxiliary equipment. A view of the jet pump outlet is shown in Figure 1. The tests proper were preceded by weighing quartz sand samples (of a particle size of 0 ÷ 0.2 and 0 ÷ 1.5 mm). Then the samples were poured into the mill through the opening in its top. Next, an extracting device (a commercial vacuum cleaner) was switched on. Its purpose was to suck the ground material from the mill through the cyclone. At the same time, the supply of compressed air directly to the jet pumps was turned on. Two tubes were connected to the mill, through which the feed was sucked from the mill bottom and, together with compressed air, shot out from the 20 jet pumps towards a fixed plate. As a result of the collision with the plate, the material was broke up. Oriented at an angle towards each other, the jet pumps shot out material jets that collided with one another, thus causing preliminary grinding of the material. The total jet from all jet pumps was directed to the plate. Separation took place in the cyclone. Coarser particles fell down on the cyclone bottom, while the dust was pulled out by the extracting device. After a preset time, the air supply was cut off, and then the vacuum cleaner was switched off. After completion of the tests, the ground material was subjected to particle-size analysis to determine the particle size composition of the product. The measurements were made using an Infrared Particle Sizer (IPS) electronic particle size analyzer [6, 7].

Fig. 1. View of the multi-jet mill nozzle outlet

The IPS electronic particle size analyzer

The particle size was measured with an Infrared Particle Sizer (IPS) electronic particle size analyzer. This is a laboratory devices used for making the automatic quantitative and size analysis of solid substance particles. The measurement for any number of particles is done in air by a contactless method, not causing any mechanical damage to the sample. The instrument allows particles of sizes ranging from 0 to 2000μm to be analyzed. The principle of its operation relies on the measurement of the flux of infrared radiation attenuated as a result of diffusion caused by particles moving within the measurement space of the probe. Changes in the light flux are recorded by a computer. The IPS analyzer has no optical limitations for measuring single small and large particles. The flux of radiation not only identifies the size of particles, but also allows them to be precisely counted within the entire measurement range. Each particle has a corresponding electric pulse that is proportional to the particle size. The set of particles is originally measured with a division into 4096 size classes and then transformed into 256 size classes available to the user. A schematic of the IPS analyzer is shown in Figure 2.

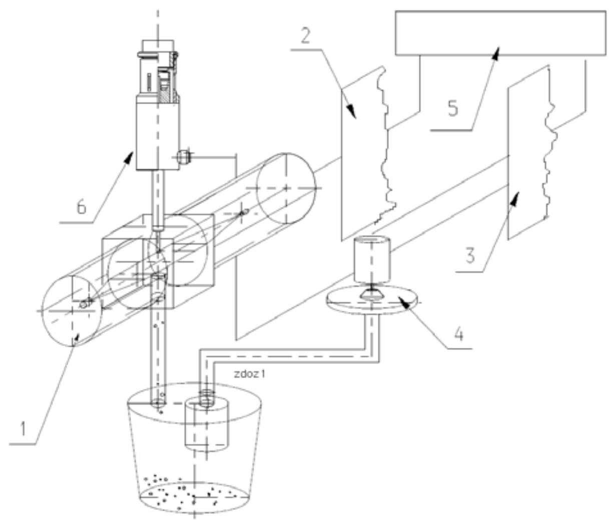

Fig. 2. Schematic of the PIS U analyzer: 1 - measuring sensor, 2 – measuring system, 3 – automatic particle batching system, 4 – miniature compressor, 5 – computer, 6 – ultrasonic batcher, 7 – variable air-flow batcher [8]

The analyzer is composed of a measuring sensor (1) and a measuring system (2) integrated with an automatic electronic particle batching system (3) that ensures the continuity of measurement and the control of particle concentration in the measuring space. The whole is controlled by a computer (5). The actuator in the automatic batching system is a miniature compressor (4) with a special characteristics matching the infinitely variable control of air flow.

A block diagram of the IPS analyzer is shown in Figure 3. The measuring system proper is the IPS measuring system. Its job is to emit and record a beam of infrared radiation that illuminates the measuring space of the probe.

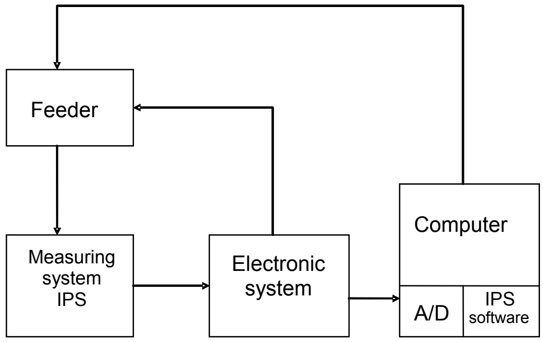

Fig. 3. Block diagram of the IPS analyzer [5]

Then, the electronic system receives an analog electric signal from the IPS measuring system, which is the response of the measuring system to the attenuation of the emitted beam of radiation. The signal is appropriately processed, amplified and transmitted to the analog-digital (A/D) card. The purpose of the card is to convert the analog signal into the corresponding digital signal. Next, the digital signal is processed in the computer with the IPS software [9].

Investigation results and the summary

The basic aim of the investigations whose part is the present study was to determine the optimal design parameters of the mill. The determination of the optimal design parameters is the condition for achieving the highest grinding efficiency.

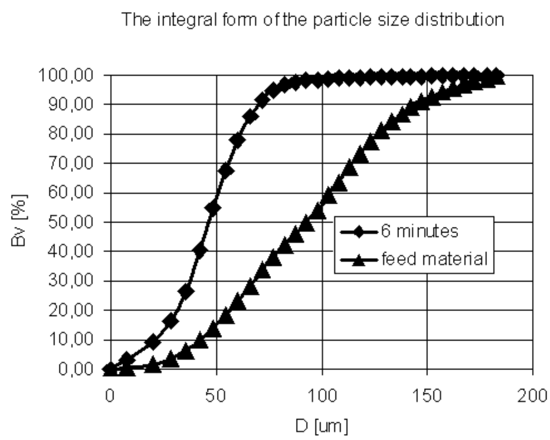

Fig. 4. Results of the particle size analysis of the feed sample and the grinding product for quartz sand - grinding duration, 6 min.; particle size, 0.2 mm.

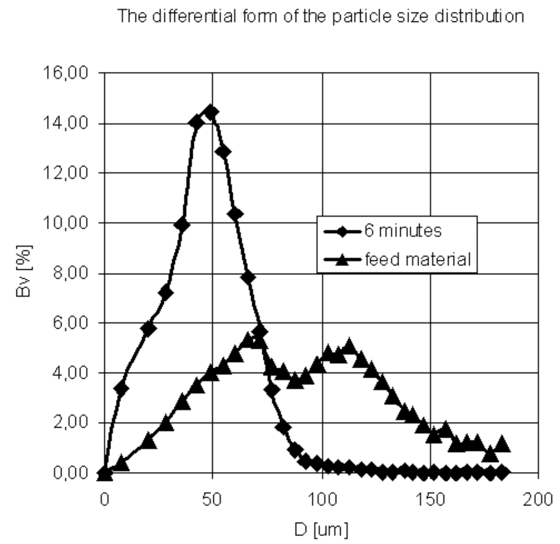

Fig. 5. Results of the particle size analysis of the feed sample and the grinding product for quartz sand - grinding duration, 6 min.; particle size, 0.2 mm.

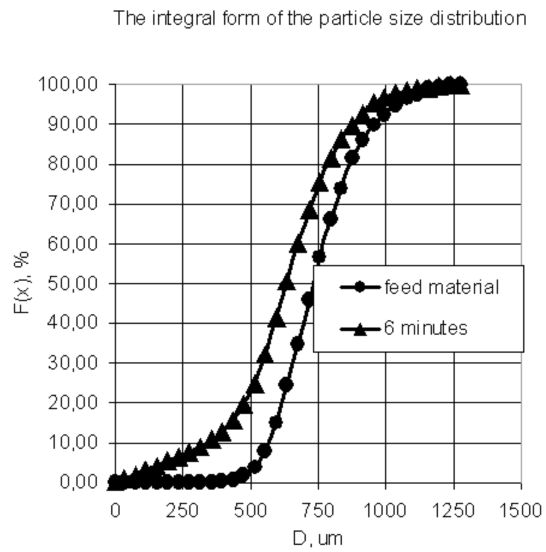

Fig. 6. Results of the particle size analysis of the feed sample and the grinding product for quartz sand - grinding duration, 6 min.; particle size, 1.5 mm.

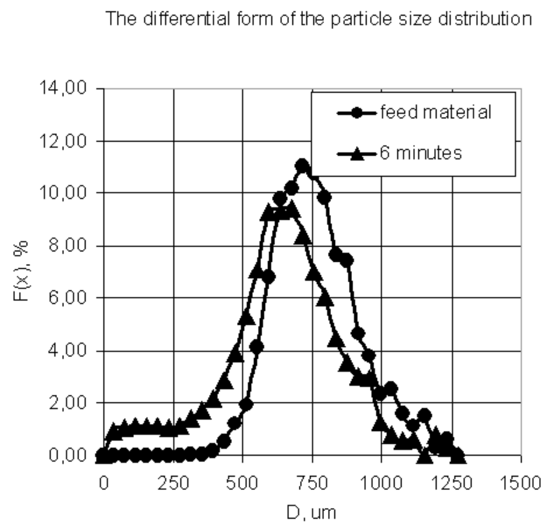

Fig. 7. Results of the particle size analysis of the feed sample and the grinding product for quartz sand - grinding duration, 6 min.; particle size, 1.5 mm.

A series of tests were carried out. The particle size distribution of the grinding product was selected as the parameter defining the process efficiency. A method that is most commonly used for describing a ground material in the form of a particle size distribution is the sieve analysis. This is a time-consuming and, in the case of fine materials, little accurate method. The electronic particle size analyzer (IPS) enables a large amount of information to be acquired in a relatively short time, which is very important in optimization processes. Moreover, material subject to determination may be very fine, which is the case for jet mills.

Example particle size testing results are illustrated in Figures 4 through 7. The results are given for different feed particle sizes and a selected grinding duration.

An additional asset of the IPS electronic particle size analyzer is the software program that allows the particle size distribution to be obtained in different forms, depending on the needs. The particle size distribution can be obtained in either a cumulative or differential form, in the form of quantitative, surface or volumetric distributions. This information is very important, and obtaining it already during the analysis helps to save time in the entire optimization process. The article is an introduction to a broader analysis of the use of the device for the measurement of particle size distribution. Future studies will analyze the reproducibility and reliability of measurements of particle size distribution.

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