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## RESEARCH OF THE INFLUENCE OF ABRASIVE WEAR OF GRINDING BODIES IN THE ROTATIONAL VIBRATION MILL

### BADANIA ZUŻYCIA ŚCIERNEGO KORPUSÓW W ROTACYJNYCH MŁYNKACH WIBRACYJNYCH

#### Abstract

This paper presents the design of a new rotational vibration mill. Experimental research of abrasive wear of grinding bodies in the processing of quartz sand was conducted. The influence dependences of varied process parameters on the specific wear of grinding bodies are demonstrated. Besides, the influence dependence of particle size on the specific wear value is shown.

**Keywords:** grinding, mill, abrasive wear

#### Streszczenie

W pracy przedstawiono projekt nowego młynka wibracyjnego. Przeprowadzono badania eksperymentalne zużycia ściernego korpusów szlifierskich podczas stosowania piasku kwarcowego. Przedstawiono wpływ różnych parametrów procesowych na specyficzne zużycie ściernic. Dodatkowo przedstawiony został wpływ wielkości cząstek stałych (ziaren piasku) na zużycie korpusów ściernic.

**Słowa kluczowe:** szlifowanie, mielenie, zużycie ściernic

## 1. Introduction

The main objective of the development and improvement of devices for dispersing materials is the intensification of the milling process, reducing energy costs, increasing performance and durability.

Therefore, a rotational vibration mill was designed. Its feature is the use of two methods of influence on the material: abrasion and impact. The design parameters of the mill are presented in Table 1.

The vibration rotational mill [1] operates as follows. The starting material and the grinding bodies in the mill enter the drum 1 via the loading and unloading opening 2. The drum cover 3 is made of transparent material that allows observing the movement of grinding bodies and grinding material in the drum mill. As a result of the rotation of the drum 1, the starting material and the grinding bodies arrive in the upper part of the drum to the angle of repose and fall down, grinding the material by impact and abrasion. The ability to independently or jointly use three modes of milling (ball, vibration and vibration rotational mode) is achieved by the use of the tubular shaft 5, inside of which the drum 4 is installed, the shaft bearings 6 and the rotation axes of the shafts are displaced relative to each other by an eccentricity  $e$  equal to 1.5 mm (Fig. 1). After completing the grinding process of the loading-unloading opening 2 is mounted in the lower position. The finished material is removed only by vibrations through a loading-unloading aperture 2, wherein a separating sieve is arranged. The frequency of oscillation of the drum is regulated by converter E3-9100-003N vector and the angular speed of rotation of the drum is regulated by a set of pulleys of different diameters.

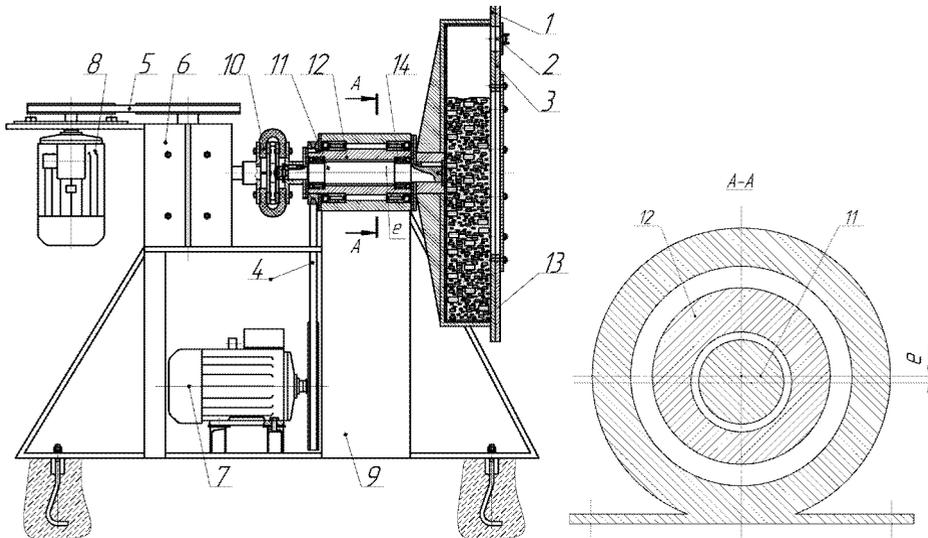


Fig. 1. 1. Scheme of rotational vibration mill: 1 – drum; 2 – loading and unloading opening; 3 – drum cover; 4, 5 – belt transmission; 6 – reducer; 7, 8 – motor; 9 – frame; 10 – flexible coupling; 11 – drum shaft, 12 – tubular shaft; 13 – grinding bodies and material; 14 – bearings,  $e$  – eccentricity

Table 1. Specifications of the rotational vibration mill

Parameters	Parameter values
Volume of the drum [m <sup>3</sup> ]	0.025
Drum diameter [m]	0.6
Drum width [m]	0.09
Diameter of loading and unloading opening [m]	0.01
Range of angular speed of rotation of the drum [rpm]	1–60
Range of frequencies of vibration of the drum [Hz]	1–50
Total engine power [kW]	1.7

## 2. Material grinding bodies and linings

Wear of the working bodies of mills by grinding the materials is important in the production of various powder materials because when there is wear, the contamination of the finished product occurs. Abrasive particles contacting with the surface of grinding bodies destroy the surface layer of the working bodies [2].

Therefore, for the industrial application of the rotational vibration mill, it was necessary to research the process of grinding bodies wear by abrasive particles, in order to determine the life of the working elements.

In order to protect the working surface of the drum rotational vibration mill from abrasion and to study the wear rate lining and cylindrical grinding bodies made of thick wear-resistant ceramic VC-100-2 are set (Fig. 2).



Fig. 2. Grinding bodies – cylinders of material VC-100-2

This material has the properties required for use in milling abrasives – high strength, hardness about 9 Mohs, wear resistance and chemical resistance, and a number of other parameters given in Table 2 [3]. Application of corundum is caused by increased demands on the purity of the final product.

Table 2. Material properties VC-100-2

Parameter	VC-100-2
Content of Al <sub>2</sub> O <sub>3</sub> [%], not less	99,7
Water absorption [%]	0,02
Density [g/cm <sup>3</sup> ], not less	3,88
Bending strength [MPa], not less	320
Temperature coefficient of linear expansion in the temperature range 20–900°C, 10 <sup>-6</sup> K <sup>-1</sup>	8,0
The dielectric constant, 1 GHz, 25°C	10,1
Dielectric loss 1 GHz, 20°C	10 <sup>-4</sup>
Volume resistivity of 100°C, OM × cm	10 × 14

The choice of grinding bodies is explained by the fact that the cylindrical grinding bodies have a large area of contact with the material being ground and give a higher productivity per unit of bulk density as compared with balls. The effect of grinding bodies of spherical shape on the material has a point-like nature, and in the case of a cylindrical shape, the contact area is several times higher given the same diameter. Therefore, it was necessary to compare the extent of wear, and we used 15 mm diameter steel balls and 20 mm diameter, and 20 mm high ceramic cylinders. Steel balls are made of steel 1.3505 and have a hardness of 179–207 HB.

No less important factor for more efficient operation of the mill is the choice of an optimum amount of grinding bodies. Therefore, it is very important to fill a certain number of grinding elements in the mill so that, while working, each row moves only along its trajectory, contacting with the other grinding bodies as little as possible. If you exceed the desired filling, it leads to the overconsumption of electricity and to accelerated wear of milling bodies and liner. Insufficient filling violates the right movement of the grinding bodies.

For ball mills, the optimal coefficient of fill is considered to be about 30–42%. Because the investigated mill is similar to the ball one, we choose the optimum utilisation of the grinding elements of  $\approx 40\%$  [4].

Investigations of the wear rate of grinding bodies are made by means of analytical scales with an accuracy of 300 MWP 0.01 grams.

To protect the drum from wear, the inner surface of the drum is covered with ceramic tiles glued on a special silk-acetate material. The material of the lining is specially selected to minimise contamination of the crushed material and has high hardness.

### 3. Material for experimental research

The main materials used in the experiments were chosen as: quartz sand and alumina brand of GN.

The use of quartz sand as a raw material is primarily due to the fact that this material has a very wide use in research projects and allows you to compare the results of research. Secondly, the problem of inaccessibility of starting materials is excluded. Thirdly, silica sand has a high hardness of about 7 on the Mohs scale. Fourthly, the use of quartz sand is justified by its mechanical and chemical inertness. Prior to the experiments, all of the material has been thoroughly washed, dried, and dispersed to the required initial fractions.

The quartz sand used in experiments consists of the following components:  $\text{SiO}_2$  – 75.0–94.0%,  $\text{FeO}_2 + \text{Al}_2\text{O}_3$  – 2.6–4.2%,  $\text{CaO}$  – 0.5–2.0%,  $\text{MgO}$  – 0.0–0.4%,  $\text{SO}_2$  – 0,1–0,8% [5].

Besides quartz, sand alumina is used in the experiments because it is more abrasive as compared to quartz sand. This is done to provide a comparison of different intensity grinding abrasive material properties, as well as the intensity of wear of the working bodies of these materials.

#### 4. Investigation of the effect of grinding process parameters on the wear of grinding bodies

For cylindrical grinding bodies used in the study, it was found out that primarily surfaces wear, which leads to a circular cylinder shape, as shown in Fig. 3. Steel balls wear more evenly over the entire surface, without visible changes of balls in geometry.

In ceramic cylinders, there were significant differences in the strength of some individual elements, whereby the percentage of the surface wear of each differs considerably.

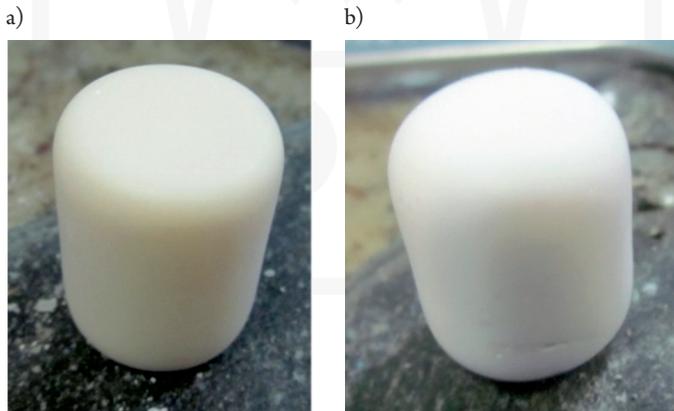


Fig. 3. Wear ceramic grinding bodies: a) before grinding, b) after grinding

Furthermore, dependence of the investigated wear grinding bodies from the drum rotation speed, the oscillation frequency and the percentage of fill material and the grinding bodies mill were studied. The worn surface of the working bodies was investigated in order to determine the wear mechanism.

Each experiment was carried out for 120 minutes, the wear rate was determined from the change in mass of one of the selected items and the total weight of grinding bodies.

The results of experimental studies have shown that the wear resistance of steel grinding bodies is several times smaller than that of the ceramic cylinder.

To determine the dependence of the wear grinding bodies, a series of experiments to grind alumina from the initial specific surface area of  $300 \text{ m}^2/\text{kg}$ , as well as to grind quartz sand under the same process parameters, were conducted. In the experiments, the following parameters varied: the drum speed (45, 50, 55, and 60 rpm), the frequency of the drum vibrations (20, 30, 40 and 50 Hz), a drum filled with grinding bodies (15, 25, 30 and 40%) and a drum filled with grinding material (8, 12, 16 and 20%).

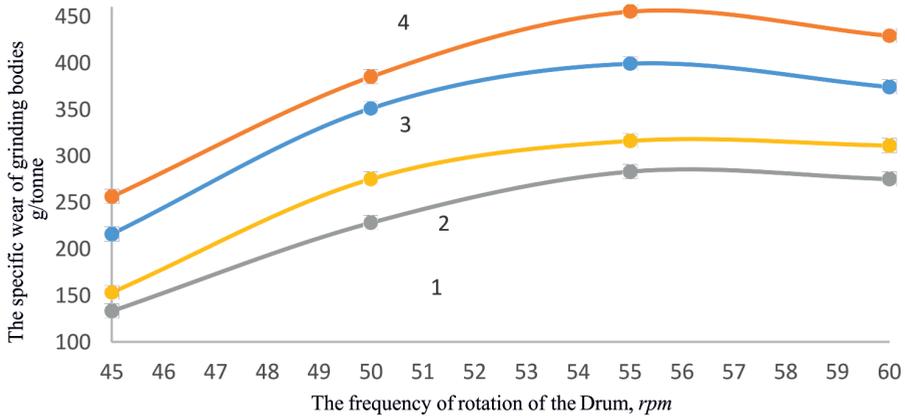


Fig. 4. Dependence of specific wear grinding bodies from the drum rotation speed: the grinding of quartz sand; 1 – ceramic cylinders; 2 – steel balls; the grinding of alumina 3 – ceramic cylinders; 4 – steel balls

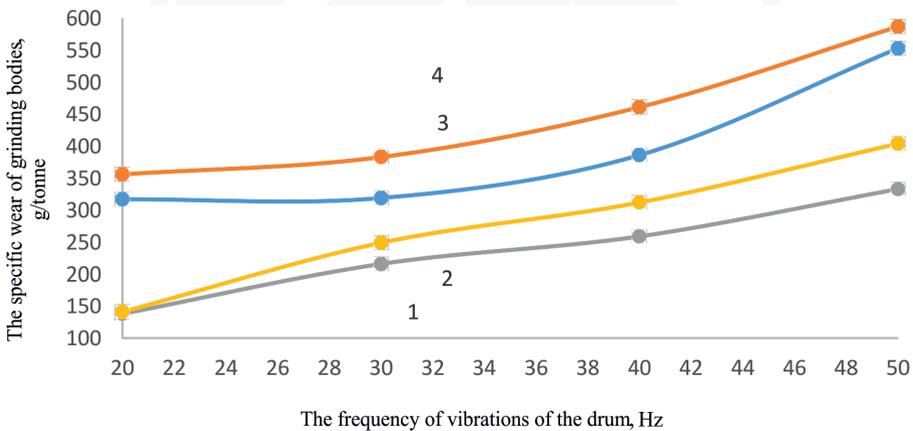


Fig. 5. Dependence of specific wear grinding bodies on the frequency of vibration of the drum: the grinding of quartz sand; 1 – ceramic cylinders; 2 – steel balls; the grinding of alumina 3 – ceramic cylinders; 4 – steel balls

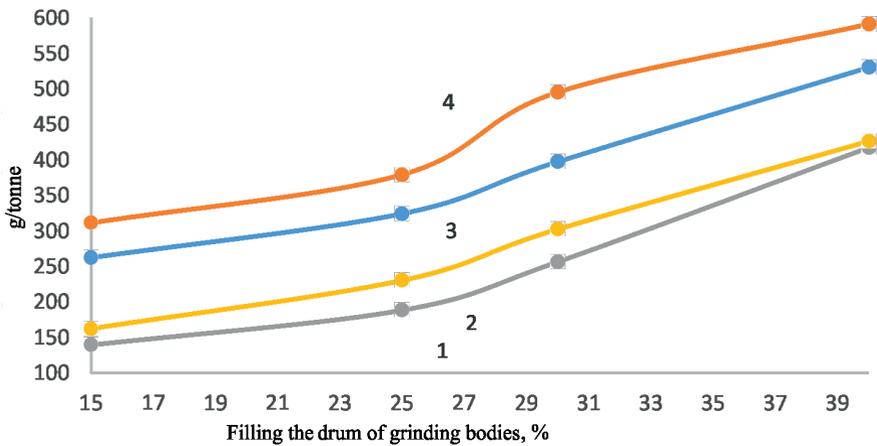


Fig. 6. Dependence of specific wear grinding bodies from the grinding bodies filling drum: the grinding of quartz sand; 1 – ceramic cylinders; 2 – steel balls; the grinding of alumina 3 – ceramic cylinders; 4 – steel balls

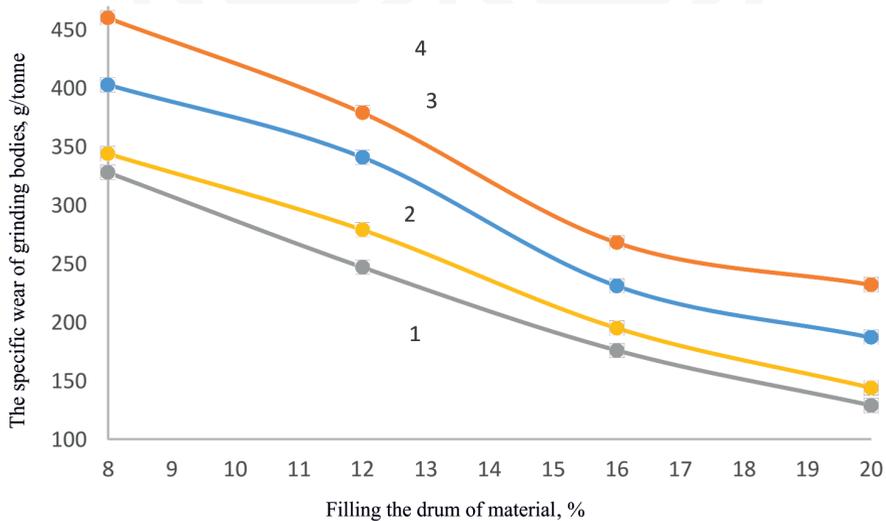


Fig. 7. Dependence of specific wear grinding bodies from filling the drum material: the grinding of quartz sand 1 – ceramic cylinders; 2 – steel balls; the grinding of alumina 3 – ceramic cylinders; 4 – steel balls

As is evident from Fig. 4, the increase in speed has led to an increase in the amortisation of the surface of grinding bodies. This can be explained by the greater force of impact between the working elements and the particulate material. No less significant factor in the deterioration of working bodies was the frequency of vibration of the drum (Fig. 5). With the increase in its intensity, the abrasion in the feed mill increased. The next experiment was similar to the previous one, but this time the investigated factors were the drum filling with

grinding bodies and the material being ground (Fig. 6, Fig. 7). The increase in the amount of grinding bodies resulted in higher intensity of abrasive wear, due to the increasing number of collisions between them per unit of time. However, the opposite situation was observed with the increase in the number of particles in the feed, since it does not allow more material to collide with each other, which minimises shots on the mill lining.

The graphs show that the grinding of the same material as the wear of steel and ceramic grinding bodies varies considerably. Note that the specific wear of steel balls was higher by at least 12%, and in some cases about 2 times greater than the ceramic cylinders. This is primarily due to the different hardness of material, steel balls have a larger mass, and hence greater collision strength.

In order to establish the dependence of the wear grinding bodies from abrasion and hardness of the material being processed, grinding of alumina as described above, and also less abrasive quartz sand was conducted. It was important to examine the effect of particle size on the wear amount. Previously, quartz sand was separated into desired fractions 1–2 mm, 0.5–1 mm, 0.25–0.5 mm, 0.125–0.25 mm and less than 0.125. Alumina was not used in this experiment, due to the lack of a large particles fraction. The research results are presented in Fig. 8.

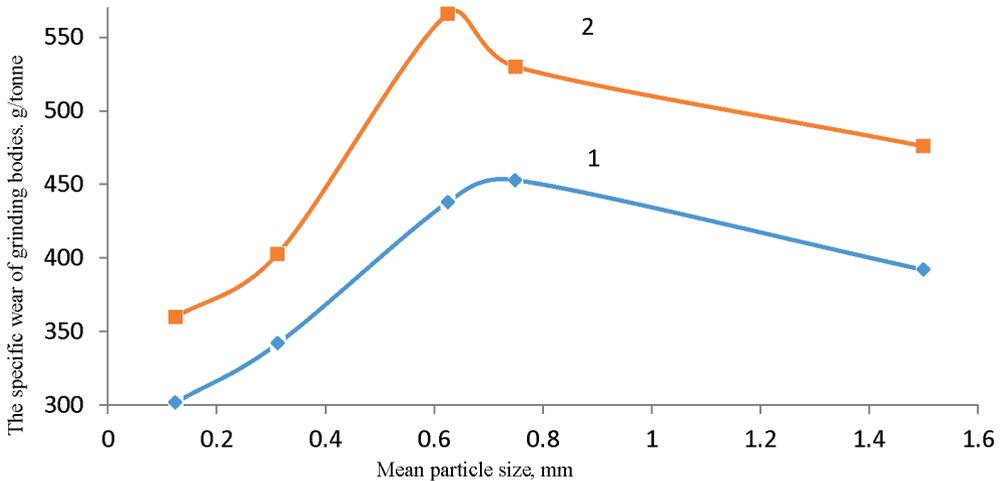


Fig. 8. Dependence of specific wear grinding bodies on the size of the crushed material particles; 1 – ceramic cylinders; 2 – steel balls

The above experiment has confirmed that particles, which roughly equal to 1 mm, have a large impact on the value of specific wear working mill surfaces. Based on the above experimental results, it can be concluded that it is necessary to use cylindrical grinding bodies constructed of VC-100-2 as the grinding bodies for grinding abrasives rotational vibration mill due to their increased wear resistance, and also the minimised contamination of the finished product (alumina).

## References

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