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REVIEW OF THE WORKING BODIES OF VERTICAL BEAD MILLS

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Abstract: *It is considered existing configurations of the working members of vertical bead mills for grinding cosmetic, pharmaceutical and food products by a wet method. In standard designs of rotors with disks and / or pins, due to the presence of centrifugal forces, there is a stagnant zone in which the movement of the beads and the product is practically not observed. As a result of which the product has an uneven particle size distribution and the time spent on the process increases. the configuration of the rotor with a reduced annular gap provides a reduction in the time of grinding of solid materials in suspension, with a smaller volume of the grinding chamber.*
Keywords: beads, configuration, rotor, grinding, disk.

INTRODUCTION

In the modern production of pharmaceuticals and cosmetics, the high level of grinding of raw materials for further use is of great importance. One way to make high-quality, low-viscosity and finely dispersed suspensions is wet grinding in bead mills. (Mende, S., Rappl, M., 2014).

EXPOSITION

Analysis of standard types of mills, working bodies and grinding process. Two types of bead mills are distinguished – these are horizontal and vertical. Horizontal bead mills are versatile and suitable for most materials, however, poorly adapted for durable particles. This type of mill is optimal for the production of nail polish, pigments, colorants, microbiological products, emulsions, medical drug, micro waxes (Stephen M., 2011; Mende S., Stenger F., Peukert W., Schweders J., 2003).

In the vertical position of the chamber, the mass of beads provides high abrasive pressure on the bottom of the chamber, which allows grinding durable materials, for example, for the production of ceramics, pigments for decorative cosmetics and paints, chocolate. Such an additional load is positive, since the grinding process has a high-energy consumption (Stephen M., 2011; Mende S., Stenger F., Peukert W., Schweders J., 2003).

The material that is crushed enters the grinding chamber into the cavity between the grinding bodies (beads) and the chamber wall, filling the entire free volume. When the shaft rotates, the medium moves in the chamber and creates compression and shear forces for suspended particles, destroying them. The fact is that shock and abrasive stresses that are present in most grinders do not work on micro- or submicron particles, so a bead mill is best suited for ultra-fine grinding (Mende, S., Rappl, M., 2014).

Grinding bodies are beads. For the manufacture of beads, glass, glass with zirconium silicate, zirconium silicate, zirconium oxide, zirconium oxide stabilized with yttrium, zirconium oxide, cerium-stabilized aluminum oxide, porcelain, steel, stainless steel are used. Beads are added to the mill by volume, and replaced as working surfaces are developed. It is advisable to use steel balls for grinding ferrites, for ceramics – from aluminum oxide, zirconium silicate, in the paint and varnish industry – glass or ceramics. Beads are made of different diameters, depending on the size of the grinding chamber and the goals of the process, from 0.05 to 5 mm. The best grinding result is achieved by using the smallest diameter of the grinding bodies. Changing the speed of the mixer has no significant effect on the grinding result. (Mende S., Stenger F., at al. 2014).

Comparative analysis of existing configurations of the working members of vertical bead mills. The rotor of a bead mill can have various configurations. For mills with low energy intensity, rotors with eccentric elements (disks) are used. The main disadvantage of this configuration is the presence of a large stagnant zone in the area between the disks near the shaft, experiencing slight loads, where there is no clear change in the shear rate in the axial or radial direction. The concentration of grinding media in that zone is markedly reduced due to the presence of centrifugal forces, from where the material pastime in the mill increases, and the particle size distribution of the milled product is not uniform. Accordingly, the outer part of the rotor is the most loaded (Stephen M., 2011).

To obtain with greater energy intensity, rotors with pins are used. However, this configuration also has similar disadvantages, as well as the version with eccentric elements: the stagnant zone increases and energy consumption increases due to overcoming the volume of beads with the product with a pin (Stephen M., 2011).

To solve the problem of the stagnant zone, there are proposals to change the size of the annular gap by increasing the diameter of the rotor. The design makes it possible to remove stagnant zones, and inside the drum to do additional cooling with an integrated separator-separator to isolate the finished product from the beads. With such installations, greater productivity can be achieved with less grinding chamber volume. However, according to the energy characteristics, a bead mill with disks, which has approximately 2 times the volume of the grinding chamber and the same level of filling with beads, consumes the same power at a comparable peripheral speed (Mende S., Stenger F., Peukert W., Schweders J., 2003; Mende, S., Rappl, M., 2014).

Laboratory bead mill (Figure 1). It is equipped with three working chambers (glasses) with a jacket for water cooling and a sampler on the lid of the glass with a sieve cartridge, which is screwed into the thread. The rotor consists of a shaft on which 4 guide disks with 4 openings with a diameter of 10 mm are fixed. Working bodies – steel beads having a diameter of 2 mm. The disc shaft is secured to the motor rotor via a keyed connection. The water supply and drainage pipes are attached to the glass nozzles by means of clamping rings. Grinding occurs in a wet way (in the presence of liquid). Engine: power 0,37 kW; engine speed 1350 rpm.

RESULTS AND DISCUSSION

The grinding process was simulated in a laboratory bead mill with a standard configuration of the rotor shaft with grinding disks using simulation software. The dissipation of energy in the working chamber and the rotation speed of the "beads-product" system were investigated. The product used was castor pharmaceutical oil. To create the model, the following parameters were adopted: conditional viscosity of the system - 1 Pa×s at 20 °C; the bulk density of beads with a diameter of 2 mm is 3.34 kg/l (Ogonowski S. at al. 2018).

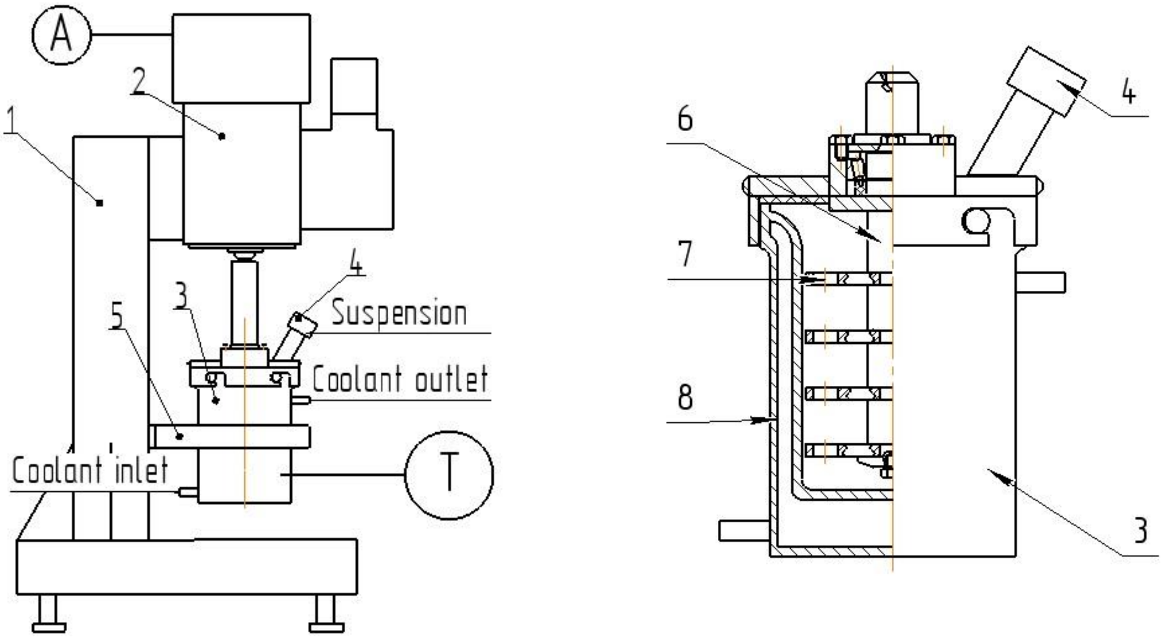

Figure 1. Experimental installation – bead mill laboratory:
1 – bed; 2 – engine; 3 – working chamber (glass); 4 – sampler with a sieve cartridge; 5 – a clip for a glass; 6 – rotor shaft; 7 – grinding disks; 8 – shirt cooling.
A – current measurement by wattmeter; T – temperature measurement by pyrometer.

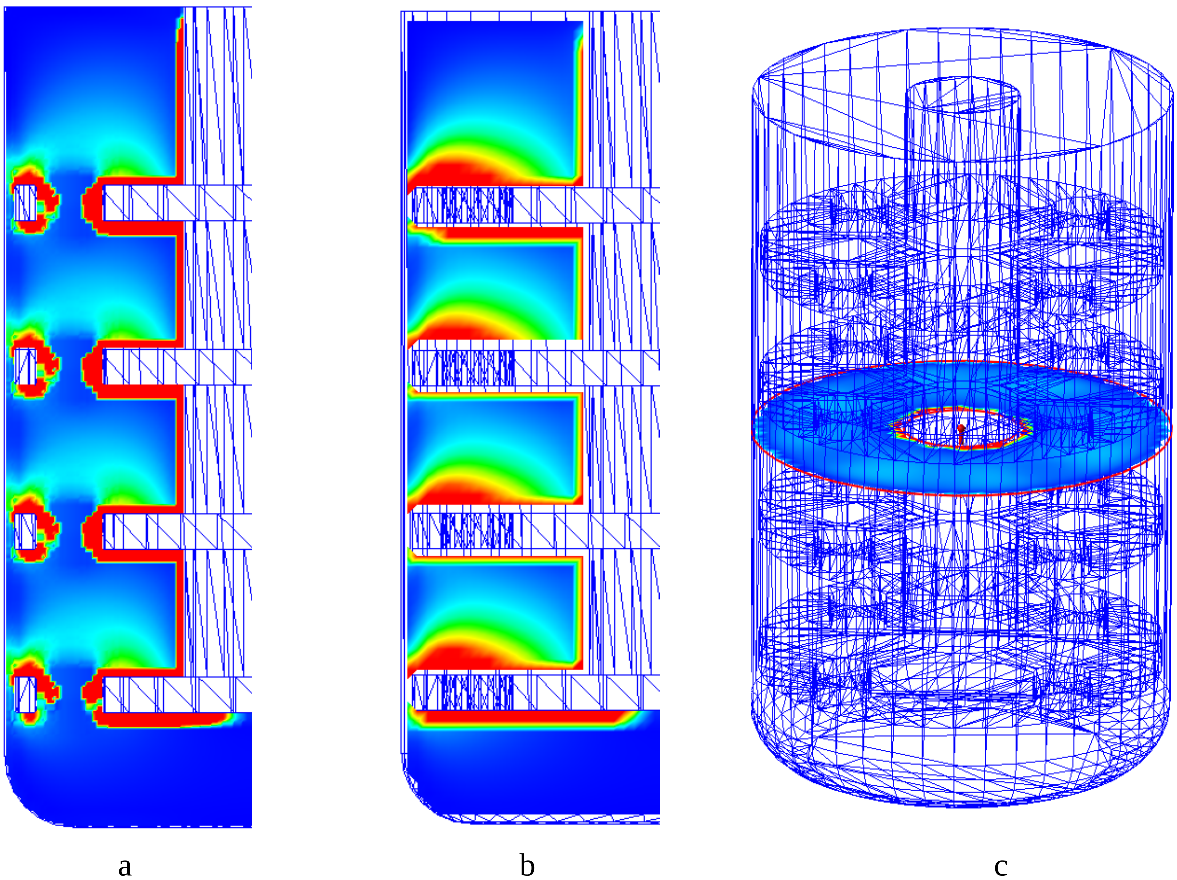

Figure 2. Simulation model. Energy dissipation:
a – Vertical plane in the holes (cut along the vertical axis);
b – Vertical plane (cut along the vertical axis);
c – Between the discs.

Simulation of dissipation (Figure 2) in the system of "beads-product" shows that the most effective mixing, friction and grinding is located in the area of the holes, which provoke an increase in the speed of mixing. The minimum efficiency is in the area near the shaft and under the disk space.

In our case, the rotating shaft significantly adds dissipation. Velocities and dissipation in vertical sections are asymmetrical above and below the disks due to gravity.

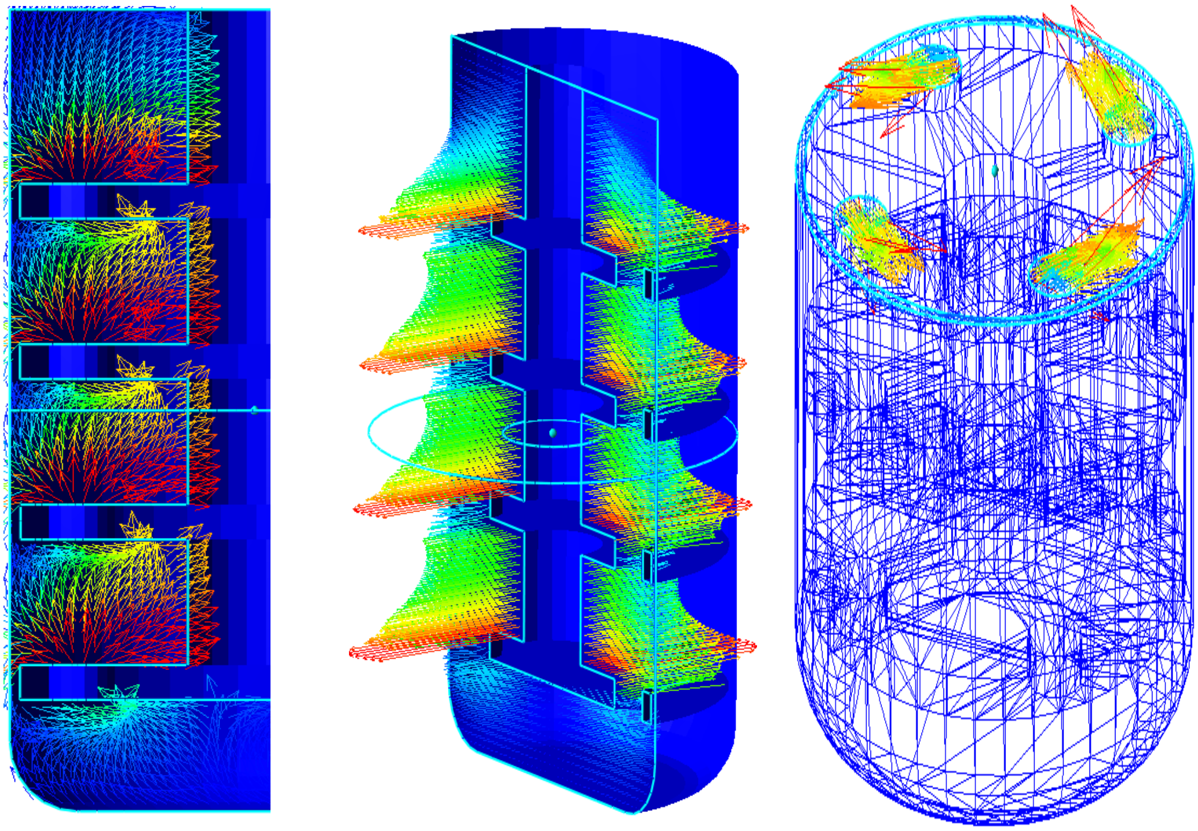
a b c

Figure 3. Simulation model. Simulation of speed:
a – Speed in a vertical plane (cut along the vertical axis);
b – Speed in the vertical plane isometry;
c – Speed in holes.

Simulation of the mixing speed (Figure 3) of the "bead-product" system shows that the highest mixing and correspondingly grinding speeds are at the top of the grinding disk, the hole in the disk increases the speed of the system, and the stagnant zones (minimum speed or no product movement at all) are under the disk near the shaft. In this shaft configuration, the holes in the disk significantly increase the speed of the "bead-product" system, which is a good result due to a decrease in the metal consumption of the structure.

CONCLUSION

In vertical type bead mills, there are stagnant zones in which the movement of beads with the product is practically not observed, as a result of which the product has an uneven particle size distribution without output. When carrying out the simulation in the simulation software of the laboratory bead mill, the zones where mixing, friction and grinding are most effective are clearly visible. In these zones, the contact of the working fluid (beads) with the crushed product in suspension is maximum, which is expressed in a high degree of dissipation and the release of a large amount of heat.

To solve the problem of the inefficiency of the zones of the working chamber, it is worthwhile to study in more detail the configuration of the rotor with a reduced annular gap, which will provide a reduction in the time for grinding solid materials in suspension and a stable speed throughout the volume of the working space, with a smaller volume of the grinding chamber.

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