Disintegrator with Intensive Action on the Ground Material

A. V. Shatalov, A. N. Maslovskaya, V. A. Shatalov, and U. V. Golubeva

Abstract Grinding coarse-grained materials into fine powders is the most complex and energy-intensive technological operation in the production of various materials [1]. The need to obtain products with high dispersion is explained by the fact that their use is technologically and economically more efficient than coarse materials. The fineness and quality of grinding of materials is of great importance for the intensification of various technological processes. Recently, for the production of fine powders, mills of intensive action with a high speed of material loading have found wide application. To increase the efficiency of the grinding process and productivity, a disintegrator with inclined cylindrical spreading nozzles has been developed. Calculations and studies have shown that this design of the disintegrator can significantly increase abrasion and shock loads on the crushed material, and therefore intensify the grinding process and increase productivity. The practical value of the work lies in the creation, on the basis of theoretical developments and experimental studies, of an improved disintegrator design, which increases the efficiency of the grinding process. The results of the work can be used in the building materials industry for the production of various multi-composition mixtures.

Keywords Grinding · Intensification · Disintegrator · Finely dispersed material · Productivity

A. V. Shatalov (✉) · A. N. Maslovskaya · V. A. Shatalov
Belgorod State Technological University Named After V.G. Shukhov, Belgorod, Russia
e-mail: tkmm_bstu@mail.ru

U. V. Golubeva
Belgorod State National Research University, Belgorod 308015, Russia

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1 Introduction

Any modern production of building materials is inextricably linked with the grinding of raw materials and semi-finished products [1]. The need to produce products with high dispersion is explained by the fact that, due to their increased reactivity, technical application is technologically and economically more efficient than coarse materials [2].

At the same time, grinding coarse-grained materials into fine-dispersed powders is one of the most complex and energy-intensive technological operations in the production of building materials, mineral processing, processing of materials in the chemical, fuel and other industries [3]. The dispersion of the resulting product largely determines the quality of the powders obtained and affects the increase in their technological and consumer properties.

Recently, for the production of fine powders, mills of intensive action with a high loading rate of the material have found wide industrial application, providing a complex shock-abrasive effect on material particles [4, 5]. Such grinding plants are disintegrators, which have a relatively high specific productivity, low specific energy consumption, small dimensions, as well as the ability to grind material with natural moisture.

The aim of this research was, based on the analysis of existing structures, to develop a fundamentally new design of the disintegrator, determine the rational modes of the grinding process, make a calculation of its main design and technological parameters.

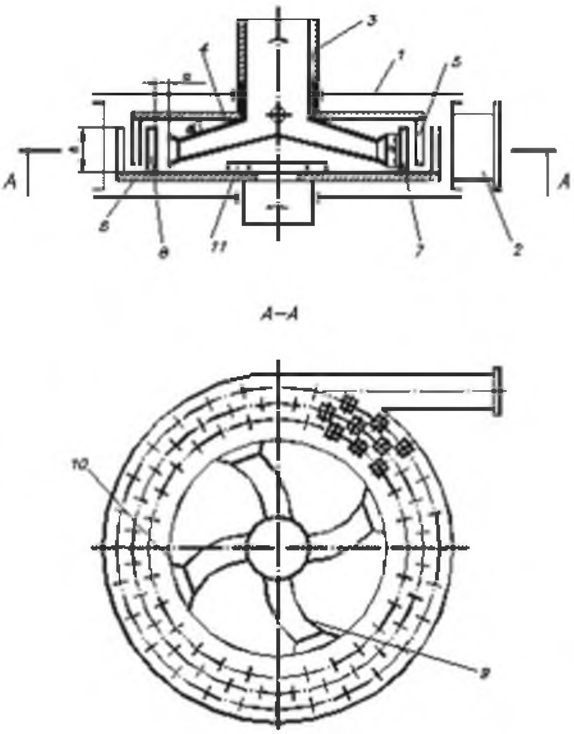
2 Materials and Methods

To increase the efficiency of the grinding process and productivity, we have developed a disintegrator with obliquely installed cylindrical spreading nozzles, which contribute to the radial acceleration of particles in the direction of the rows of impact elements (Fig. 1) [6, 8–10].

The disintegrator contains a cylindrical body 1 with a tangential discharge pipe 2, an axial loading pipe 3, to which the upper disk 4 is rigidly attached. Concentrically located striking elements 5, 7, 8 are installed on the upper 4 and lower 6 disks. The pitch between the striking elements of the first inner row is greater than the striking elements of the subsequent rows, and this pitch depends on the size of the starting material so that the pieces of the starting material freely pass between the striking elements of the first inner row. The cross-section of the percussion elements is shown in the form of a square.

In the central part of the grinding chamber, at the outlet of the loading nozzle 3, there are cylindrical spreading nozzles 9, bent in the direction opposite to the direction of rotation of the upper disc, at the end of each of the spreading nozzles, a diffuser 10 is fixed, the larger diameter D of which is equal to 0.8 h of the height of

Fig. 1 Disintegrator with obliquely mounted cylindrical spreading nozzles



the shock elements, and the distance a between the ends of the diffusers and the impactors exceeds the maximum size of crushed particles. The angle of inclination of the spreading nozzles is greater than the angle of repose of the crushed material. On the lower disc 6, the blades of the fan wheel 11 are rigidly fixed, creating a ventilation effect in the dead zone under the spreading nozzles. The maximum pitch between the impact elements is 0.1–0.5 of the particle diameter of the initial product, and the minimum pitch is 1.2–1.3 of the particle diameter of the finished product.

The disintegrator works as follows (Fig. 1). The material to be crushed is fed through the loading nozzle 3 and directed to the spreading nozzles 9, from where, under the action of centrifugal forces and wall pressure forces through the diffuser 10, it is thrown into the zone of action of the first inner row of impact elements 7 and receives the speed corresponding to this row. Pieces of material are destroyed and, under the action of the tangential component of the impact force and centrifugal force, are thrown onto the next row of impact elements 5, rotating in the opposite direction.

Striking the impact elements of the second row, the material particles bounce off it, changing the velocity vector, and are ejected from the trajectory of the second row, moving further. The use of the spreading nozzles 9 can significantly increase the speed of the radial emission of the particle to the rows of impact elements.

After successively passing all the rows of impact elements, the material, crushed to the required size, is removed from the disintegrator through the tangential discharge pipe 2.

A number of designs of centrifugal batchers has been developed for the accelerated supply of raw materials to the zone of active action, in which the bulk material moves under the action of centrifugal force. To determine the operating and design parameters of dispensers, it is necessary to know the patterns of movement of bulk material in the working area of the dispenser. The state of the material in the hollow loading nozzle 3 during the expiration is characterized by the speed of free fall. It is known that the rate of fall is a function of the height H and does not depend on the density of the flow particles [1]. The design of the shaft 3 provides for the particles to fall into the acceleration zone from a certain height.

One of the main characteristics of the considered disintegrator is performance. With a continuous supply of material by booster pipes to the zone of active exposure, productivity can be determined by the following formula:

$$Q = \psi \cdot D_i \cdot C \cdot z \cdot Vo \cdot \rho, \tag{1}$$

where

- ψ coefficient taking into account the run-up of particles in a centrifugal field;
- D_i the average particle size, m;
- C clear impact size, m;
- z number of the striking elements of the first inner row;
- Vo speed of material movement along the working surface of the striking element;
- ρ bulk density of material, kg/m^3.

3 Results and Discussions

Figure 2 shows the layout of the first and second inner rows of the disintegrator striking elements. Let's introduce the following designations: O—the center of rotation of the rotors; R_1 and R_2—distances from the center of rotation of the rotors to the middle of the striking elements, respectively, of the first and second rows; a—side of the square of the cross-section of the striking element; DE = L_1—the minimum distance between the working elements of the second row, at which the slip of particles between them is possible.

Having determined the angles β_2 и β_1 from the triangles AOB и AOC, the minimum distance between two percussion elements in the second row is obtained:

$$L1 = DE = 2DK = 2R2 \sin \frac{\arcsin \frac{(R_1 + \frac{a}{2}) \cos \alpha}{R_2 - \frac{a}{2}} - \arcsin \frac{(R_1 + \frac{a}{2}) \cos \alpha}{R_2 + \frac{a}{2}}}{2} \tag{2}$$

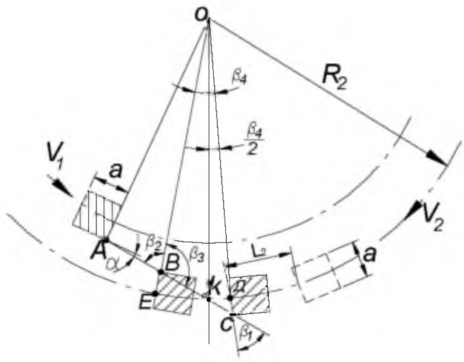


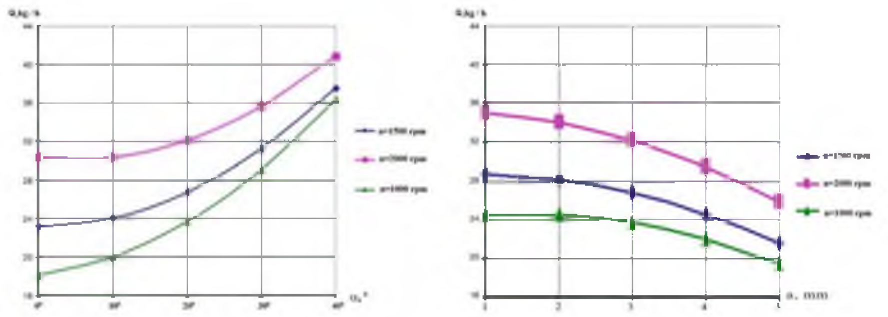
Fig. 2 Scheme for determining the distance between adjacent impactors

In fact, the second row moves towards and L_1 will be larger than in Eq. (2). During the movement of a particle of material with a velocity V on a segment of the BC, the impactor of the second row must pass the path L_2 with an angular velocity of ω_2. The minimum distance L between two adjacent impactors is determined as the sum of L_1 and L_2:

$$L = 2R2\sin\frac{\left[\arcsin\frac{\left(R_1+\frac{a}{2}\right)\cos\alpha}{R_2-\frac{a}{2}} - \arcsin\frac{\left(R_1+\frac{a}{2}\right)\cos\alpha}{R_2+\frac{a}{2}}\right]}{2} + \frac{\omega_2 R_2}{V_1}\left(R_2-\frac{a}{2}\right)\frac{\sin\left[\arcsin\frac{\left(R_1+\frac{a}{2}\right)\cos\alpha}{R_2-\frac{a}{2}} - \arcsin\frac{\left(R_1+\frac{a}{2}\right)\cos\alpha}{R_2+\frac{a}{2}}\right]\cdot\left(R_2+\frac{a}{2}\right)}{\left(R_1+\frac{a}{2}\right)\cos\alpha} \tag{3}$$

Similarly, we determine the distance between adjacent percussion elements on the third row. The number of collisions of material particles with impact elements in the grinding chamber exceeds the number of rows of impact elements due to an increase in the concentration of material particles in the material processing zones (2nd and 3rd rows of impact elements). The grinding degree reaches 500 and more [7, 8].

Thus, in the course of analytical studies, the dynamics of movement of particles of the crushed material in the accelerating units of the disintegrator was established, taking into account its design features. Analytical relationships are obtained for calculating the trajectory of movement of material particles in the grinding chamber of a disintegrator with various impact elements. The use of a disintegrator developed by us [6] with inclined cylindrical spreading nozzles increases the concentration of material particles in the flowing zones of processing of the 2nd and 3rd circles with impact elements, leads to an increase in abrasive and shock loads on the crushed material, makes it possible to significantly intensify the grinding process and increase performance. Experimental studies were carried out on the experimental setup we created. Figure 3 shows the experimental dependence of the



a) b)

Fig. 3 **a** Dependence of productivity on the angle of installation of the plates Q = f(α), **b** Dependence of productivity on the gap between the rows of beats in the last row Q = f(a)

productivity Q on the angle of installation of the plates, α and on the gap between the rows of beats, *a* in the last row. The maximum efficiency is achieved at $\alpha = 40^0$ and a clearance of $a = 1$ mm.

4 Conclusion

1. Based on the analysis of the development of technology and technology for disintegrator grinding, a new design of a disintegrator with horizontal discs is proposed.
2. Analytical relationships were obtained for calculating the trajectory of movement of material particles in the grinding chamber of a disintegrator with various impact elements.
3. Derived analytical dependences to determine: the speed of movement of particles of the material in the disintegrator; the number of striking elements in each row of the disintegrator with a different cross section; productivity and power consumption, taking into account the design features and the mode of the grinding process.
4. Experimental studies have been carried out to determine the optimal parameters of the grinding process.

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