The study of the wear of the working elements of the disintegrator and its effect on the degree of grinding of bulk material

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Abstract. Currently, disintegrators are the most effective devices for producing fine powders. However, they have a significant drawback - the rapid wear of the working elements, affecting the quality of grinding and the duration of the disintegrators without replacing them. As a result of the studies conducted, the influence of wear of working elements on the particle size distribution of crushed sand was evaluated. It was revealed that the main reason for the wear of working elements is abrasive wear caused by the sliding of particles of material on the surface of the working element at the time of their collision. In the process of grinding, the wear rate of the working elements decreases, which is associated with a change in its profile and plastic hardening of the material. An analysis of the shape of the working element showed that its impact surface during the grinding process tends to acquire a profile at which an optimal angle of collision with material particles will be ensured, while all the energy received at the time of impact is spent on splitting the material. The proposed technique can be used in studies to assess the impact of various parameters of the disintegrator and the properties of the material being ground on the degree of wear of the working elements and the quality of grinding.

1. Introduction

In the food, chemical, pharmaceutical and other industries, various fine and medium disperse powder materials are widely used. The degree of grinding of such materials affects the rate of various technological processes and the quality of the final product [1-5].

Various types of grinders are used to grind solid materials and obtain fine powders. Disintegrators are the most effective among existing grinding devices [5-9]. They relate to impact grinding machines, the working elements of which are rods fixed in two disks rotating in opposite directions. The grinding of the material occurs due to the forces arising from the collision of particles with each other and with the working elements of the disintegrator. The main parameters affecting the frequency and strength of the collision of the particles of material with the working elements are the speed of rotation of the disks and the distance between adjacent rods [9, 10].

When the rods repeatedly collide with particles of the crushed material, these elements of the disintegrator wear out. The wear mechanism of the disintegrator rods is associated with the
simultaneous impact and sliding of particles of material on the surface of the rod, resulting in the indentation of particles, the displacement of a certain volume of the material of the rod with its subsequent separation. The wear process is affected by the mechanical characteristics of the material of the working elements and particles of the crushed material, as well as their collision speed [9, 10]. Due to wear of the working elements, the distance between adjacent rods increases, which leads to an increase in the probability of entrainment of material particles from the grinding chamber without mechanical impact on them and, as a result, the grinding quality decreases [11, 12].

2. The purpose of the study
From the analysis of the above it follows that when assessing the performance of disintegrators, it is necessary to take into account the degree of wear of the working elements when grinding bulk materials.

The purpose of the study is to develop a methodology for assessing the impact of wear of working elements on the degree of grinding of bulk material.

3. Equipment, materials and methods
When conducting the research, we used an experimental plant to assess the wear of the working elements of the disintegrator and its effect on the degree of grinding of bulk material (figure 1), the main technical characteristics of which are given in table 1.

As grinding material, class I sand of medium size was used (particle size modulus is from 2.0 to 2.5), corresponding to GOST 8736-2014 «Sand for construction works. Specifications».

When determining the particle size distribution of the crushed material, the sieve method was used. Samples of crushed material weighing 100 g were taken after processing 5, 10, 20, 30, 40 and 50 kg of the starting material. Sifting was carried out through silk sieves with a mesh size of 0.28, 0.22, 0.15...
and 0.12 mm (GOST 4403-91 «Fabrics of silk and synthetic threads for sieves. General specifications»). To weigh the residues on the sieves, a laboratory balance DEMCOM DL-3102 was used.

When determining the degree of wear of the working elements, they were taken from the working disk of the disintegrator and weighed simultaneously with sampling.

Table 1. Technical characteristics of the experimental setup for assessing the wear of the working elements of the disintegrator and its effect on the degree of grinding of bulk material

| Parameter                                      | Unit of measurement | Value |
|-----------------------------------------------|---------------------|-------|
| Disintegrator drive motor power               | kw                  | 3     |
| Disk rotation frequency                       | rpm                 | 6000  |
| Feeder performance                            | kg/h                | 25    |
| The external radius of the feed channel       | mm                  | 130   |
| Radius of the position of the rods centers    | mm                  | 145   |
| Initial diameter of the rod                   | mm                  | 10    |
| Initial mass of the rod                       | g                   | 15    |
| Number of rods                                | pcs                 | 36    |
| Rod material                                  | -                   | Steel 45 |
| Hardness of the rod material                  | HB                  | 285   |
| Inter-disk channel width                      | mm                  | 10    |

The averaged mass (m) of a single working element was determined by the expression:

$$m = \frac{m_z}{z},$$

where $m_z$ – mass of all working elements, g; $z$ – number of working elements.

The degree of wear was assessed using the coefficient of wear ($C_w$), which was determined by the formula:

$$C_w = 1 - \frac{m}{m_0},$$

where $m_0$ – the initial mass of the working element.

4. Discussion of the results

The results of experimental studies are shown in table 2. An analysis of the results obtained indicates a significant change in the particle size distribution of the crushed material during wear of the working elements. So at 45% wear of the working elements, the content of the fraction with a particle size of less than 0.15 mm decreases about 1.5 times.

It should be noted that the wear rate of the working elements decreases as the amount of crushed material increases. The probable causes of a decrease in wear rate are:

– reduction in the frequency of impacts of working elements and material particles due to the entrainment of a larger number of crushed particles from the grinding chamber;
– changing the geometry of the working element and hardening of the material caused by riveting as a result of the impact of particles of material on the working surface of the rod.

An analysis of the geometry and state of the surface of the working element (figure 2) indicates that the main reason for its wear is the abrasive effect of the crushed material caused by its sliding on the surface of the rod.
As a result of wear, the working surface of the rod acquires a certain profile that provides an optimal angle of collision of the particle of the material with the working element, excluding their sliding. In this case, all the energy received during the collision is spent on cracking the material. In this case, further wear is accompanied by chipping of metal particles from the surface of the rod.

**Table 2.** Change in particle size distribution of crushed sand depending on the wear of the working elements of the disintegrator

| The mass of crushed sand, kg | Coefficient of wear $C_w$ | Fraction content, % |
|-----------------------------|---------------------------|---------------------|
|                             |                           | over 0.28 mm | over 0.22 mm | over 0.15 mm | over 0.12 mm | less than 0.12 mm |
| 5                           | 0.08                      | 0.3          | 5.6         | 12.7         | 19.8         | 61.6               |
| 10                          | 0.19                      | 0.5          | 6.5         | 14.3         | 20.2         | 58.5               |
| 20                          | 0.31                      | 1.6          | 7.7         | 17.1         | 21.1         | 52.5               |
| 30                          | 0.38                      | 2.8          | 9.4         | 19.6         | 21.9         | 46.3               |
| 40                          | 0.42                      | 5.3          | 12.7        | 21.2         | 21.6         | 39.2               |
| 50                          | 0.44                      | 6.7          | 13.2        | 22.0         | 21.7         | 36.4               |

**Figure 2.** Working element of a disintegrator: a – initial state; b – worn state after grinding 50 kg of sand

5. **Conclusion**

Wear of the working elements of the disintegrator is the main reason for reducing the efficiency of its work, which consists in the instability of the quality of the crushed product and the short duration of the device without replacing the working elements [9, 11, 12]. Reducing the effect of wear of working elements on the performance of disintegrators is provided depending on the type of product being ground by increasing the number of working elements, finding their optimal profile, using high hard alloys for their manufacture, etc.

It should be noted that studies related to increasing the efficiency of disintegrators are empirical. However, there are no unambiguous solutions that would allow us to assess the effect of the hardness of the material or the profile of the working element on its wear resistance and, as a consequence, on the quality of grinding. The proposed technique can be used in studies to assess the influence of material properties of working elements, their profile, properties of the material being ground, disk rotation speed on the degree of wear of working elements and the quality of grinding material.

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