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CRUSHING OF MATERIALS IN THE SPHERICAL MILL WITH THE MIXER

In article results of a grinding such differing on the ability for grinding materials as a chalk, kaolin, amorphous silicon oxide, in a spherical mill with a mixer are presented. In quality milling bodies of 2.8–3.0 mm were used pig-iron a ball in diameter. Speed of working body made 10 m/s. The initial fraction of 0.5–3.0 mm as a result of a grinding is finished till the final size 0.2–50.0 μm. Approximately 80% of particles had the size less than 10 μm. Dependences of efficiency dispersion from duration of influence for the different defining sizes of particles are received. Possibility of analytical representation of the total characteristic in the form of the equation of Rozina – Rammlera is shown.

Introduction. Recently in foreign and Russian literature there have appeared a lot of information on the research of spherical mills with mixers [1–6], which are applied in various industries to crush particles till micron sizes and even less than 1 μm. As crushing bodies in them glass and corundum balls in diameter of 1–3 mm are used. Data on creation of large-sized spherical mills with mixers [7] with productivity to 20 t/h are given. The analysis of process of spherical crushing showed [8] that such units can have big prospects for superthin crushing when the main way of impact on a material is attrition. The prospects of the specified crushing unit as a mechanical system have predetermined the urgency of scope of scientific researches on studying of its technological and design data and their optimization.

Main part. The spherical mill with a mixer of a horizontal type (Fig. 1) is chosen as the object of the research. The diameter of the installation case makes 196 mm, total amount – 9 l. The role of the mixing device is carried out by disks with the openings, established on a driving shaft. The obligatory elements of the studied mill, as well as all modern mills with mixers, are the trellised dynamic separator and the mesh filter. As the crushing bodies pig-iron balls in the diameter of 2.8–3.0 mm, and the crushed material – chalk with the size of particles of 1–3 mm, kaolin – 0.5–2.0 mm, amorphous oxide of silicon (“white soot”) – 0.2–0.5 mm were used. The choice of the materials is caused by a wide use of their finely dispersed fractions in the production of various products: rubber, dyes, paper and pottery. Besides these materials considerably differ on their grindability.

At the initial stage of studying of any crushing unit the kinetics of grinding of a material in it is important. Therefore the researches were carried out on a mill working in a periodic mode. The grinding was carried out only in a wet condition at the volume ratio of crushing bodies, the material and the water, equal to 1 : 0.75 : 0.5.

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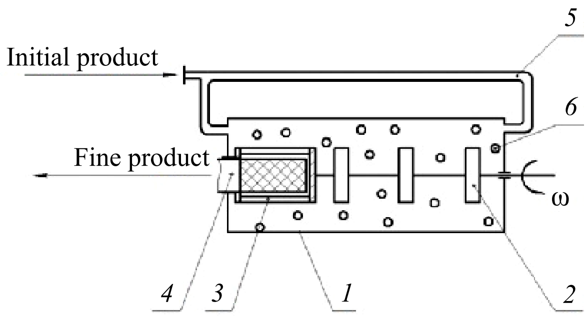


Fig. 1. Scheme of laboratory installation:
1 – cylindrical case; *2* – rotating disks (mixers);
3 – separator; *4* – mesh filter;
5 – circulating branch pipe; *6* – crushing balls

On Fig. 2 the fineness characteristics for three studied materials after 15-minute processing in a mill with a mixer are presented. In all cases the maximum size of particles doesn't exceed 50 μm. The minimum size made 0.2 μm and increased from “white soot” to kaolin and chalk that testifies to the best grindability of these materials. Thus the disperse structure of the crushed product for “white soot” is more uniform.

On the private characteristic of “white soot” one maximum of about five-percent maintenance of particles in diameter of 10 μm is noted. There are few such peaks for chalk, and especially kaolin on the characteristic that points to higher polydispersity of the product. The reason for that can be the heterogeneity of the structure of these materials, in particular the presence of a considerable share of such hard crushed component, as quartz sand in which crystal oxide of silicon prevails. In this regard the kinetics of crushing is best of all traced on the dispersion change of “white soot” (Fig. 3). Here the fineness characteristics of the specified product are presented at a 5- and 30-minute processing in a mill with a mixer. In the aggregate with a 15-minute processing (Fig. 2, *c*) they reflect the real picture of the change of the crushing product dispersion in time. The fact of its increase with time is evident, but at the same time the fact of decrease in speed of this increase is obvious as well. So, the comparison of the private characteristics at a 15- and 30-minute grinding indicates its shift towards smaller product, yet its maximum characterized in the size of 10 μm decreases slightly. Studying fineness total characteristics received by means of the laser microanalyzer, gives the chance to establish the interrelation between the size of a certain class and its share in the product total mass. In Table 1 the data for “white soot” at different time of grinding are presented. Besides some share of a class (fraction) from 5 to 99% is taken for defining parameter and its maximum size is established.

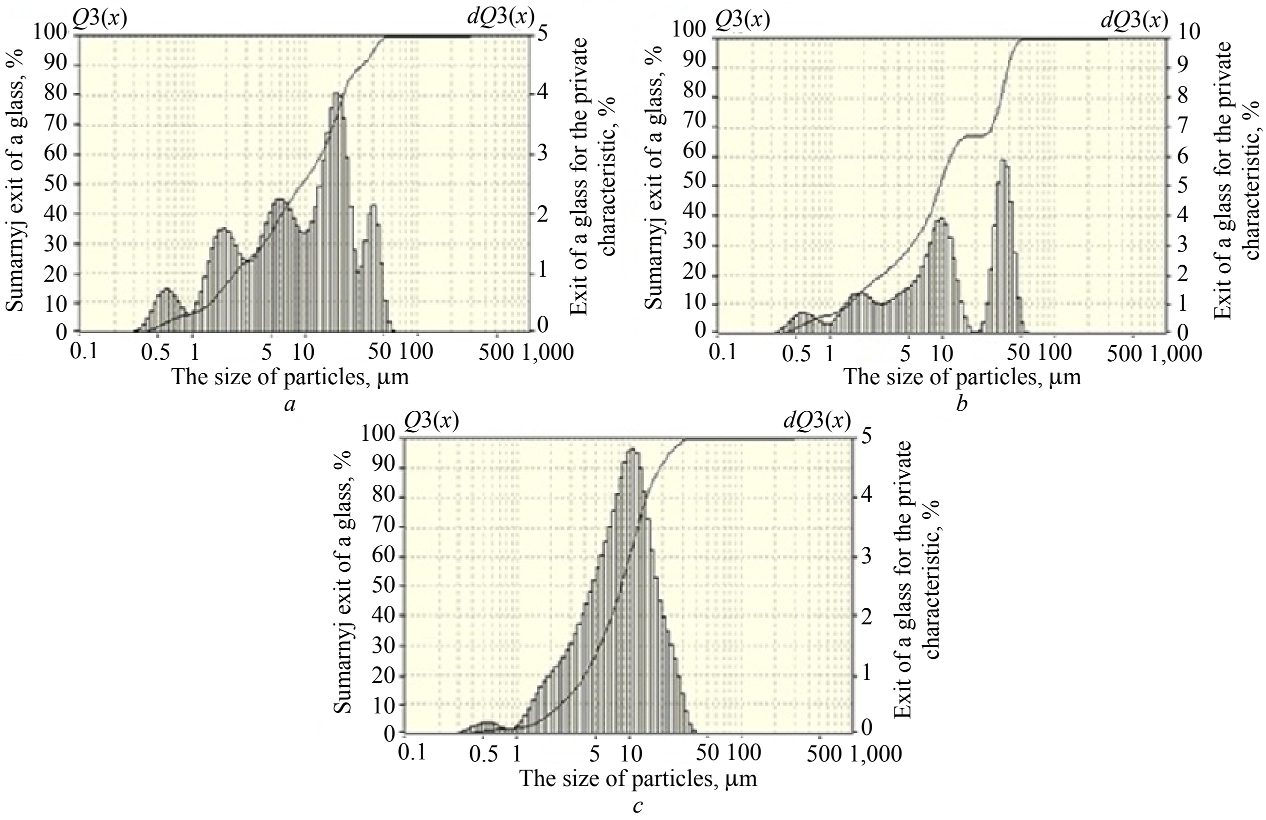


Fig. 2. The fineness characteristic of distribution of the particle size in the test volume after 15 min of grinding: *a* – chalk; *b* – kaolin; *c* – “white soot”

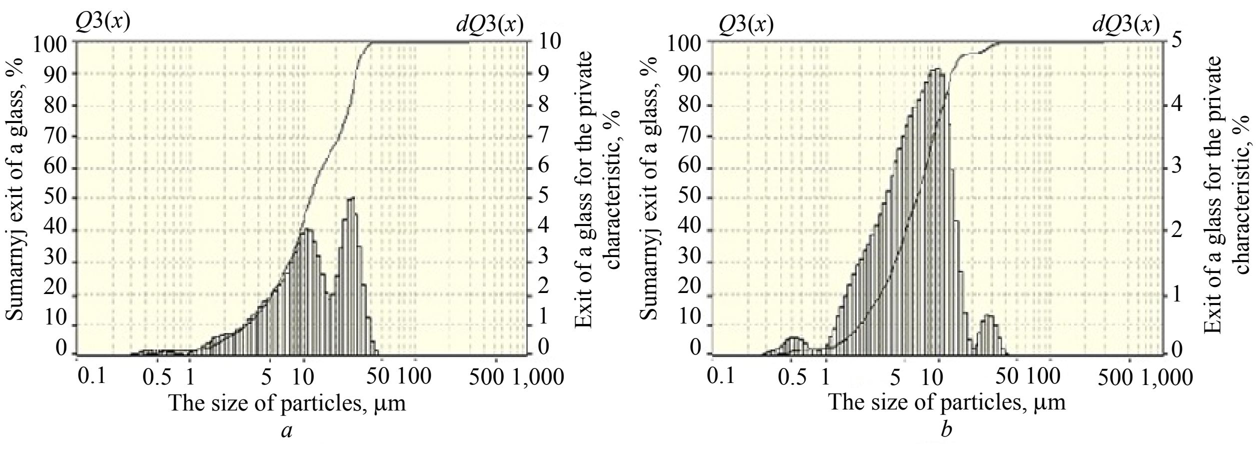


Fig. 3. The fineness characteristic of distribution of the particle size in the test volume “white soot”: *a* – 15 min; *b* – 30 min

According to Table 1 the reduction of the size of particles and the increase of a share of smaller fractions is accurately traced at grinding time increase. For 30 min of processing in a spherical mill with a mixer the size of particles of "white soot" doesn't exceed 30 μm, and 80% from them – 11 μm.

Table 1

The maintenance of the sizes of particles in a test at different duration of grinding

Fraction share, %	Maximum size of particles at different time of grinding, μm		
	5 min	15 min	30 min
5	1.997	1.728	1.468
50	11.583	8.518	6.392
80	25.276	14.260	10.926
99	38.310	29.594	30.657

Using the total characteristics of fineness "on a minus" which are presented as results of the analysis of dispersion, it is possible to solve another task – having chosen a certain size, to define in the ground product a share of particles less than this size. Such data for different materials are provided in Table 2. These indicators once again confirm the decrease in a grindability of materials from chalk to "white soot". By the received results for "white soot" the dependences of dispersion efficiency on impact time (Fig. 4) are constructed. The efficiency thus was determined from the formula

$$E = 100 - R, \quad (1)$$

where R – the share of a product exceeding any certain size, %.

Table 2

Share of particles of the ground product in the selected tests

The defining size, μm	Share of fractions, %, for different materials at 5 min grinding duration		
	chalk	kaolin	"white soot"
1.0	9.7	8.7	2.5
10	71.1	62.9	42.5

We have taken 1 μm as the particle size in Fig. 4, *a*, and 10 μm in Fig. 4, *b*.

By the kinetic curves (Fig. 4) there accurately Ftraced the reduction of the size of particles (increase in dispersion) both for the fraction of 1 μm, and for the fraction of 10 μm. Notably in the studied time span (5–30 min) the share of a small fraction (1 μm) decreases for only 1%, and a large (10 μm) – for more than 30%. It testifies that at the reduction of the size of particles the process of their dispersion is made difficult.

Processing of the experimental data gave the chance to receive the empirical dependences for the calculation of the dispersion efficiency. They are presented in the form of a polynom of the second degree:

– for fraction less than 1 μm:

$$E_1 = 0.0013t^2 - 0.0067t + 1.5; \quad (2)$$

– for fraction less than 10 μm:

$$E_{10} = -0.0263t^2 + 2.253t + 32.08, \quad (3)$$

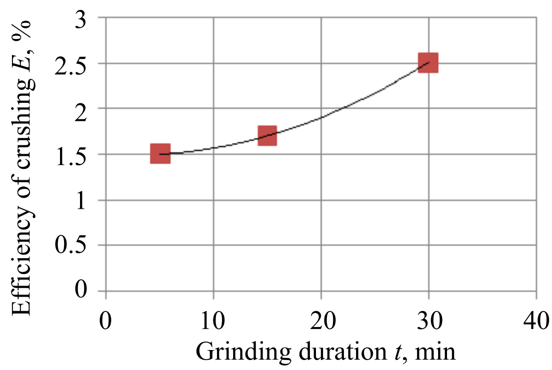
where E_1 and E_{10} – efficiency of crushing for the size 1 and 10 μm respectively, %; t – time of crushing, min.

The divergence of the experimental and calculated data doesn't exceed 0.013–0.05%.

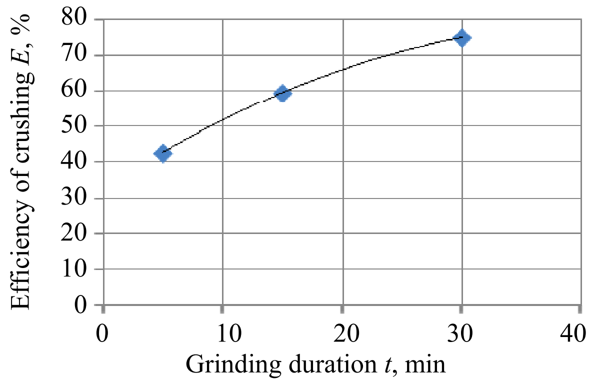
The main, universally accepted in technology and engineering is the total characteristic by which it is possible to determine an output of any fineness class [9]. In logarithmic system of coordinates this characteristic will be more often transformed to a straight line. On this basis, the experimental data can be processed in the form of Rozin – Rammler equation [9]:

$$R_p = 100e^{-bd^n}, \quad (4)$$

where R_p – a total class output "on plus" (d is larger); d – the defining size of particles (class size), μm; b and n – the parameters depending on the property of the material and the dimension of d.



a



b

Fig. 4. The dependence of the dispersion efficiency from the impact time for the different defining sizes of particles: *a* – 1 μm; *b* – 10 μm

The processing of the experimental results presented in the form of the total characteristic for ”hite soot” with the grinding time of 15 min (Fig. 2, *c*), allowed to receive the Rozin – Rammler equation with the corresponding factors:

$$R_p = 100e^{-8.4136d^{-0.2169}}. \qquad (5)$$

The error of calculation for the equation (5) doesn't exceed 0.004%.

Such equations can be received for all total characteristics.

Conclusion. As a result of the researches of crushing of materials with various grindability in a spherical mill with a mixer the disperse structure of the final product is established. Their total characteristics by which it is possible to determine an output of any fineness class are received. Possibility of analytical submission of the total characteristic in the form of Rozin – Rammler equation is shown.

The kinetics of crushing of materials in a spherical mill with a mixer is analysed and the equations for calculation of the change of the disperse structure of the final product in time are received.

It is established that the initial product in the size of 0.2–3.0 mm during 5–30 min can be finished to particles in the size of 0.2–50.0 μm. In some cases the minimum size doesn't exceed 30 μm, and 80% of these particles is less than 10 μm. It testifies to high efficiency of crushing in a spherical mill with a mixer.

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