

Some Peculiarities of the Process of Preparing the Zeolites Containing Breeds in a Ball Mill

Adilkhodjaev Anvar, Shaumarov Said, Umarov Kadir, Kadyrov Ilkhom



Abstract— The article presents the results of studies of grindability of zeolite-containing rocks in ball mills with different grinding conditions. The results of studies of grindability of zeolite-containing rocks, optimization of the grinding process and determination of the specific productivity of industrial mills are presented. From a practical point of view, the data obtained can reduce the energy consumption of the grinding process of zeolite-containing rocks and increase the values of equipment efficiency and improve the quality of the finished product.

Keywords: zeolite-containing rock, mechanical activation, ball mill, aggregation, optimization, specific surface, average particle diameter, specific productivity.

I. INTRODUCTION

Portland cement is currently the main binder. The production of this type of mineral binder is a sufficient energy and material intensive process accompanied by a large amount of CO₂ emissions. According to the Gigaton Throwdown Initiative (2009), “the cement industry is responsible for about 5% of total CO₂ emissions, or 2.1 gigatons per year.” During the firing of cement clinker during the decomposition of raw materials, 0.53 kg of CO₂ per ton of clinker is formed, with this 0.37 kg is released during the combustion of fuel. Thus, the total environmental load reaches 0.9 kg of CO₂/t clinker. Given the annual growth in production and use of cement, this fact poses a significant threat to the environment [1,14].

The search for solutions to such a global problem is very relevant. The world is constantly looking for ways to mitigate the negative effects of CO₂ emissions into the atmosphere in cement production. In particular, it has been proved by numerous studies that one of the promising methods of reducing the negative environmental impact factors of

products formed during high-heat treatment of materials is the method of replacing part of cement clinker with directional mineral additives. As a result of joint grinding of a part of clinker with such additives, prerequisites are created for the development of various types of binders with a certain set of properties, reduction of energy costs for production, and reduction of CO₂ emissions into the atmosphere [1,15]. As a natural additive, silicon-oxygen and aluminum-oxygen compounds with the ability to independently hydrate hardening, which include zeolite-containing rocks, are most effective.

Deposits of zeolite-bearing rocks (CSP) were discovered in the Republic of Uzbekistan in the early 1970s, among them of particular interest are the CSPs of the Beltau Upland which is located in the vicinity of the Kuldzhuktai ridge, within the southern part of Central Kyzylkum [2,16].

It is known [3-5,17] that many chemical-technological, as well as physico-mechanical characteristics of finely ground mineral substances depend on the size of particles obtained by using external force.

Dispersion and mechanical activation have a great influence on the surface properties of minerals and rocks: there is a noticeable change in the physical properties and chemical activity of the substance. This is explained not only by an increase in the specific surface area and a decrease in particle sizes, but also by a change in the structure, in particular, amorphization of the surface areas due to the occurrence of mechanochemical processes [6–9,18].

The scientific and technical literature contains a fairly large number of publications on mechanical activation in the context of saving energy and raw materials. However, the grinding of some rocks with different physical and mechanical properties is not fully covered [10].

In order to expand information on the development of micro-fillers based on the BSP of the Beltau deposit, this article presents the results of studies of the grinding of zeolite-containing rocks, optimization of the grinding process and determination of the specific productivity of industrial mills.

II. RESEARCH METHODS

The grinding process of zeolite-containing rocks was carried out in a laboratory ball mill SHLM-100 in three modes: abrasion, impact-abrasion and impact. The material was crushed to a specific surface of 2000 - 11000 cm²/g with preliminary drying of the feedstock to a constant weight at a temperature of ± 105°C.

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The grinding fineness was evaluated on a PSX-11A surface meter. and determined the specific surface (S, cm²/g) and the mass-average particle size (d, μm) of the powders under study. For control of aggregation, sieve No. 008 was used.

III. MATERIAL GRINDING STUDIES

The grindability of the material depends on its physical properties. In the table. 1 shows data characterizing the grindability of various materials compared to Portland cement clinker, the grindability of which is taken as a unit [11].

Table 1. Grindability of various raw materials

Name of material	Grindability
Limestone	1,2-1,8
Granulated blast furnace slag	0,8-1,1
Flask	1,3-1,4
Track	0,5-0,6
Quartz sand	0,6-0,7
Zeolite-containing tripoli (Khotynetsky deposit)	0,3-0,4
Cement Clinker	1,0

The results of a change in the specific surface and average particle diameter of zeolite-containing rocks under different grinding conditions are shown in Fig. 1,2.

In our studies, to compare the grindability of various materials, we studied the DSPs of the Beltau deposit, the sand of the Kuiluky quarry and the quartzite sandstone of the Navai deposit (Kulzhuktau).

In order to identify the experimental conditions, all starting materials were ground to a specific surface of 1100 cm²/g. After daily exposure at t = ± 25 °C, their grindability was determined in a laboratory ball mill IIIJM-100 (Fig. 3).

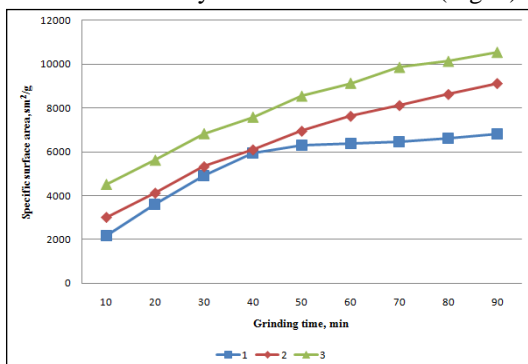


Fig. 1. The change in the value of the specific surface of the DSP during abrasion (1), impact-abrasion (2) and impact mode (3)

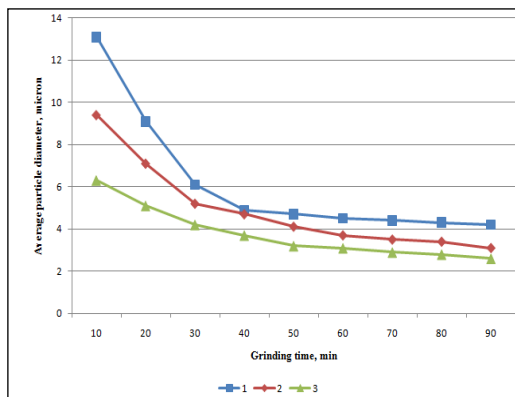


Fig. 2. Change in the average particle diameter of the DSP during abrasion (1), impact-abrasion (2) and impact mode (3)

It has been established that DSP has the highest grindability, the specific surface of which increases in 90 minutes from 1100 cm²/g to 9130 cm²/g.

This is because the DSP has a polymineral composition, consisting mainly of minerals, the tensile strength of the contact zone between which is much lower than the strength of quartz crystals. The grindability of quartzite sandstone is somewhat lower.

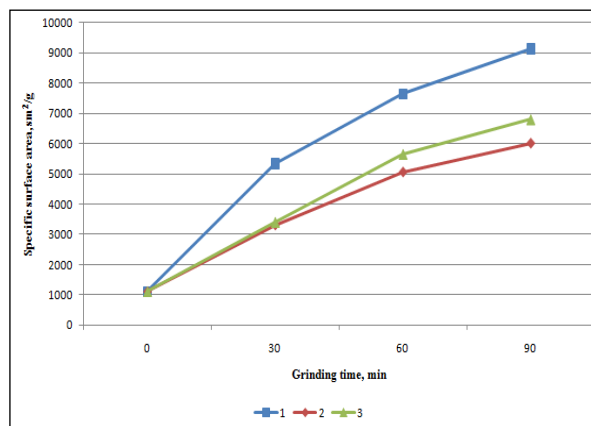


Fig. 3. Grindability of DSP (1), sand (2) and quartzite sandstone (3) under shock-abrasive grinding

Within 90 minutes, the specific surface is reached 6800 cm²/g. The sand of the Kuyluk quarry for 90 minutes of grinding showed a specific surface area of 6000 cm²/g. This is because the tensile strength of the contact zone between the rock-forming minerals of the sand is higher than that of the DSP and quartzite sandstone.

After reaching the value of the specific surface of DSP 4520 cm²/g, the residue on sieve No. 008 begins to increase. This phenomenon is called aggregation or adherence of particles.

There are various assumptions explaining the phenomena of sticking and aggregation. The most widely used is the electrostatic theory of a double surface electric layer, according to which the phenomenon of contact electrization is observed during grinding [11].

IV. DETERMINATION OF THE SPECIFIC PRODUCTIVITY OF INDUSTRIAL MILLS

Grinding cannot be measured by any physical constant material. It is a technical characteristic that depends not only on the physical properties of the materials being ground, but also on the method and grinding conditions. In order for the values characterizing the grindability to be of practical value, they should possibly more accurately reflect the influence of the grinding properties of the crushed materials on the performance of industrial mills.

In order to compare the results obtained during tests in a laboratory mill, with the performance of industrial mills, we evaluated the relative productivity per unit of the nominal volume of the mill.

$$B_{ycl} = \frac{B}{V_{ycl}} = \frac{B}{V\sqrt{D}} = \frac{B}{0,0837} = 11,94B_{ycl} \quad (1)$$

where B_{ycl} - specific productivity per unit conditional volume in kg / hour / unit; B - productivity of a laboratory ball mill, kg/h;

D is the inner diameter of the mill, equal to 0.7 m; V is the internal volume of the chamber, equal to 0.1 m³; V_{ycl} - the conventional volume of the mill, equal to:

$$V_{ycl} = V * \sqrt{D} = 0,1 * \sqrt{0,7} = 0,0837$$

The results of specific productivity are presented in Fig. four.

When the fill factor of the laboratory mill $\phi = 0.4$ shock-abrasive grinding, the load of raw materials is 15 kg. The calculations found that under industrial conditions, for 1 hour of grinding the DSP to a specific surface of 3000 cm²/g, it is possible to produce a finished powder weighing 6500 kg.

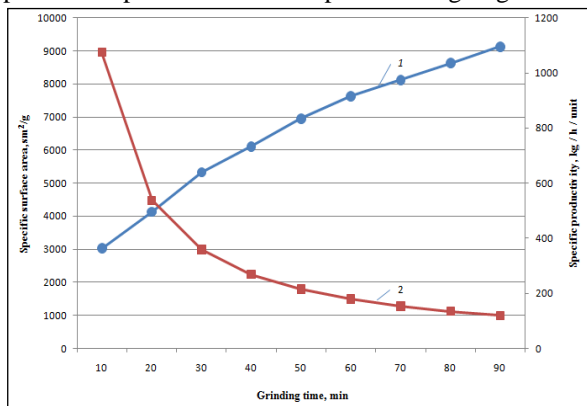


Fig. 4. The specific productivity of the industrial mill, depending on the specific surface of the DSP in shock-abrasive grinding

To obtain a DSP with higher specific surface indices: the output of the mass of ground powder from the specific surface of 4100; 5300; 6100; 6900; 7600; 8100; 8600 and 9100 cm²/g are respectively 3220; 2150; 1620; 1290; 1075; 920; 800 and 700 kg.

VI. BALL MILL GRINDING PROCESS OPTIMIZATION & RESULTS

The experimental results of the grinding process of the DSP were processed using methods of mathematical statistics [12,13]. Using MS Excel, a regression analysis was performed to calculate the regression equations.

As a result of processing, power-law models are obtained that reflect the relationships between the properties under study and their initial factors that have the following form:

$$Y = c + a_1x_1^2 + b_1x_1 + a_2x_2^2 + b_2x_2 + a_3x_3^2 + b_3x_3 + \dots + a_nx_n^2 + b_nx_n \quad (2),$$

where, Y is the investigated property; xi are the initial factors; ai, bi, c are the coefficients of the regression equation.

The following data were taken as variable factors:

x1 - is the average particle diameter, microns; x2 - mill productivity, kg / h; x3 - is the number of revolutions of the mill drum.

In the process of mathematical processing of the experimental results, regression coefficients were obtained (Table 2), which, after checking for significance, formed the basis of the regression equations of the studied factors. The calculated values of the studied properties of the varying factors are presented in table. 3.

Validation of the obtained regression equations was carried out by calculating the adequacy variance (or residual variance) and determining the calculated value of the Fisher criterion F_p , which was compared with the table F_t . If the condition $F_p < F_t$ is fulfilled, the resulting equation is considered suitable for describing the initial dependence within the studied range of factors.

Table 2. Regression coefficients

Coefficient	Values of regression coefficients		
	abrasive grinding	shock abrasive grinding	impact grinding
c	24640	7148,62	-14,248
a ₁	116,06	56,23	-769,45
b ₂	-1396,35	-961,29	3845,9
a ₂	1,5033	-0,024	-1,848
b ₂	-380,15	-5,73	413,47
a ₃	0,000918	-0,0001	-0,0006
b ₃	-6,18105	1,69	6,6142
R ²	0,99	0,99	0,99
S _{BOcomp}	0,08	0,08	0,07
F _p	0,0002	0,0002	0,0015
F _T	19,3295	19,3295	19,3295

Thus, the obtained quadratic models adequately describing the relationship between the studied properties and the initial variation factors are described by the following equations:

for abrasive grinding mode:

$$Y_{yp} = 24640 + 116,06X_1^2 - 1396X_1 + 1,5033X_2^2 - 380,15X_2 + 0,00918X_3^2 - 6,18105X_3;$$

for shock abrasive grinding mode:

$$Y_{yp} = 7148 + 56,23X_1^2 - 961,29X_1 - 0,024X_2^2 - 5,73X_2 - 0,0001255X_3^2 + 1,6971X_3;$$

for shock grinding mode:

$$Y_{yp} = -14248 - 769,45X_1^2 + 3845,9X_1 - 1,848X_2^2 + 413,475X_2 - 0,00065X_3^2 + 6,6142X_3.$$

An analysis of the obtained models made it possible to establish the levels of variation factors providing the required specific surface area under various grinding conditions.

Table 3. The calculated values of the test results

Experience Number	Variation Factor Levels			The calculated values of the research results		
	X ₁	X ₂	X ₃	S _{уд.} 35 rpm	S _{уд.} 40 rpm	S _{уд.} 45 rpm
1	+1	+1	+1	2177	3023	4522
2	+1	+1	-1	3604	4127	5635
3	+1	-1	+1	4911	5331	6804
4	-1	+1	+1	5938	6125	7593
5	-1	-1	-1	6280	6928	8581
6	-1	+1	+1	6411	7620	9139
7	-1	-1	-1	6473	8163	9763
8	+1	-1	-1	6585	8608	10210
9	+1	0	0	6810	9132	10521

VII. CONCLUSION

In the study of the grinding of the DSP, it was found that the effective grinding modes of the DSP of the Beltau field are the abrasion and shock-abrasion regime. It was revealed that, when grinding in shock mode in 10 min, the specific surface reaches up to $S_{sp} = 4520 \text{ cm}^2/\text{g}$ and particle aggregation is observed.

As a result of processing the experimental results, power-law models are obtained that reflect the relationships between the properties under study and their initial factors. The determination coefficient R^2 of the actual models is $R^2 = 0.88$. The reliability of the obtained equations is 0.83-0.88%.

Determining the rational mode of operation of the mill during the grinding process with the required degree of grinding allows to significantly reduce the energy consumption of the production process by increasing the value of the efficiency of the equipment and improving the quality of the finished product.

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