Наведено результати досліджень дроблення магнетитових кварцитів у відцентрованих дезінтеграторах і конусній дробарці. Показано переваги використання відцентрованих дезінтеграторів. Розроблена математична модель процесу руйнування матеріалу у відцентрованих дезінтеграторах. З використанням класичного методу гіпотез одержано формулу для визначення швидкості вильоту матеріалу з розгінного ротора дезінтегратора, що забезпечує необхідне руйнування матеріалу

Ключові слова: дроблення, кварцити, крупність, відцентрований дезінтегратор, ротор, енерговитрати, математична модель процесу руйнування матеріалу ударом в полі відцентрових сил

Приведены результаты исследований дробления магнетитовых кварцитов в центробежных дезинтеграторах и конусной дробилке. Показаны преимущества использования центробежных дезинтеграторов. Разработана математическая модель процесса разрушения материала в центробежных дезинтеграторах. При использовании классического метода гипотез получена формула для определения скорости вылета материала с разгонного ротора дезинтегратора, что обеспечивает необходимое разрушение материала

Ключевые слова: дробление, кварциты, крупность, центробежный дезинтегратор, ротор, энергозатраты, математическая модель процесса разрушения материала ударом в поле центробежных сил

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INVESTIGATION OF THE PROCESS OF CRUSHING SOLID MATERIALS IN THE CENTRIFUGAL DISINTEGRATORS

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1. Introduction

Crushing and grinding are the main ore pretreatment processes, without which the mineral concentration is impossible [1].

The process of primary processing of mineral resources can be divided into two stages: release of minerals, that is liberation of valuable minerals grain from accompanying grains of other minerals and gangue; separation of minerals (concentration proper), that is extraction of valuable minerals unbonded grains into a concentrate. Technological purpose of comminution processes is to reveal (liberate) the minerals closely interwoven or fused with each other (with further application of hydrometallurgy, chemical concentration methods) – to open the surface of the valuable component, exposing it to contact with the reagent. Fineness of grain, up to which it is necessary to crush and grind the material before the concentration, is defined by the size of valuable mineral impregnations and the process, admissible for mineral concentration [2].

Crushing and grinding are the most power-consuming and costly processes in the mineral concentration cycle. At the same time, energy saving in both housing and production is of growing importance in the context of economic crisis. Mining is one of the most power-consuming sectors of the national economy of Ukraine. The most power-consuming processes in this sector are the ore disintegration (crushing and grinding) ones. Their capital and operating costs make 50–70 % of all concentration costs. Therefore, improvement of comminution equipment, application of the most efficient and economical methods and patterns of prior operations are of great importance for the national economy. The improvement of ore disintegration technology and equipment is an extremely actual scientific and technical problem [3].

2. Sources analysis and problem statement

Modern theoretical and experimental investigations aimed at generation of enabling ore disintegration technology and equipment are carried out in different directions.

First of all, an adequate mathematical formulation of ore disintegration process and determination of power inputs are being sought. The paper [4] investigates the Relationships between comminution energy and product size for magnetite ores. It was found that the Rittinger equation fits the experimental data well. However, Bond's equation does not fit the experimental data well, and therefore Bond equation needs modifying. The paper [5] also detects the considerable difference between Bond crushing energy and work done by the jaw crusher for rocks. On the whole these researches reflect again a well-known fact of qualitatively faithful but quantitatively narrow applicable (only for certain conditions, materials, crushers, etc.) Rittinger, Kirpichev-Kick and Bond equations.

In the second place, the search also continues for means of optimization of crushers efficiency from the point of view of power reduction and production gain. Research presented in the paper [6] has investigated the relationship between strain rate, impact energy, the degree of fragmentation and energy efficiencies of fragmentation under laboratory conditions. Compressive failure of ore samples under different strain rates was investigated for this purpose. Laboratory testing and computer simulations showed that a greater amount of energy was required for breakage with increasing strain rate and also samples broken at higher strain rates tended to produce a greater degree of fragmentation. For the present the matter of application of these results for conditions of free impact crushing in industrial crushers remains open – only laboratory tests were carried out. The transference of their results into the industrial conditions requires extra research in order to trace the completeness and correspondence of laboratory physical simulation under the criterion of similarity of different types of crushing equipment to industrial conditions, correspondence of laboratory and industrial factor space (load capacity, impact energy). Beyond any doubt interesting laboratory results demonstrated in the paper [6] require accurate 'connection' with a real-life industrial environment of different types of crushing equipment. Then the problems and prospectives of their application in ore comminution cycles will become more apparent.

In the third place, in comminution practice physiochemical releasing influences on rock itself are applied in order to increase efficiency and decrease power-intensity of these processes. In so doing the well-known Rehbinder effect showing in strength reduction and embrittlement, enhancement of solid plasticity, which facilitate its disintegration and grinding, is applied [7]. Surface processes causing Rehbinder effect can be adsorption, surface acoustic wave, moistening, surface electric charge, chemical reactions. At the same time, the Rehbinder effect application area is restricted to the so-called wet crushing in an aqueous medium. It fails under dry crushing and grinding (no wetting of ingoing material).

In this respect, the comparative studies of crushability of different materials are also carried out. It has been found experimentally [8] that grindability of granite is substantially lower than grindability of iron-ore. Using this difference one can build a selective grinding scheme, select granite coarse grains out of fine iron-containing size by means of control screen sieving, dump oversized granite, send undersized iron ore to the next grinding stage and in such a way decrease the power-intensity of the grinding process. This way suffers from a principal shortcoming – the possibility of application of this technology only under a considerable quantity of impurities in iron ores, having substantially different from iron ore strength characteristics.

In the fourth place, exploratory researches of alternative non-mechanical crushing and grinding methods for iron ore are carried out. The research [9] demonstrates the possibility of selective electrical high-energy impulse comminution of iron ore. It was found that high-energy impulse efficiency is different upon iron-containing grains and gangue. Grindability grows in direct proportion depending on iron content. This very method can also be used for ore particles pre-weakening with their further mechanical crushing [10]. Electrical comminution finite element method on the example of iron-phosphate ore showed that the process was strongly dependent on the composition of minerals and the size and form of particles, which creates certain problems for its application, for broadly classified ore material with wide contrast of characteristics of individual ore grains in particular [11]. As of today, iron ore electrical comminution method is on the scouting stage of research and not performed in mass-production operations.

It should be noted that there are a lot of crushability (grindability) estimation techniques [12, 13]. That is the reason why data given by different researches using different methods can not be compared at all, or can be used only for qualitative but not the quantitative analysis.

The paper [14] provides experimental evidence of the high efficiency of ore crushing in centrifugal disintegrators, which stipulates the utility of further investigations in the field of material crushing mechanism in these apparatus. The assumption was the following: in decreasing power-intensity under the ore comminution processes, manufacturing content and power-intensity redistribution between the cycles of crushing and grinding towards the growth of proportion of crushing cycles in the whole process of ore disintegration can have good prospects. This idea can be realized through the reduction of crushed material size from 25–30 mm to 10–0 mm, because every millimeter of reduction of nominal crushing cycles size allows to decrease the power-intensity by 1,0–1,5 % and to increase the crushing cycles productivity by the same amount. Such a size of crushed material can be obtained in the apparatus of new generation, the most prospective being inertial crusher (KID) and centrifugal disintegrators (CD), implementing the principle of material crushing via stroke in the field of centrifugal forces [3, 14]. The study [15] shows on the example of Inguletskiy Iron Ore Mining and Processing Plant (InGOK, Ukraine), that crushers of new generation can be used both in the enterprises under construction and existent crushing plant under modernization. At the same time, extra studies are necessary to define the rational operating conditions for crushing solid materials in apparatus of new generation.

Thus, the process of disintegration of solid materials in centrifugal disintegrators had not been sufficiently studied, which restrains its industrial implementation and stipulates the necessity of further investigations in this field. In particular, dependences of grain-size composition parameters on disintegrator behavior, dependence of technological concentration parameters on crushing method, and dependence of energy parameters on disintegrator behavior are of theoretical and practical interest.

3. Investigation aim and tasks

The aim of this paper is to study the process of disintegration of solid materials in centrifugal disintegrators via stroke in the field of centrifugal forces.

The following tasks were performed in order to achieve the aim of this paper:

– identification of disintegrator rotor speed influence (and therefore the solid clot flight speed in the field of centrifugal forces) on the change of product granulometric composition, namely: determination of dependence of finished particular size fraction on disintegrator speed; determination of dependence of reduction range and finished material average particle size on disintegrator rotor speed;

– determination of crushing method influence on technological parameters of concentration: centrifugal disintegrators crushing; crushing in KMD-2200 cone crusher;

– electric power cost measurement depending on disintegrator speed;

– building of mathematical model of a process, under which material is crushed through via stroke in the field of centrifugal forces.

4. Materials and methods of material crushing via stroke in the field of centrifugal forces process study

The research was carried out using the ingoing material of magnetite quartzite sized –100 +20 mm; with strength from 12 to 16 according to Protodyakonov Rock Strength Scale.

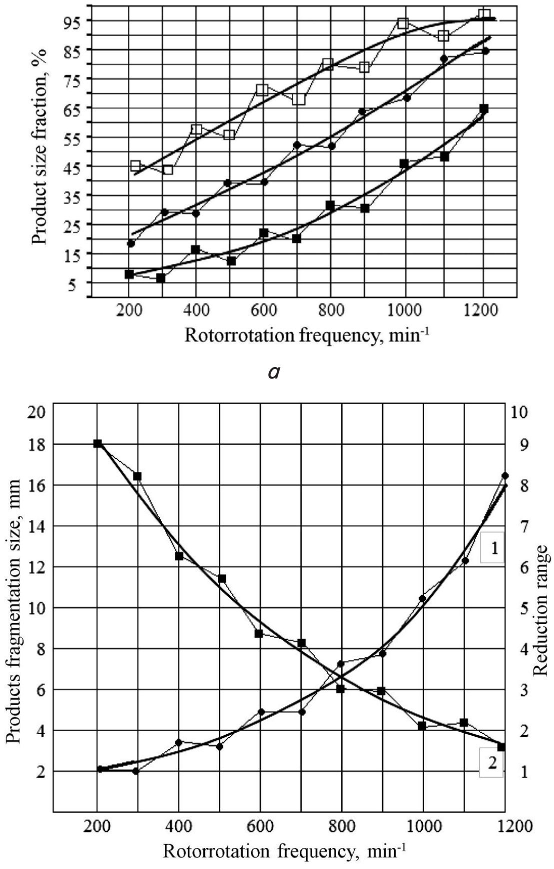
Physical simulation of crushing process was carried out in semiindustrial and industrial conditions of PJSC "Research and Design Ferrous Metal Ores Concentration and Agglomeration 'Mechanobrchormet' Institute" experimental plant and Northern Iron Ore Enrichment Works concentration plant, Ukraine (Northern GOK) using CD-10 and CD-50 disintegrators with productivity of 10 and 50 t/h.

Original material was delivered to charging apparatus and then sent to accelerated rotor brought to rotation by means of driving engine through the rotor shaft. Material sent to rotor was gripped by overspeed ribs, accelerated, thrown out of the rotor and hit the bumper plate. As a result of a hit the material crushed to the required size, herewith the size of the crushed product was adjusted by means of material flight speed, being determined by accelerated rotor rotation frequency [14].

All the studies are carried out in single-factor experiment regime with a variation of the factors: disintegrator rotor rotation frequency by means of special fluid flywheel within the limits 200–1200 min^{-1}, with disintegrator productivity 10 and 50 t/h (using conveyor ribbon-like measuring pocket). Building of the mathematical model of a process, under which material is crushed via stroke in the field of centrifugal forces, was carried out through the analytic method with further experimental validation. To this effect classical hypothesis method – one of the common approaches to disclosing the internal laws of phenomena under analysis and their theorizing – was applied [16]. When employing this method the scientific understanding is reached through the building of proper model based on assumptions about the internal structure of an object and the form of relations between its elements. Thus, the phenomena under analysis are regarded as a result of certain causal effects mechanism. The empiric basis of hypothesis method is the results of well-known advanced and technological studies of the process under analysis. This method stipulates the study of physical processes (subprocesses) according to the scheme: initial experimental basis – making a scientific assumption (hypothesis) – drawing a conclusion out of this assumption – experimental validation of conclusions (findings) or their comparison with present data and proved propositions. Validated assumptions become scientific propositions of the process under study.

5. Results of investigation of the process of crushing solid materials via stroke in the field of centrifugal forces

The technological studies established the main technological parameters of disintegrator behavior and their dependence on its high-speed mode of operation (Fig. 1).



a

b

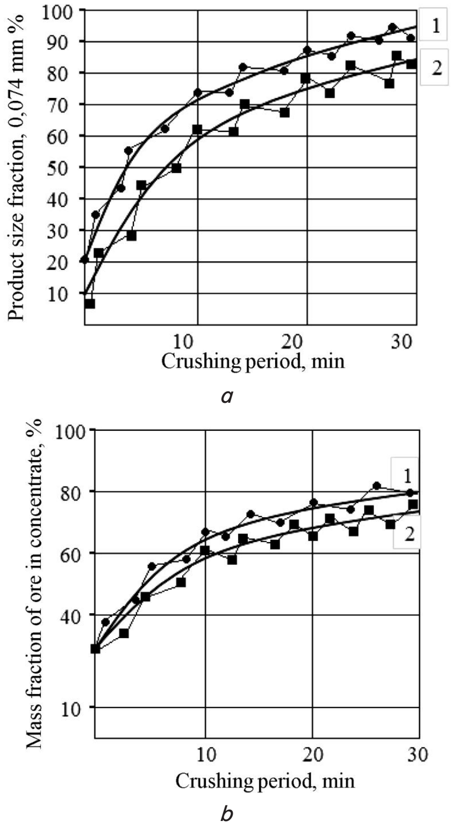
Fig. 1. Dependence of technological parameters on disintegrator mode of operation: *a* — product size mass fraction (curves 1, 2, 3 — sizes minus 10 mm, 5 mm, 1 mm respectively); *b* — reduction range (1) and average size (2)

To identify the effect of crushing method in the field of centrifugal forces on other concentration processes the comparative surveys of grindability and ability of crushed products to go through the process of concentration in KMD-2200 and CD-50 crushers were carried out.

The effect of crushing method on technological parameters of concentration are shown in Fig. 2.

The dependence of power parameters on the disintegrator mode of operation is represented in Fig. 3.

While investigating the process of disintegration of solid materials via stroke in the field of centrifugal forces, realized in centrifugal disintegrators, special emphasis should be placed on the range of rotor rotation frequency 200–1200 min^{-1}, as it is of technological importance and technologically achievable by means of special fluid flywheel use.



a

b

Fig. 2. The effect of crushing method on technological parameters of concentration: 1 — crushing in centrifugal disintegrator; 2 — crushing in n KMD-2200 cone crusher; *a* — product size fraction — 0.074 mm in crushed products, *b* — mass fraction of ore in concentrate

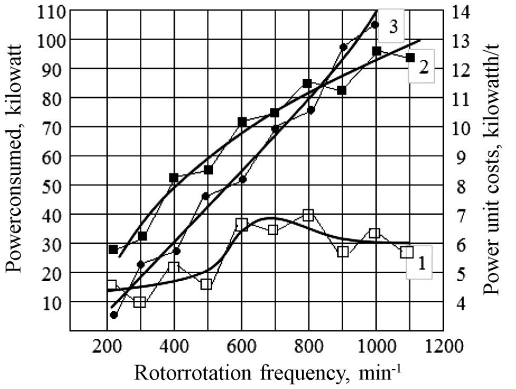


Fig. 3. Dependence of power parameters on the disintegrator mode of operation: 1 — power consumed by the idle drive; 2 — power consumed under load; 3 — power unit costs

6. Discussion of results of investigation of the process of crushing solid materials via stroke in the field of centrifugal forces

The behavior of product classes mass fraction depending on rotor rotation frequency, as can be seen in Fig. 1, *a*, depends little on product classes size over the range 1–10 mm. Directly proportional and almost linear dependence of product classes mass fraction on rotor rotation frequency is natural. Specificity is observed only at the boundary point of 1200 min^{-1}, where the curve for –10 mm class flattens out, and the curves for –5 mm and –1 mm classes still demonstrate a visible increasing behavior tendency even under higher rotor rotation frequency.

On the face of it, such a result may appear strange, as according to Rittinger's law, the energy necessary for material comminution is proportional to the change of outer specific surface, and the latter depends substantially on the product size. Yet when analyzing classic curve S (d) of outer specific surface S depending on product size d [17], it can be easily seen that nonlinearity appears only under product size reduction 0.5 mm and less (Fig. 4). And curve piece S (d) – moderate increase area S_{spec} – corresponds to range 1–10 mm (Fig. 1, *a*), as in the experiment. This fact can explain the linear and almost identical character of curves of the behavior of product sizes mass fraction depending on rotor rotation frequency in the product size classes range 1–10 mm. Nonlinear and even sharply different tendencies of this curve can be obviously expected for product classes –0.5 mm, –0.1 mm, etc. Thus, scientifically and practically this product size range (0.5–0 mm) is of special interest and it can be a subject of further investigations.

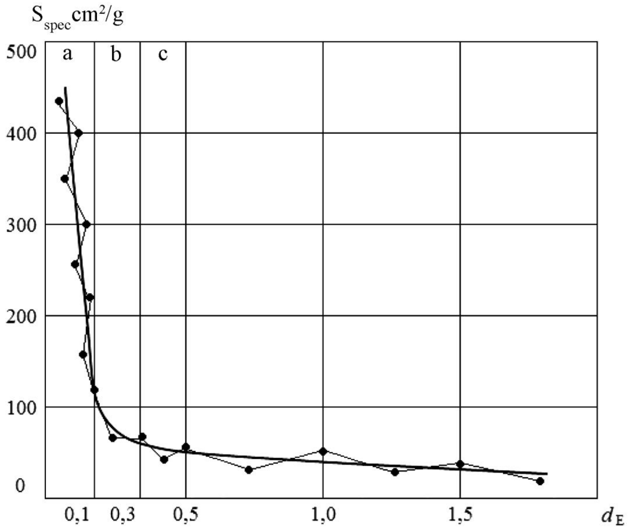


Fig. 4. Dependence of loose material outer specific surface S_{spec} on grain equivalent diameter d_E: *a* — fast increase area; *b* — medium area; *c* — moderate increase area S_{spec}

Dependence of reduction range (1) and average size (2) on disintegrator behavior (Fig. 1, *b*) corresponds to behavior of product classes mass fraction depending on rotor rotation frequency (Fig. 1, *a*). In quantitative terms when rotor rotation frequency increases in the range 200–1200 min^{-1}, average weighted size decreases from 18.3 to 3.00 mm, and reduction range increases from 1.1 up to 7.0. Herewith the tendency to reduction ratio decrease against the background of higher productivity is observed (Fig. 1, *b*).

The effect of crushing method on technological parameters of concentration (Fig. 2) shows, that mass fraction of iron in the concentrate of grind left after CD crusher is by 3.0–3.7 % higher than in KMD–2200 grind. It is explained by more selective exposure of mineral component in centrifugal disintegrator grind.

Similar behavior of curves a and b in Fig. 2 is explained by the overwhelming concentration of iron-bearing minerals in 0.074 mm class.

The study of dependence of power parameters on the disintegrator mode of operation (Fig. 3) shows, that drive power consumption grows from 26.0 to 100.0 kilowatt under utilization 75 t/h with the rotor rotation frequency increase, and when idle – from 12.0 to 37.0 kilowatt. Specific power consumption (reduction range nonmetering) changes from 0.37 to 1.4 kilowatt-hour initial power supply.

Under the disintegrator rotor rotation frequency 1200 min^{-1}, which corresponds to maximum –10, –5 and –1 class yield, power consumed under drive load is thrice as much when idle.

The hypothesis for theoretical interpretation of the process of crushing in the centrifugal field is put forward, according to which grain shattering process of the material of volume V can be represented as a series of specified geometric progression.

For example, it was experimentally found that grain of material of volume V, when accelerated to some extent on the driven element of centrifugal disintegrator, escapes through the field of centrifugal forces and when hit against the rigid obstacle (disintegrator bumper plate) crushes into n clots. In so doing the first grain of volume 1/2 V, the second of volume 1/4 V, the third of volume 1/8 V etc.

Hence, in such a case series denominator equals 2, 4, 8, 16…2k, and the series itself, and thus a scheme of crushing of original grain of volume V can be described in terms of the following geometric progression:

$$V=\frac{V}{2}+\frac{V}{4}+\frac{V}{8}+\frac{V}{16}+....+\frac{2V}{2^K}. \tag{1}$$

In this series, the last member has coefficient 2, as it is implied that the value of the finest grain of crushed material cannot be less than two molecule volumes, since it is impossible to comminute a material mechanically to the molecular level.

Under other experimental conditions (grain volume, strength, speed), material can be comminuted according to the following scheme:

$$V=\frac{2}{3}V+\frac{2}{9}V+\frac{2}{27}V+....+\frac{2}{3^{K-1}}V+\frac{2V}{3^K}. \tag{2}$$

There can exist other schemes for different conditions, but all of them in general are described with the following geometric progression:

$$V=\frac{n-1}{n}V+\frac{n-1}{n^2}V+\frac{n-1}{n^3}V+......\frac{n-1}{n^{k-1}}V+\frac{n}{n^k}V. \tag{3}$$

Exponent in these equations is found:

$$\frac{V}{n^K}\geq V_{mol};$$

$$V_{mol}=\frac{M}{\rho\cdot N_A};$$

$$\ell_q V-k\ell_q n\geq \ell_q V_{mol};$$

$$k\leq\frac{\ell_q V-\ell_q V_{mol}}{\ell_q n}, \tag{4}$$

where V_{mol} – molecule volume, V – material grain volume, M – material molar mass; ρ – real density; N_A – Avogadro number for material gram-molecule $\left(N_A=6{,}02\cdot 10^{-23}\right)$.

In the case when the volume of source material grain is 1 m^3, the above mentioned series will look like:

$$1=\frac{1}{2}+\frac{1}{4}+\frac{1}{8}+....+\frac{1}{2^{K-1}}+\frac{2}{2^K}, \tag{5}$$

$$1=\frac{2}{3}+\frac{2}{9}+\frac{2}{27}+....+\frac{2}{3^{K-1}}+\frac{2}{3^K}, \tag{6}$$

$$1=\frac{n-1}{n}+\frac{n-1}{n^2}+\frac{n-1}{n^3}+...+\frac{n-1}{n^{K-1}}+\frac{n}{n^K}. \tag{7}$$

Thus, based on the introduced approach and representation of source material grain comminution as the geometric progression of the above mentioned kind, we can forecast the quantity and size of all the spectrum of fragments obtained out of the source grain. Let us now consider the mechanism of separation of material grain escaping through the field of centrifugal forces when hit against the rigid obstacle. Initial conditions are: grain lateral dimension is less than rigid obstacle (armor) thickness, that is $\delta_{\delta\rho}\geq\delta_{\kappa}$; the period of time under which sound goes through the armor is greater than it goes through the material grain $t_3\text{v.br.}\geq t_3\text{v.k}$; elastic limit on grain pressing (G) is less than the grain force ratio in effect, to grain area $\frac{F_K}{S_K}$; material grain is of oval form, close to sphere form with diameter d (or radius r). Material grain is accelerated up to speed V by driven element of centrifugal disintegrator – accelerated rotor – and moves in the field of centrifugal forces till comes to rigid obstacle – disintegrator bumper plates (fettling). Stroke is direct, central, that is at 90° angle, perpendicularly to a plate. Then the largest area of grain lateral dimension is:

$$S=\pi\cdot r^2=\frac{\pi\cdot d^2}{4}.$$

According to the Newtonian law, the force of the stroke is:

$$F=m\cdot a,$$

where m – ore grain mass, kg; a – grain acceleration, obtained when stopped (speed suppression to zero); F – force, affecting the grain, kg.

Material mass equals:

$$m=\rho\cdot V_0=\rho\cdot\frac{4}{3}\pi\cdot r^3=\rho\frac{\pi d^3}{6},$$

where ρ – material density, kg/m^3, V_0 – material grain volume, m^3.

Then effective stroke force equals:

$$F=\frac{\rho\cdot\pi\cdot d^3}{6}\cdot a. \tag{8}$$

Acceleration per time of stroke is

$$a=\frac{v}{t}, \tag{9}$$

where v – speed under the stroke; t – time of force action.

Proceeding from the assumption that time of force action corresponds to the time of distribution of elastic wave in the material grain under free stroke, let us put down:

$$t=\frac{d}{u}, \tag{10}$$

where u – speed of elastic wave distribution in the material (acoustic speed).

Taking into account the formulae (9) and (10), let us determine the force in effect under free stroke:

$$F=\frac{\rho\cdot\pi\cdot d^3\cdot v\cdot u}{6d}. \tag{11}$$

Material grain strength condition is represented as:

$$\frac{F}{S}\langle\left[G\right], \tag{12}$$

where $\left[G\right]$ – given material allowable failure strain; S – material grain lateral dimension area:

$$S=\frac{\pi d^3}{4}. \tag{13}$$

Taking into account the expressions (11) and (13), the grain strength condition will be represented as:

$$\frac{\dfrac{\rho\cdot\pi\cdot d^3\cdot v\cdot u}{6d}}{\dfrac{\pi d^2}{4}}\langle\left[G\right]. \tag{14}$$

After simple transformations we get:

$$\frac{2}{3}\rho\cdot v\cdot u\langle\left[G\right]. \tag{15}$$

Then strength condition is represented as:

$$v\langle\frac{3}{2}\cdot\frac{\left[G\right]}{\rho\cdot u}. \tag{16}$$

Hence, the condition of material destruction under free direct stroke in the centrifugal forces field appears:

$$v\geq\frac{3}{2}\cdot\frac{\left[G\right]}{\rho\cdot u}. \tag{17}$$

When finding the destructive speed under the indirect stroke, it is necessary to take into account the value of the angle of material and rigid obstacle meeting (centrifugal disintegrator bumper plates):

$$v\geq\frac{3}{2}\cdot\frac{\left[G\right]}{\rho\cdot u\cdot \mathrm{Sin}\lambda}. \tag{18}$$

The smaller the $\mathrm{Sin}\lambda$, and hence the meeting angle, the greater the boundary speed of particle escape. For instance, for λ=30° it grows twice in comparison with boundary speed under the meeting angle $\lambda=90°$. Let us assume that minimal boundary speed calculated using the formula (18) $v_{\lim}$ under which material grain starts crushing, provides its minimal destruction and causes the reduction of its lateral dimension half (that is the degree of piece reduction equals 2).

When it is necessary to reduce the size of ingoing material a third, the speed should be stepped up half as much; in order to reduce the size quarter, escape speed should be stepped up twice and so on. In such a way, in order to provide the required degree of material reduction n, it is necessary to introduce a coefficient n/2. Then the required speed of material escape out of the operating cylinder of centrifugal disintegrator, necessary for providing the required reduction degree, can be calculated by the formula:

$$v=\frac{2}{3}\cdot\frac{\left[G\right]}{\rho u4}\cdot=\frac{n}{2}=\frac{3}{4}\cdot\frac{G\cdot n}{\rho\cdot u}, \tag{19}$$

for disintegrator, designed in a way to provide the maximum meeting angle λ=90° for material under crushing process and bumper plates.

$$v=\frac{3}{4}\cdot\frac{\left[G\right]\cdot n}{\rho\cdot u\cdot \mathrm{Sin}\lambda}, \tag{20}$$

with material and bumper plates meeting angle λ.

Value ρu in the denominator of obtained formulae is material acoustic stiffness. Thus, on the basis of represented above analytical dependences, acoustic stiffness is one of the intensity criteria, when distracting a material with free stroke. Let us introduce its conventional representation:

$$A=\rho\cdot u$$

and we obtain the final formula for calculating the material escape speed out of the accelerated disintegrator rotor, which provides required destruction of material:

$$v=\frac{3}{4}\cdot\frac{\left[G\right]\cdot n}{A\cdot \mathrm{Sin}\lambda}. \tag{21}$$

The introduced theoretical interpretation of the process of crushing a material via stroke in the field of centrifugal forces is recommended for application both for describing the qualitative state of centrifugal disintegrator material destruction and calculating speed operation mode when designing the centrifugal disintegrators.

7. Conclusions

As a result experimental and theoretical investigation of magnetite quartzite crushing in CD-50 centrifugal disintegrator and KMD-2200 cone crusher it was established that:

1. Mass fraction of size classes minus 10 mm, 5 mm, 1 mm of material crushed in centrifugal disintegrator is in direct proportion to rotor rotation frequency. The character of this dependence is close to linear. Specificity is observed only at the boundary point of 1200 min^{-1}, where the curve for the –10 mm class flattens out, and the curves for –5 mm and –1 mm classes still demonstrate a visible increasing behavior tendency even under higher rotor rotation frequency.

Size classes minus 10 mm, 5 mm, 1 mm product yield under the disintegrator rotor rotation frequency 1200 min^{-1} is 95 %, 87 % and 60 % respectively. The degree of magnetite quartzite crushing increases monotonously from 1.1 to 7 under the increase of the disintegrator rotor rotation frequency from 200 to 1200 min^{-1}.

Average size of product material under the increase of the disintegrator rotor rotation frequency from 200 to 1200 min^{-1} decrease from 18 to 3.3 mm.

2. Mass fraction of iron in the concentrate of grind left after CD crusher is 3.0–3.7 % higher than of grind left after KMD-2200. It is explained by more selective exposure of mineral component in centrifugal disintegrator grind.

It was experimentally established that under the same size of ingoing ore 100–0 mm in the grind product of CD-50 crusher, mass fraction of classes minus 10, 5, 1 and 0.074 mm is 42, 32, 13.5 % greater than that of KMD-2200 grind products. Grindability of ore after CD-50 is 10 % higher, and its ability to be concentrated on average 3.3 % higher after KMD-2200 on the account of better mineral elements opening.

3. For centrifugal disintegrators drive power consumption grows from 26.0 to 100.0 kilowatt under utilization 75 t/h with the rotor rotation frequency increase, and when idle – from 12.0 to 37.0 kilowatt. Specific power consumption (reduction range nonmetering) changes from 0.37 to 1.6 kilowatt-hour initial power supply.

4. Mathematical model of a process under which material is crushed through via stroke in the field of centrifugal forces

has been developed. The final formula for calculating the material escape speed out of the accelerated disintegrator rotor, which provides required destruction of material, was obtained by means of classical hypothesis method application.

Thus, the use of centrifugal disintegrators on the stages of fine grinding instead of traditional cone and hammer crushers will allow to decrease the power unit costs for fine grinding substantially. Moreover, a decrease of grind product size from 25 mm to 10 mm will allow to reduce the expenditure of power on grinding no less than 1 % per each millimeter of size reduction of grind product arriving to the mill.

Carried out scientific research is a final stage of a complex work on development, research and implementation of technology of magnetite quartzites centrifugal disintegrator crushing. On the basis of obtained positive results, the authors intend to investigate the possibility of implementation of the centrifugal disintegrator for crushing of other qualitatively similar raw material, in particular, natural building stone for crushed stone production.

In addition, the application of the acoustic method, being recently wide used by national scientists when studying the regularities of solid material destruction, is considered to be rational in further studies of centrifugal disintegrators.

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