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Iron ore benefication processes optimization

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Summary. Optimal separation characteristics for the spiral classifier, operating in a closed loop with primary reduction stage ball mill of the processing plant, the deslimer and flotation machine were obtained in this work.

These characteristics were obtained by Sugeno fuzzy model, information about the performance of technological units, pulp density and solid phase particle size distribution dynamics under the radiation pressure of a high-energy ultrasound as well as economic indicators of the process.

Key words: mineral processing, high-energy ultrasound, particle size distribution, the characteristics of pulp.

INTRODUCTION

Process optimization of mineral processing requires a rigorous mathematical and economic-mathematical methods for calculating the optimal separation limits φ_{sopt} of physical properties variation range of the feedstock particles [Tihonov 1984].

A compact theory of the benefication processes, based on the concepts of minerals fractional composition and separation characteristics of processing machines, presented in [Tihonov 1984]. Fractional composition allows to estimate the distribution of pulp solid phase and mineral components by fractions, differing by physical properties of the particles. Separation characteristics estimates the extraction degree of each fractions to the concentrate in relation to processing raw materials. These two concepts allows to predict the benefication technological results (recovery, content, extraction) of any material by any process flowsheet, compare with each other processing machines and process flowsheets and solve the economic optimization problems of multicomponent raw benefication etc.

The conceptions of mineral particles $\gamma(\xi)$ and valuable components $\beta(\xi)$ distribution by fractions with different physical properties ξ, introduses for quantitative evaluation of mineral products while the separation characteristics $\varepsilon(\xi)$ evaluating the extraction ε of narrow mineral fractions to the products, introduces to quantify agregates and flowsheets.

The solution of this task allows to define both the best benefication technological line structure, and the technological units parameters providing its maximum productivity at set quality of the final product and the minimum costs for process.

Since useful iron-containing minerals have strong magnetic properties, the most logical and promising way of processing is the combined use of magnetic fields and other factors, for example, ultrasound [Morkun 1998, Morkun 2004, Porkuian 2005, Porkuian 2006, Kobus 2008].

The key characteristic is the crushed ore particle-size distribution function for a large class of concentrating technologies. To build a particle-size distribution function of pulp solid phase is possible by prior spatial particle separation in the test medium and using the radiation pressure of a high-energy ultrasound for these purposes is presented in [Morkun 2010] This approach will be used to evaluation of particle vector velocity field $\vec{v}(\xi, x, y, z, t)$ and finding the function of $\gamma(\xi,x,y,z,t)$.

RESEARCH OBJECT

The task of research is mathematical modeling of the benefication technology separation processes, analytical description and pilot testing of the high-energy ultrasound radiation pressure effects on pulp flow to estimate crushed ore particle-size distribution, determine its mineral species and build the separation characteristics of classifying and processing units.

RESULTS OF RESEARCH

The expression for the radiation pressure force, represented by total and differential cross sections for scattering and absorption of ultrasonic waves on the particles is predented in [Morkun 2007]:

$$F_r = \frac{I}{c}\left(\sigma_p + \sigma_s \mu\right), \qquad (1)$$

where: I - incident wave intensity; c - velocity of wave propagation;

$$\mu = \frac{2\pi}{\sigma_s} \int_{-1}^{1} d\cos v \frac{d\sigma}{d\Omega}(\cos v)(1-\cos v)$$

For spherical particles of radius r the differential scattering cross section is given by:

$$\frac{d\sigma}{d\Omega}\left(\cos v\right) = \frac{r^2}{9}(kr)^4\left(a_1 - \frac{3}{2}a_2 \cos v\right)^2, \qquad (2)$$

where: $a_1 = 1-\left(rc^2/\rho_{\text{т}} c_{\text{т}}^2\right)$;

$a_2 = 2\left(\rho_{\text{т}} - \rho/2\rho_{\text{т}} + \rho\right)$;

$\rho_{\text{т}}, c_{\text{т}}$ - density of a particle and ultrasound velocity in a particle material;

ρ - medium density.

At high frequencies $\sigma_p \ll \sigma_s$, thus

$$F_r = \frac{4}{9}\pi r^2 (kr)^4\left(a_1^2 + a_1 a_2 + \frac{3}{4}a_2^2\right)\frac{I}{c}. \qquad (3)$$

Behavior of the particles concentration and their distribution by size in the field of high-energy ultrasound depends on the mass of the particle, the frequency and intensity of actuating radiation[Landau 1954, Morkun 1999]. Let's evaluate the effect of the ultrasound radiation pressure on the change in concentration of particles of radius r. Let's suppose that slurry flows with velocity V in the positive direction of the x-axis and $n_r(Z,t)$ is a particles concentration of radius r at a depth Z in time t (Fig. 1). On this basis:

$$\frac{\partial n_r(Z,t)}{\partial t} = -\frac{\partial}{\partial Z}\left[V_r(Z,t)n_r(Z,t)\right] \qquad (4)$$

where: $V_r(Z,t)$ is the velocity of the particle displacement of radius r with coordinate Z in ultrasonic field.

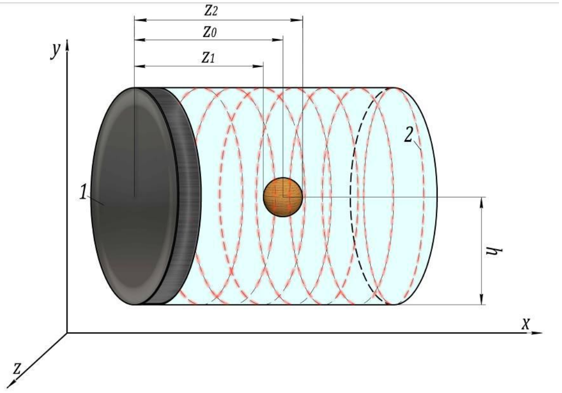

Fig. 1. Motion of the crushed ore particle in the pulp flow under the radiation pressure of high-energy ultrasound

Numerical characteristics of ultrasonic pulse propagation process in the the pulp produced with HIFU Simulator v 1.2 [Soneson 2011].

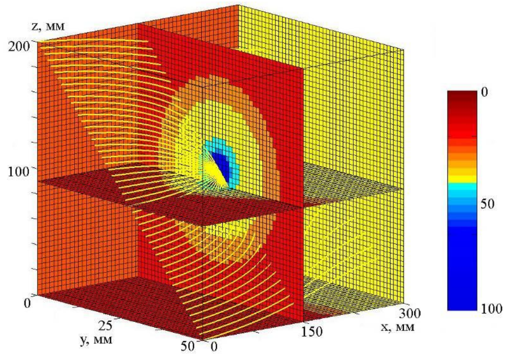

Fig. 2. Intensity step sampling of the ultrasonic field in the spatial coordinates

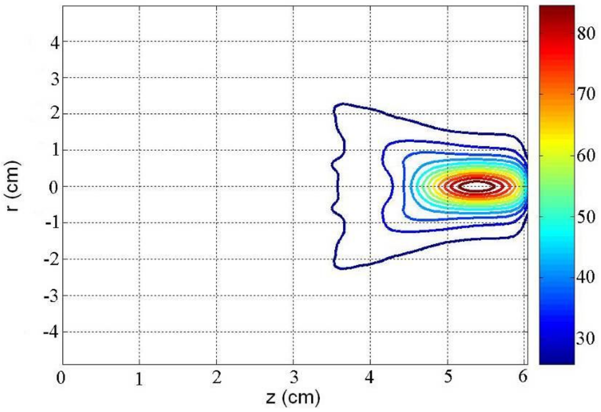

Fig. 3. Power distribution of the ultrasonic radiation at a distance z = 5,37 cm from the source.

The results of three size fractions ore particles displacement modeling in the pulp flow under radiation pressure of the high-energy ultrasound are shown in Fig. 4. Positions of each particle size on the tenth step connected by solid lines.

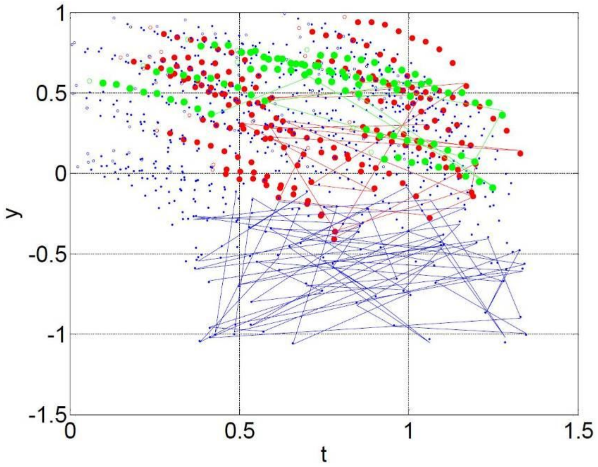

Fig. 4. The results of three size fractions ore particles displacement modeling under radiation pressure of the high-energy ultrasound

The developed program calculates the high-energy ultrasound intensity at a certain point of the measuring range which allows to implement the predicted displacement of crushed ore particles of a certain mass and changes in the size distribution of the pulp solid phase under the controlled high-energy ultrasound radiation pressure.

Optimal separation characteristics for the spiral classifier, operating in a closed loop with primary reduction stage ball mill of the processing plant, the hydrocyclone and flotation machine were obtained in this work.

These characteristics were obtained by Sugeno fuzzy model, information about the performance of technological units, pulp density, solid phase particle size distribution dynamics under the radiation pressure of a high-energy ultrasound as well as economic indicators of the process. Mean square error of the model identification for control sample of 36 points is 0.94.

Flotation is the most complete and versatile operation of mineral processing.

Dynamics and results of the flotation process depends on many factors. There are the mineral composition, the nature of impregnation, and other minerals properties, solid phase size distribution, the density and temperature of the pulp, composition of the water, reagent treatment, flotation machine design, etc [Glembotskyi 1981, Brożek 2012].

For the simulation of physical processes that determine flotation, accurate data of the gas phase characteristics, the most important of which are the concentration and gas bubbles distribution, are required. These parameters are highly dependent on a variety of operational, technical, and physical-chemical factors, the effects of which should be considered in the modeling of the flotation process. [Miskovic 2011]

Efficiency of the flotation process is directly related to the number of collisions between particles and bubbles, which are strongly dependent on the ratio of particle diameter to bubble diameter. In a flotation system where bubbles are much larger than particles, a flow streamlines around the bubble sweep particles near the bubble surface and prevents attachment of valuable mineral particles to the bubble. Hence, in order to provide optimal conditions for the flotation, it is necessary to generate bubbles with sizes similar to the size distribution of particles in the pulp.

Bubble size is considered to be one of the most important parameters affecting the performance of froth flotation cells. However, monitoring, controlling and predicting bubble size is a very challenging task[Brożek 2012].

For floatation process intensification the method of the combined effects of ultrasound on reagents and the liquid phase of the pulp is offered.

The use of ultrasound in the flotation technology related to a number of specific phenomena accompanying the propagation of ultrasonic vibrations in liquid media. Among these phenomena the special place is taken by cavitation. It is expressed in the appearance of gas bubbles (cavities)in the liquid in which ionization of molecules and atoms, pressure (up to several thousand atmospheres) and temperature (hundreds of degrees) increasing. It is known that gas (cavitation) bubbles are formed easily at the liquid-solid interface, energetic acting on the surface of the latter [Chernykh 2003].

Ultrasonic pulp treatment significantly increases floatability of minerals and reduces reagent-collector consumption. Treatment of the ore particles surface layer leads to the emergence of active regions with uncompensated bonds, which is one of the reasons for sonicated minerals floatability improvement .

The proposed flotation control method allows to operate the phase composition of pulp more effectively, it is more eco-friendly by reducing the amount of flotation reagents, as well as energy efficient.

An important element in iron ore concentrate production string of mining-and-processing integrated works is hydraulic benefication in deslimers [Shohin 1980, Shinkorenko 1980], the application of which, can improve the iron total mass fraction in underflow to 0.5 – 2,3%, depending on the stage of benefication.

A characteristic feature of the feedstock separation process in deslimers is the feed stream power formation. [Lyashchenko 1940] These flows are the result of the movement of the solid phase particles, the division of which is due to their different gravitational size. Exactly these flows generated by initial feed supply, providing the ability to separate the solid phase components and to obtain underflow with high content of useful component.

It is established that efficiency of hydraulic benefication process increases at longer interaction of initial raw material particles with the two-phase medium in the reception capacity of a deslimer, namely in a zone of airborne particles. Hence it was offered to change the spatial orientation of a initial feed stream with traditionally descending to the ring - radial. Change of initial feed stream spatial orientation leads to change of a particles movement trajectory allows to remove littering nonmetallic particles of -0,025+0 mm to the drain.

The calculation of ore particle mass hydraulic granularity with size of - 0.07 + 0 mm with a density of 2.6-4.2 g/cm^3, suggests that the hydraulic granularity is related with geometrical parameters of particles and their density. Change dynamics of a magnetite ore hydraulic granularity has a parabolic dependence of density from geometrical parameters.

Analysis of the calculations results showed that mostly rock and re-crushed ore particles with high-grade joints (which is basically less than 0.025 mm) get to the drain with updraft flow velocity of 0.0025 m/s for the radial initial feed of deslimer (with respect to 9 m-long deslimers).

The presence of the larger particles in the drain due to the turbulent flows, which spontaneously perform mass transport of solids to the upper part of the tank of drain formation zone.

Radial feed has the advantage over the descending feed because the finding time of suspended particles in the apparatus airborne area higher in 1.8-2 times than descending feed. Flow distance, which it passes to interacting with the thickening area is 1.6 m. -1.8 Whith descending feed this value is 0.8 m.

It is established that desliming efficiency depends on particles finding time in the apparatus airborne area. This time were 5,2-5,5 seconds with a radial feed (with efficiency of 22,1-22,3%) that is almost twice more, than with a descending feed - 2-2,2s. where desliming efficiency is 17,8-18%.

Proposed benefication technologies optimisation methods is expedient to use in automatic control systems of iron ore beneficiation technological processes [Morkun 2007, Ulshin 2010].

CONCLUSIONS

Evaluations of size distribution and particle velocities vector field $\vec{v}(\xi, x, y, z, t)$ of pulp solid phase at any technological process point *(x,y,z)* helps to form the status function $\gamma(\xi,x,y,z,t)$ and determine the separation characteristics of $\varepsilon(\xi)$ of classifying and processing machines based on economic performances.

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ОПТИМИЗАЦИЯ ПРОЦЕССОВ ОБОГАЩЕНИЯ ЖЕЛЕЗНОЙ РУДЫ

Владимир Моркун, Сергей Гончаров,
Андрей Пикильняк, Андрей Кривенко

Аннотация. В работе получены оптимальные сепарационные характеристики для спирального классификатора, работающего в замкнутом цикле с шаровой мельницей первой стадии измельчения обогатительной фабрики, дешламатора и флотационной машины. Эти характеристики получены при помощи нечёткой модели Сугэно, информации о производительности технологических агрегатов, плотности пульпы, динамики гранулометрического состава её твёрдой фазы под действием радиационного давления высокоэнергетического ультразвука и экономических показателях процесса.

Ключевые слова: Обогащение полезных ископаемых, высокоэнергетический ультразвук, распределение частиц по размерам, характеристики пульпы.