Pulse method of magnetite demagnetizing

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ABSTRACT: The article presents experimental results of classification of magnetized and demagnetized suspension of magnetite concentrate. It shows a high degree of demagnetization in a pulsed mode. The aim of this article is to evaluate effectiveness of magnetite suspension classification with implementation of pulse demagnetizing method, using experimental results.

1 INTRODUCTION

To provide disclosure of magnetite grains during the enrichment of magnetite quartzite there is a need to mill them to a particle size less than 50 μm. This process is carried out in ball mills with three-stage central discharge. Presence of the finished class in grinding zone reduces speed of the process and leads to undesirable overgrinding of magnetite grains. As a consequence, it increases the cost of magnetite quartzite enrichment. Discharge of the finished class is performed by external devices such as spiral classifiers at first stage of grinding and hydrocyclones at the second and third stages. The value of circulating load coefficient of the mill, which exceeds 200% in existing enrichment schemes, depends on the efficiency of the classifying devices. Efficiency of classification of magnetite particles with fineness of 50 microns in hydrocyclones of HC-500 series does not exceed 80%, if not to take into account their magnetic flocculation.

Magnetic separation is applied after each stage of grinding. As magnetite particles have residual magnetization, it leads to their magnetization. Magnetic flocculation, occurring in suspension of magnetized particles, increases their effective size. It further decreases the classification efficiency and increases the coefficient of circulating load.

Furthermore, magnetite particles less than 74 μm are widely used in coal preparation as a weighting agent for dense-media separation. Magnetic flocculation of the weighting particles leads to faster delamination of suspension. It increases lower size limit of enriched coal and enhances error of separation.

In general, it can be assumed that residual magnetization of magnetite plays a negative role in process of minerals' enrichment. Its reduction, or demagnetization of particles, is a burning task.

2 DEMAGNETIZATION METHODS

Ferromagnetic loses its magnetic properties when it is heated to a temperature above the Curie point. For magnetite it is equal to 580ºC. Such a method of magnetite demagnetization is the most comprehensive, but it is unacceptable in mineral processing due to its high energy expenditure.

Another demagnetization method is to place a particle in an external alternating magnetic field, with a smooth induction decrease from a maximum value, which should be greater than the residual magnetization, to zero. In this case, demagnetization of fixed particles will occur according to the hysteresis curves shown in Figure 1 (Vikulov et al. 2012).

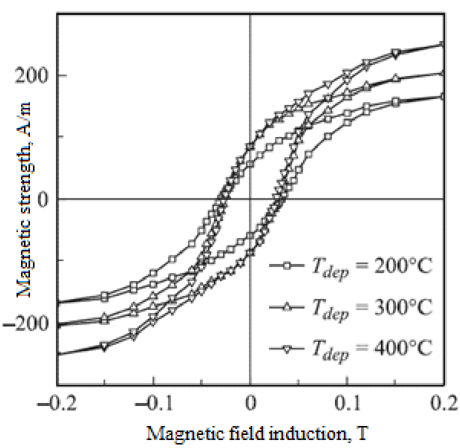

Figure 1. Hysteresis loops of magnetite films obtained at different substrate temperatures.

This mode of external field influence can be achieved in special devices, which are used for demagnetizing. Their concept is shown in Figure 2. Structurally, it is a solenoid – tube of non-magnetic material on which sections of specially designed electromagnet are situated. It provides a smooth reduction of alternating magnetic field induction during the magnetite particles moving through the tube (in the direction shown by arrow) while the solenoid is constantly connected to an AC power source. Degaussing occurs according to the hysteresis curves during the ejection of particles from the solenoid, wherein the ejection period should be at least an order of magnitude greater than the period of alternating current. Capacitor is connected in parallel to the solenoid, providing currents resonance at mains frequency to reduce power consumption. Quality factor (Q-factor) of the formed oscillation circuit must be over 10, so the coils are made of expensive copper. For example, weight of the coil with the pipeline diameter of 450 mm reaches up to 500 kg.

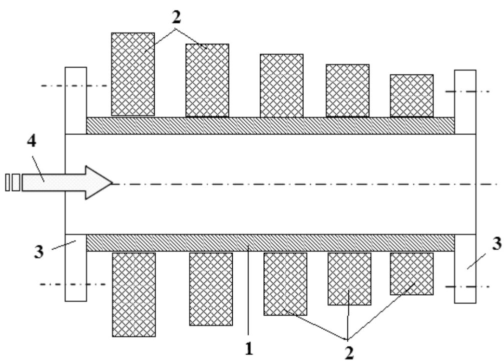

Figure 2. Demagnetizing apparatus: 1 – pipe of non-magnetic material; 2 – coils of electromagnet; 3 – flanges; 4 – direction of magnetite slurry flow.

On the other hand, damped current oscillations can be set up in the solenoid coil, and the number of oscillations should be greater than 5, which is ensured by the appropriate quality of the oscillatory circuit. In this case, all the particles located inside the solenoid, where maximum magnetic field induction is greater than their residual magnetization, will be subjected to demagnetization (Berezniak et al. 2012).

For this purpose we designed laboratory apparatus for degaussing of magnetite suspension. It follows the design of a typical solenoid, where damped oscillations are excited and through which a magnetite suspension passes. The outer and inner coil diameters are 20 mm and 12 mm respectively, and its length is 130 mm. The solenoid is a three layers winding of copper wire with a diameter of 1.2 mm and comprises 300 turns. Its inductance is 220 μH and active resistance is 0.5 Ω.

Damped oscillations in the solenoid are excited by a generator. See the change of the magnetic field induction in the center of the solenoid in time in Figure 3.

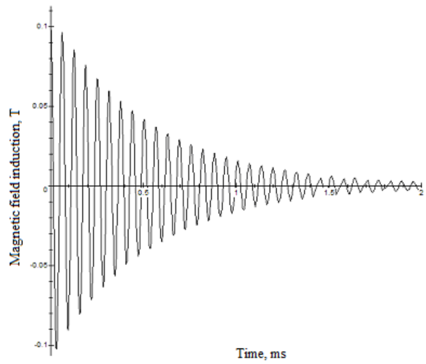

Figure 3. Dependence of magnetic field induction in the center of the coil on time.

3 EXPERIMENTAL RESULTS

We carried out a research and studied suspension demagnetization on magnetite concentrate after flotation from Ore Dressing Plant “Poltavskiy” (Poltava ODP). Suspension of magnetite with a solid content of 350 kg/m^3, pre-magnetized in a constant magnetic field with induction of 0.35 T and stirred, was passing through a glass tube with inner diameter of 6 mm, which was located inside the solenoid.

Submission of suspension in the tube was implemented via funnel. Volumetric flow rate of slurry was $1.5\ 10^{-5}$ m^3/s, the speed of its movement in solenoid was 0.53 m/s. Thus, residence time of the particles of magnetite inside solenoid was 245 ms. Cycle time was 120 ms, so every particle of magnetite passing through solenoid was demagnetized at least twice.

Effects of alternating magnetic field on the slurry flow were evaluated by optical testing of pulp samples. See the magnetized slurry optical testing in Figure 4 and optical testing of slurry which has undergone demagnetization in Figure 5.

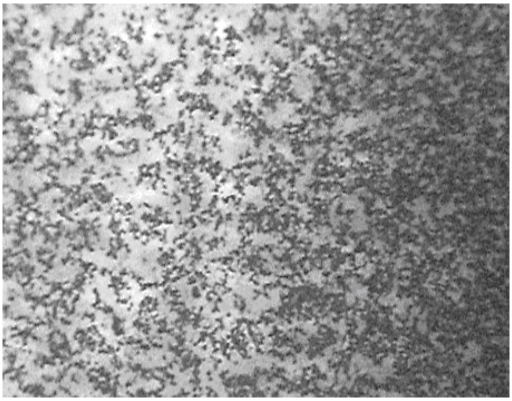

Figure 4. Magnetized slurry optical testing.

Figure 5. Demagnetized slurry optical testing.

Analysis of the results shows that performed magnetic exposure leads to demagnetization of pulp particles and significantly reduces the size of their aggregates. At the same time, physical impact on the suspension does not affect the structure and size of aggregates.

Study suspension was stirred in glass cylinder with a diameter of 55 mm and a height of 23.5 cm, and then the time of movement of sediment and clarified zone interface was recorded to determine the settling velocity. Lack of experimental points on demagnetized magnetite settling curve is caused by formation of the transition zone, consisting of magnetite and quartz fine particles. Only quartz particles were remaining in clarified zone (Berezniak et al. 2012).

Results of research in the form of charts are shown in Figure 6.

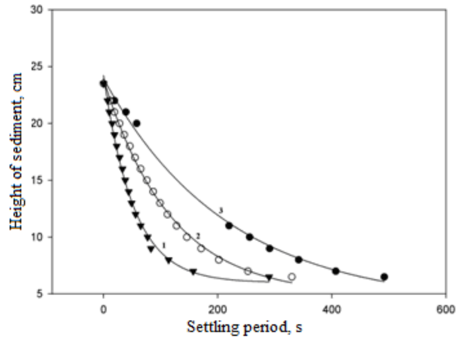

Figure 6. Dependence of magnetite sediment height on time. 1, 2 and 3 – magnetized, initial and demagnetized magnetite suspension respectively.

As can be seen from graphs of magnetite settling, the average settling rate of demagnetized magnetite suspension is 3.4 times less than that of magnetized and 1.7 times less than that of initial suspension.

Furthermore, we performed the study of classification of magnetized and demagnetized magnetite suspension, prepared from Poltava ODP concentrate, on a laboratory model of hydrosizer. Content of magnetite in concentrate was 69%, and content of less than 50 microns particles was more than 94%.

Results of research are shown in Tables 1 and 2.

Table 1. – Dependence of critical size of minerals on the flow rate in hydrosizer.

Mineral	Density, kg/m^3	Flow rate, mm/s	Calculated boundary grain size, µm
Magnetite	5400	17.4	85.2
		6.63	52.6
Silica	2700	17.4	137.1
		6.63	84.6

Table 2. – Distribution of magnetite suspensions during the separation in hydrosizer.

Calculated boundary grain size for magnetite, µm	Product yield, %			
	Magnetized		Demagnetized	
	Overflow	Underflow	Overflow	Underflow
85.2	51.2	48.8	93.1	6.9
52.6	23.1	76.9	79.7	20.3

Suspension was classified at two upstream rates. As can be seen from Table 1 at a rate of 17.4 mm/s virtually all magnetite and silica particles should fall into the overflow product. However, after magnetization of slurry the yield of the overflow product was 51.2%. With nearly all the silica particles were carried into the overflow (with the exception of a small amount of beans entrapped in magnetic floccules), we can conclude that more than a half of magnetite particles forms floccules larger than 85 microns. After demagnetizing the yield of overflow product was more than 93%. It indicates fairly complete demagnetization of magnetite particles.

At a flow rate of 6.63 mm/s more than a half of the magnetite and all silica particles should fall into the overflow. However, less than 20% of magnetite particles fell into the overflow product as a result of magnetic flocculation. As follows from Table 2, quantity of magnetite with particle size of less than 53 microns that fell into the overflow product after demagnetizing is 3.75 times greater than without demagnetizing. That also indicates a sufficiently complete demagnetization of magnetite particles.

4 CONCLUSIONS

To sum up, putting the demagnetization apparatus before the operation of classification of the ground product will significantly reduce the circulating load of the mill. Thus, the application of the pulse method of magnetite demagnetizing in the flow chart of magnetite quartzite enrichment will improve its overall efficiency and reduce energy costs.

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