Reduction of Mineral Overgrinding in Sulfide Ore Dressing Technology

T I Intogarova¹, O S Valieva², Y P Morozov³

¹Mirny Polytechnic Institute (Branch), Ammosov North-Eastern Federal University, 14, Oyunsky ave., Mirny, 678170, Russia
²Mirny Polytechnic Institute (Branch), Ammosov North-Eastern Federal University, 14, Oyunsky ave., Mirny, 678170, Russia
³Ural State Mining University, 30, Kuibyshev ave., Yekaterinburg, 620144, Russia

E-mail: tatyana.intogarova@mail.ru

Abstract. The paper briefly considers the specifics of the material composition of sulfide ores and reflects the causes of losses in dressing. The basic dressing principles are given. The main ways to reduce ore overgrinding are briefly specified and described. The concept of flotoclassification and its relevance in closed-circuit grinding is described. The flowsheets of grinding and flotoclassification of sulfide ores are substantiated. Possible options of flotoclassification flowsheets in closed-circuit grinding are described. The use of flotoclassification in closed-circuit grinding of the hydrocyclone overflow allows obtaining an on-spec concentrate in the overflow of the tapered launder. Flotoclassification in closed-circuit grinding under laboratory conditions has been simulated. The experiment is described in detail. The simulation scheme, the finished product balance, and the qualitative and quantitative diagram of flotoclassification in closed-circuit grinding are given. The experimental results show the efficiency of the proposed way of reducing mineral overgrinding in the sulfide ore dressing technology.

1. Specifics of the material composition of sulfide ores
Copper sulfide, copper-zinc and polymetallic ores are characterized by very complex textural and structural parameters. The impregnated ore textures are represented by large irregular accumulations, areas of fragments of complex sulfide formations, shale laminated textures with impregnated sulfides, and coherent formations with sulfide and rock mineralization.

Sulfide ores contain several sulfide generations with different physical and mechanical properties, density, microhardness, and various trace impurities [1-3].

The complexity of the processed ore material composition, the high interpenetration of useful minerals cause difficulties in the exposure of these minerals during grinding. The mineral exposure degree depends on many factors and increases with a decrease in the size at which secondary slurry is formed [4].

In real conditions, the ore contains the mineral grains in a wide range of sizes, which have various shapes and are unevenly distributed in the rock; therefore, when exposing the bulk of the minerals during grinding, part of the minerals are over ground and secondary slurrys are formed, which themselves float poorly and have a negative impact on the flotation of floating minerals [5-11].
Thus, the underexposure of mineral aggregates and the formation of secondary slurries in grinding are the main causes of high loss of metals in the final flotation tailing and in different concentrates.

2. Ways to reduce mineral overgrinding

As a result of a theoretical analysis of the mineral phase exposure in the preparation of the ore for dressing [6], the principles of classification of grain-size categories and building dressing flowsheet based on the exposure characteristics and grain-size distribution of the ore have been formulated. According to the G.O. Chechotta’s ‘Grind nothing extra!’ and V.Z. Kozin’s ‘Dress nothing extra!’ principles, when building dressing flow sheets, it is advisable to extract the valuable component particles into a concentrate, and waste rock ones into tailings as they are exposed, which sharply reduces the mineral overgrinding.

A way to reduce the mineral overgrinding is the use of preferred fracture in the formation of structural elements and exposure at each stage of the feedstock processing [12].

Another way to reduce the mineral overgrinding when grinding ore before flotation is the use of the fractional concentration principle, which is widely used in the staged flotation flow sheets [13, 14].

According to [6], the general dressing scheme should comprise five stages. At each stage, one of the specified grades is isolated, and undresses fine grains are removed. The undressed grade should be isolated at each stage of dressing since fine grains hinder the dressing. However, the non-ferrous metal ore dressing flow sheets have a completely different structure. As a rule, such flow sheets are multistage, and with each stage, the properties of aggregates in terms of the separating feature magnitude become closer to those of mineral pieces. In such flow sheets, rock is isolated at each stage, but in this case, the useful mineral is overground. It turns out that such flow sheets do not meet the basic requirements, i.e. grind, or dress nothing extra.

3. Flotoclassification in closed-circuit grinding

An effective way to improve flotation performance by reducing mineral overgrinding is the use of flotoclassification in a closed-circuit grinding [15, 16].

Grinding flow sheets [17] differ in the number of grinding stages and the presence of classification operations in them; they may include operations of preliminary, verifying, and control classification of overflow and sands [18, 19]. From the whole variety of grinding flow sheets, let us consider the option of grinding with a verifying classification. This option is often used at the first grinding stage in two- and multi-stage flow sheets. Such flow sheets ensure the specified size of the ground product, and the off-spec product is returned back to the mill. Given the impossibility of obtaining a finely ground finished product when grinding copper sulfide ores, the control classification of the overflow is applied. Such flow sheets increase the classification front, and the classifier operation is unstable. To ensure the specified size of grinding and eliminate the control classification shortcomings, let us consider the optimal option of flotoclassification in closed-circuit grinding.

Flotoclassification comprises flotation and hydraulic classification of the foam product, overflow, and sands in a single vessel. A fundamentally new flotoclassification area is the use of tapered launders to dress the foam product. Its variants allow obtaining one on-spec or several different-quality foam products and reducing power and operating costs while improving the dressing indicators. The foam product dressing in the tapered launders provides for the formation of different-quality foam layers and the division of the foam in height into dressing products [20]. The formation of different-quality foam layers is determined by the secondary concentration of minerals, which has been studied in sufficient detail in [21]. Narrowing the foam flow due to an increase in the foam layer height and a decrease in the foam surface area reduces the coalescence of bubbles and increases the likelihood of re-fixing of the released floating particles in the foam. The increase in the foam layer thickness facilitates the division of the foam flow into different-quality top and bottom products.

Flotoclassification in closed circuits of processing ores and dressing tailings can be used for the classifier overflow and sands.

The flowsheet with the flotoclassification of the hydraulic classification sands allows extracting the
exposed minerals into the concentrate and thereby avoid overgrinding of particles.

The flowsheet with the flotoclassification of the hydraulic classification overflow ensures the circulation of the bulk of the sands bypassing the flotoclassification, which allows using smaller standard sizes of flotoclassifiers at a given initial tailing yield. When processing ores, such a flowsheet allows obtaining an on-spec concentrate – overflow in the foam product of the flotoclassifier, which is sent to flotation according to the existing scheme, and the sands are returned to the mill.

Options of flotoclassification in closed-circuit grinding without hydraulic classification are possible. The flotoclassifier can be fed with ground material with a grain size of up to 10 mm. In this case, there is no need to use hydrocyclones. It is advisable to use these flow sheets when processing the concentration plant tailings. The flowsheet with the supply of initial material to the mill is recommended for processing old clumped tailings requiring preliminary disintegration. The flowsheet with the supply of the material feed to flotoclassification can be used when processing fresh plant tailings.

Let us consider the option of flotoclassification in closed-circuit grinding for the hydrocyclone overflow, the flow sheet of which is shown in Figure 1.

The flowsheet operation principle is as follows: the initial material is fed to grinding, and the ground product flows to hydraulic classification, where it is separated into overflow and sands. The hydrocyclone overflow flows to flotoclassification, the process takes place in a bowl-type vessel with tapered launders. Flotoclassification gives foam product, which is dressed in tapered launders to obtain the bottom and top products, overflow, and sands that are combined with hydrocyclone sands and returned to regrinding. This flowsheet ensures the circulation of the bulk of the sands bypassing the flotoclassifier, which allows using smaller standard sizes of flotoclassifiers at a given initial tailing yield. The above flowsheet allows improving the further flotation indicators due to the extraction of exposed valuable mineral particles in the flotoclassifier immediately as they are exposed in grinding.

The proposed flowsheet allows obtaining an on-spec concentrate in the top product of the tapered launder, middlings in the bottom product of the tapered launder, which are sent for further processing, and tailings in the flotoclassifier overflow.

4. Flotoclassification in a closed-circuit grinding
Flotoclassification in closed-circuit grinding has been simulated in a laboratory flotoclassifier on the copper ore of the Yelenovskoye deposit; the design provides for the foam product dressing in a tapered launder, Figure 2.
Figure 2. Simulation of Flotoclassification in Closed-Circuit Grinding.

In the ore, copper is mainly represented by chalcopyrite. Chalcocite, coveline, and bornite are present in the ore in small quantities. A sample of ore with a mass fraction of copper of 2.0 %, crushed to 85 % of the grade minus 0.071 mm was studied. The experiments were performed as follows: a weighed sample portion of 1,000 g was ground in a laboratory mill for 20 minutes.

The ground product was treated with xanthate at a flow rate of 60 g/t and then classified in a hydraulic classifier. The hydrocyclone overflow and the foaming agent T-80 was fed to the flotoclassifier’s chamber and mixed for 5 minutes. In the flotoclassification of the first sample, the top and bottom products of the tapered launder and flotoclassifier overflow and sands were obtained. The flotoclassifier sands of the first experiment were combined with the second initial material sample, the mixture was ground, hydraulic classified, and flotoclassified in the modes specified. Experiments with the next portions were performed in a similar way. 5 portions were processed.

The final products obtained after processing the fifth sample were dried, weighed, and their chemical composition was analyzed.
The experiment results are given in Table 1 in the form of a finished product balance and in Figure 3 in the form of a qualitative and quantitative diagram.

**Table 1. Flotoclassification Finished Product Balance in a Closed-Circuit Grinding.**

| Product                | Yield, γ % | Mass fraction of copper, β % | Extraction of copper, ε % |
|------------------------|------------|------------------------------|---------------------------|
| Tapered launder top    | 5.19       | 17.03                        | 44.20                     |
| product                |            |                              |                           |
| Tapered launder bottom | 33.39      | 3.03                         | 50.60                     |
| product                |            |                              |                           |
| Overflow               | 60.84      | 0.17                         | 5.20                      |
| Sands                  | 50.0       | 1.98                         | 50.1                      |
| Initial material       | 150        | 2.00                         | 150.1                     |

**Figure 3. Qualitative and Quantitative Diagram of Flotoclassification in Closed-Circuit Grinding.**

5. Conclusions
The experiment results have shown that the flotoclassifier operation in closed-circuit grinding of copper ore with a mass fraction of copper of 2.00 % allows obtaining an on-spec concentrate with a mass fraction of copper of 17.00 % in the tappered launder top product with the 44.2 % extraction of copper into it, copper middling in the tappered launder bottom product with a mass fraction of copper of 2.98 % with 50.6 % extraction of copper into it. Herewith, tailings with a mass fraction of copper of 0.17 % are obtained in the overflow with 5.2 % copper loss in the tailings. The reduced use of the machinery in the subsequent flotation front is possible.

Implementing this technology will significantly reduce the mineral overgrinding, obtain an on-spec copper concentrate in the foam product, and reduce the subsequent flotation front and the flotation capital and operating costs.
6. References

[1] Bocharov V A 2019 Theory and practice of separation of minerals of massive refractory polymetallic ores of non-ferrous metals (M : ed. "Mountain Book") p 510

[2] Algebraistova N K 2009 Technology of concentration of non-ferrous metal ores [electronic resource] Electronic educational complex Access mode: www.geokniga.org

[3] Chandramohan R, Holtham P and Powell M 2010 The Influence of Particle Shape in Rock Fracture XXV International Mineral Processing Congress (September) pp 3163-3171

[4] Bocharov V A 2007 State, prospects of development of technology of deep and complex processing of non-ferrous metal ores Mining magazine 2 p 65

[5] Abramov A A 2017 Flotation methods of enrichment: textbook (M : Publishing house of Moscow State City University) p 600

[6] Kozin V Z 2001 Study of ores for washing Lecture notes (Ekaterinburg) Publishing house of UGGGA 142 p

[7] Tomasz P Olejnik 2006 Grinding kinetics of selected minerals with reference to the number of contact points Physicochemical Problems of Mineral Processing 40 247-254

[8] Jankovic A 2003 Variables affecting the fine grinding of minerals using stirred mills Minerals Engineering 16 337-345

[9] Tasdemir A, Ozdag H, Oral G 2011 Image analysis of narrow size fractions obtained by sieve analysis - an evaluation by log-normal distribution and shape factors Physicochemical Problems of Mineral Processing 46 95-106

[10] Norazirah A, Fuad S H S and Hazizan M H M 2016 The Effect of Size and Shape on Breakage Characteristic of Mineral Procedia Chemistry Elsevier Ltd. 19 pp 702-708 doi: 10.1016 / j.proche.2016.03.073

[11] Barrios G K P, de Carvalho R M and Tavares L M 2011 Extending breakage characterization to fine sizes by impact on particle beds Mineral Processing and Extractive Metallurgy 120 37-44

[12] Hopunov E A 2013 Selective destruction of mineral and technogenic raw materials (in beneficiation and metallurgy) (Yekaterinburg: OOO UIPTs) 429 p

[13] Chanturia V A 2018 Innovative processes of deep and complex processing of technogenic raw materials in the conditions of new economic challenges Materials of Intern. scientific-practical conf. "Effective technologies for the production of non-ferrous, rare, precious metals." (Almaty) pp 7-13

[14] Shadrunova I V 2018 Principles of construction of technological lines for processing poor natural and technogenic raw materials using centrifugal shock technology Mat-ly Mezhduunar. scientific-practical conf. "Effective technologies for the production of non-ferrous, rare, precious metals" (Almaty) pp 76-81

[15] Valieva O S 2019 Advantages of using flotation classifiers in a closed grinding cycle Gornyi zhurnal 2 pp 51-56

[16] Bekhurina E A 2018 Proposal for the implementation of flotation classification in a closed grinding cycle Materials of Intern. Scientific and practical. conf. "Efficient technologies for the production of non-ferrous, rare and precious metals" (Almaty) pp 76-81

[17] Morozov Yu P 2009 Designing of concentration plants Part I The composition of the project and the procedure for design: textbook for universities Ural. state mountain un-t. (Ekaterinburg; UGGU Publishing House) 304 p

[18] Palaniandy S, Yahyaei M and Powell M 2017 Assessment of hydrocyclone operation in the gravity induced stirred mill circuit Minerals Engineering 108 83 - 92

[19] Frausto J J, Ballantyne G R, Runge K, Powell M S and Cruz R 2017 The impact of classification efficiency on comminution and flotation circuit performance "Metallurgical Plant Design and Operating Strategies - World's Best Practice (MetPlant 2017)" (Perth, WA, AusIMM) 298-314

[20] Bekhurina E A 2017 Using the process of secondary concentration of minerals in foam to improve the technological indicators of flotation classification Mat-ly mezhdunar. scientific.
tech. Conf. "Scientific foundations and practice of processing ores and technogenic raw materials." (Yekaterinburg: publishing house "Fort Dialogue - Iset") pp 324 - 328

[21] Faley E A 2016 Flotoclassification with the separation of the foam product in a tapering chute Materials of the Intern. scientific. - tech. Conf. "Scientific foundations and practice of processing ores and technogenic raw materials." (Yekaterinburg: publishing house "Fort Dialogue - Iset") pp 242 - 245