Process Optimization of Grinding and Flotation of Copper-Molybdenum Ores with the Use of Model-Based Criteria

Erdenezul JARGALSAIKHAN[1], Khurelchuluun ISHGEN[2]

[1] National University of Science and Technology "MISiS", Leninskiy prospect, 4, Moscow, Russia, 119049; email: zul479@gmail.com
[2] Erdenet Mining Corporation, Friendship Square, Bayan-Undur soum, Orkhon province, Mongolia, 61027; email: khurelchuluun@erdenetmc.mn

http://doi.org/10.29227/IM-2019-02-22

Submission date: *18-08-2019* | Review date: *02-09-2019*

Abstract

Many plants have issues of decrease in metal recovery and quality of concentrates. Consequently, we researched influence in enrichment processes. The purpose paper is improving the technical and efficiency complex of enrichment copper-molybdenum ore. This paper developed control algorithm of grinding and flotation processes. It was assumed optimization method of economic-based technological processes.

The control algorithm consists of ore model coming for processing in the formation, as a mixture to certain types of ores. The choice of enrichment modes based on the obtained information about the grade of processed ores. An economic criterion is used as an efficiency criterion, the sum cost of lost metals and the costs of improving the quality of the concentrate. Account the ore grade and the response to the metal content allows to better taking into account the objective characteristics of processed ore. The result of the developed control algorithm allows increasing the technical and economic efficiency of the whole complex of copper-molybdenum ore enrichment.

Keywords: copper-molybdenum ores, grinding, flotation, modeling, ore grade, optimization criteria

Introduction

The perspective direction of algorithms are the development and application of model-oriented criteria of optimization. (Bartolacci et al, 2006, Daniel et al., 2010). One such example is developed at the GOK "Erdenet" Plant control algorithm processes of enrichment for the grade of the ore.(Delgerbat, 2002, Ganbaatar et al., 2011). Also, promising direction is the application of criteria based on economic estimates, the complex criterion in particular of reducing the losses of valuable components. (Schena et al., 1995, Morozov et al., 2017). The combination of these methods is a good platform for creating a complex control algorithm that takes into account the properties of processed raw materials to the greatest extent.

Method of control algorithm

Control algorithm developed the grinding and flotation processes, shown in Figure 1, assumes a consistent implementation of methods for estimation the grade ore and the economically-based optimization of technological processes.

This control algorithm is implemented in two circuits. The first circuit regulates the productivity taking into account the ore grinding size. The second level – the regulation of lime and collector. The regulatory objective was maintained optimal conditions for milling and collective flotation operations.

The layout of flotation process control algorithms is based on the principle of two-level control, when the optimal calculated parameters of the grinding and flotation processes is based estimation of grade ore, and the determination of the main parameters for typical ores is carried out using economic-based optimization criteria.

The control algorithm is described in detail in the grade of ore (Morozov et al., 2008, 2013) and consists in the representation of ore supplied for processing, mixtures ores of certain grades, and choice of mode enrichment based on information about the processed grade ore.

The optimal parameters of grinding and flotation processes are calculated taking into account the contribution of each metal to the cost of commercial products.

As a criterion of efficiency, it is advisable to use a special economic criterion-the loss function, expressed as the cost of lost metals, and the cost of improving the quality of the concentrate:

$$Q_t = \varepsilon^*_{Cu} C_{Cu}\alpha_{Cu} + \varepsilon^*_{Mo} C_{Mo}\alpha_{Mo} + \varepsilon^*_{Py} C_{Py}\alpha_{Py};$$

where: ε*; C; α – loss, price and content in the ore of copper ($_{Cu}$), molybdenum ($_{Mo}$), pyrite ($_{Py}$). Under the price of pyrite is understood to be the cost of extracting pyrite from copper concentrate in a selective cycle.

This criterion was justified and proposed in (Ganbaatar et al., 2017). A special feature is the control algorithm developed and described in this paper. The fact is that the optimal parameters of the grinding and flotation processes are initially calculated for individual ore grades.

Results of experiments

In Figure 2 shows the dependence of extraction of metals and the optimization criterion in the collective copper-molybdenum flotation of various ores. It shows that for certain parameters (recovery of copper, molybdenum and iron) are impossible to improve for determining process conditions.

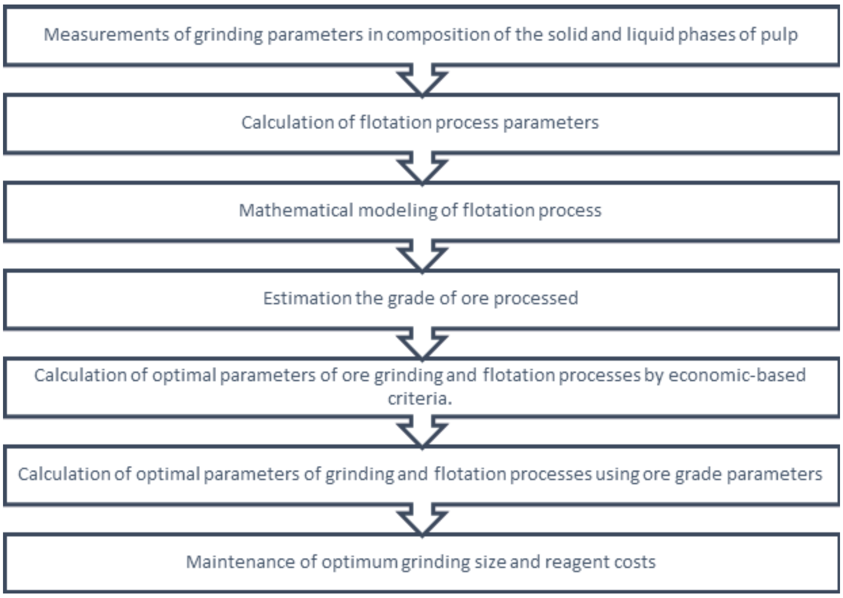

Fig. 1. General control algorithm for the flotation process by ore grade of estimation procedure and economically-based optimization criteria
Rys. 1. Ogólny schemat sterowania procesem flotacji według oceny jakości rudy i ekonomicznych kryteriów optymalizacji

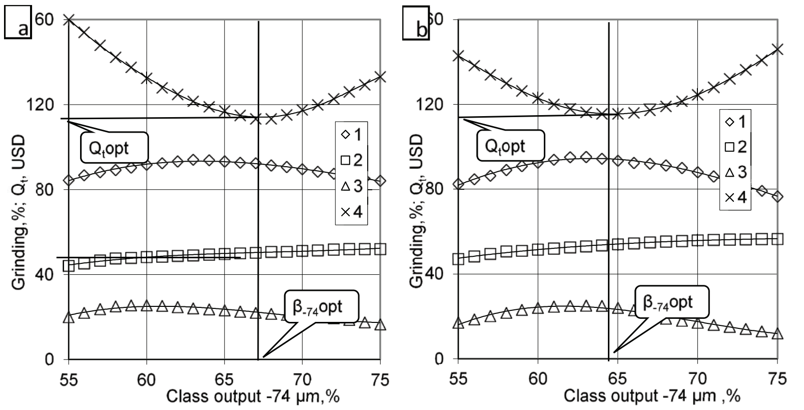

Fig. 2. Dependence of copper (1) molybdenum (2) and iron of pyrite (3) recoveries in collective concentrate and optimization criterion Q_t (4) at size of grinding for massive primary ore (a) and mixed secondary sulfidized ore (b)

Rys. 2. Zależność odzysku miedzi (1) molibdenu (2) i żelaza z pirytu (3) w koncentracie kolektywnym i kryterium optymalizacji Qt (4) dla wielkości rozdrobnienia rudy surowej (a) i mieszanki rudy siarczkowej (b)

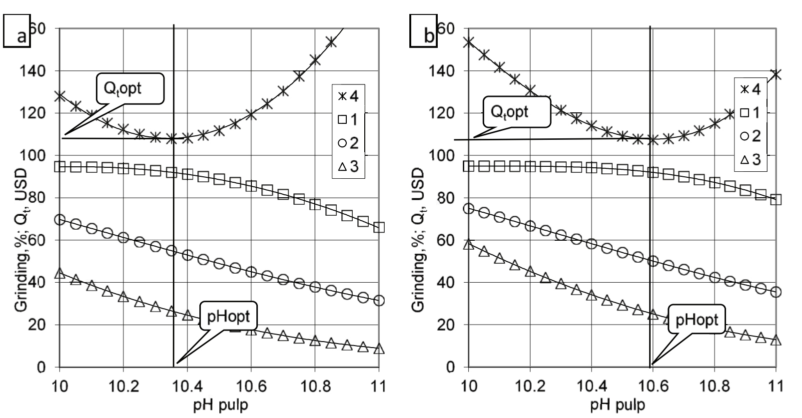

Fig. 3. The dependence of copper recoveries (1) molybdenum (2) iron of pyrite (3) in collective concentrate and optimization criterion Q_t (4) from the pH collective flotation of massive primary ore (a) and mixed secondary sulfidized ores (b)

Rys. 3. Zależność odzysku miedzi (1) molibdenu (2) żelaza i pirytu (3) w koncentracie kolektywnym i kryterium optymalizacji Qt (4) od odczynu pH flotacji dla rudy surowej (a) i mieszanki rudy siarczkowej (b)

Tab. 1. Values of technological parameters setpoints in control systems of grinding and classification processes
Tab. 1. Wartości nastaw parametrów technologicznych w układach sterowania procesami mielenia i klasyfikacji

№	Process of parameter	MPO	MSSO	PPO	MOO	MSO
1	Size of the grinding - class output – 74 μm, %	67.5	64.5	67.0	66.0	66.0
2	pH of pulp in flotation	10.36	10.59	10.50	10.31	10.55

MPO – massive primary ore; MSSO – mixed secondary sulfidized ores; PPO – poor pyrite ore; MOO – mixed oxidized ores; MSO – mixed sericitized ore.

Tab. 2. Parameters and test results of model-based control algorithm of grinding and flotation processes at the GOK "Erdenet" plant
Tab. 2. Parametry i wyniki sterowania w oparciu o modelowy algorytmu sterowania procesami mielenia i flotacji w zakładzie GOK „Erdenet"

Parameter of process	Ordinary mode of control		New control algorithm	
	Interval of variation	Average value	Limits of variation	Average value
Productivity, t/h	856 – 911	878	848 – 918	918
Size of crushed ore, % class-74 μm	64.5 – 65.3	65.0	64.0 – 65.9	65.0
Consumption of collector, g/t	13.8 – 15.8	14.81	13.5 – 16.0	14.83
Consumption of lime, kg/t	1.34 – 1.55	1.45	1.30 – 1.60	1.46
pH liquid phase	10.3 – 10.45	10.37	10.3 – 10.46	10.38
Copper recovery in collective concentrate, %		91.6		92.2
Copper recovery in product concentrate, %		88.7		90.1
Molybdenum recovery in collective concentrate, %		59.1		60.1
Molybdenum recovery in product concentrate, %		51.6		52.7
Loss function (Qt) in the collective flotation concentrate, USD/t		11.1		10.8
Loss function (Qt) as a whole by factory, USD/t		13.2		12.9

In this research, for the improving conditions process used Q_t function, the dependence of which on size of grinding is seen in Figure 2.

Analysis represented Figure 2 dependencies show that the improvement of technological parameters were determined by the behavior of all ore components and optimal grinding conditions for different types of ores. In these tests, for massive primary ore, the function is low, reduce losses at size grinding of 67.5%, class output -74 μm, and for mixed secondary sulfidized ore at size of grinding 64.5%, class -74 μm.

It can be seen from Figure 3 that dependence of the optimization criterion for collective copper-molybdenum flotation of different types of ores also makes it possible to determine the improvement of technological conditions.

Figure 3 shows analysis of the dependencies that the improvement of technological parameters are determined by the behavior of all ore components and optimal flotation conditions for different types of ores.

Thus, for massive primary ore, the minimum loss function is observed at pH = 10.36, and for mixed secondary sulfidized ore at pH = 10.59.

The results in the Table1 show that calculations of the optimal parameters of the grinding and flotation processes are basis for calculation of grinding and flotation automatic control systems.

Control algorithm testing and analysis of results

The algorithm developed an existing, when tested in ASTPC of enrichment factory. It can be seen from the Table 2, the use of model-based control algorithm to grinding and flotation processes. This makes possible to increase the indicators of enrichment in the collective flotation cycle and at the enrichment factory. Characteristically, the average size of grinding ore has not changed. However, the interval of variation size of the grinding ore has expanded. It is connected to the variation of the setting function in the control system. Consumption of the collector and lime also has not changed (Table 2). Similarly, the interval of variation expenses of reagents has expanded.

Conclusion

The average value and interval of variation pH have not changed. In general, these results suggest that using model-based criteria does not change the average parameters of the mode. However, account of grade ore and responding to the content of metals allow better objective characteristics of the processed ore. Consequently, using a new algorithm allowed to achieve an increase in metal extraction and further reduce the cost of copper and molybdenum.

The results finding of this study indicate that using economic-based criteria can make possible to improve the technical and economic efficiency complex of enrichment copper-molybdenum ore.

Acknowledgements

The authors would like to thank the GOK "Erdenet" Plant in Mongolia.

Literatura – References

1. BARTOLACCI, G, et al. Application of numerical image analysis to process diagnosis and physical parameter measurement in mineral processes. Minerals Engineering journal, Elsevier B.V, Canada, Volume 19(6–8), Part 1, 2006, p. 734–747, ISSN 08926875.
2. DANIEL, Sbárbaro., RENÉ DEL, Villar. Advanced Control and Supervision of Mineral Processing Plants. Springer-Verlag London, 2010, p.376, ISSN 1430-9491.
3. DELGERBAT, L. Investigation, modeling and optimization of grinding processes and collective flotation of copper-molybdenum ores. Mining Information and Analytical Bulletin, Moscow, 2002, p. 226-230.
4. GANBAATAR, Z. et al. The enrichment of copper-molybdenum ores using integrated radiometric assay grade ore. Mining information-analytical bulletin, 2011, p. 176-182.
5. GANBAATAR, Z. et al. Management of the processes of copper-molybdenum ores enrichment using advanced quality control. Mining sciences and technologies, 2017, p. 40-48.
6. MOROZOV, V.V, et al. Modern Algorithm and system for monitoring and control of milling and flotation process. Preprints of the 18th IFAC World Congress, IFAC (ed.), Seoul, 2008, p. 222-228.
7. MOROZOV, V.V, et al. Modern systems of automatic control of processes of grinding and flotation of copper-molybdenum ore. 16th IFAC Symposium on Control, Optimization and Automation in Mining, Minerals and Metal Processing, Volume 15, Part1, IFAC (ed.), 2013. p. 166-171.
8. MOROZOV, V.V., ZHARGALSAIKHAN, E. Optimization of the flotation process using economic criteria. Proceedings of the 11th Congress of the Enrichers of the CIS Countries, Moscow, 1, 2017, p. 161-164.
9. SCHENA, G.D., GOCHIN, R.G, Application of engineering economics methods to decision making in mineral processing. Proc. of the XIX Int. Mineral Processing Congress, San Francisco, USA, Volume 1, 1995, p. 267 – 272.

Optymalizacja procesu mielenia i flotacji rud miedziowo-molibdenowych z wykorzystaniem kryteriów modelowych

Wiele zakładów wzbogacania rud napotyka na problemy ze spadkiem uzysku metalu i jakością koncentratów. W związku z tym zbadano wpływ różnych czynników na proces wzbogacania. Celem pracy jest optymalizacja ilościowa i jakościowa kompleksu wzbogacania rudy miedziowo-molibdenowej. W artykule przedstawiono algorytm sterowania procesami mielenia i flotacji. Przyjęto metodę optymalizacji ekonomicznej procesów technologicznych. Algorytm sterowania składa się z modelu nadawy, który przyjęto jako mieszaninę minerałów. Wybór trybów wzbogacania zachodzi na podstawie informacji o jakości przetwarzanych rud. Kryterium ekonomiczne jest stosowane jako kryterium wydajności, łączne straty metali i koszty poprawy jakości koncentratu. Uwzględniono skład rudy, reakcja na zawartość metalu pozwala lepiej uwzględnić charakterystykę przerabianej rudy. Opracowany algorytmu sterowania pozwala na zwiększenie efektywności technicznej i ekonomicznej całego kompleksu wzbogacania rudy miedziowo-molibdenowej.

Słowa kluczowe: rudy miedziowo-molibdenowe, mielenie, flotacja, modelowanie, jakość rudy, kryteria optymalizacji