www.czasopisma.pan.pl PAN www.journals.pan.pl

ARCHIVES
of
FOUNDRY ENGINEERING

DOI: 10.24425/118812

Published quarterly as the organ of the Foundry Commission of the Polish Academy of Sciences

ISSN (2299-2944)
Volume 18
Issue 1/2018

61 – 64

11/1

Investigation of a Crushing and Grinding Unit of an Electropulse Installation

I.P. Kurytnik [a, *], B.R. Nussupbekov [b], D.Zh. Karabekova [b], A.K. Khassenov [b], A.Sh. Kazhikenova [b]
[a] The Witold Pilecki State Higher School, 8 M. Kolbego str.,
32-600 Oświęcim, Poland
[b] E.A. Buketov Karaganda State University,
University street, 28. 100028 Karaganda, Kazakhstan
*Corresponding author. E-mail address: ikurytnik@outlook.com

Received 06.12.2017; accepted in revised form 20.02.2018

Abstract

The paper proposes a new electropulse apparatus for processing natural raw materials. The temperature of the crushing-and-reducing assembly of an electropulse plant is found. The results of ore crushing are presented and optimal engineering factors are offered. The elemental analysis of the test material is obtained. It is reported that the electropulse processing at the reduction stage made for significant increase in the content of non-ferrous and rare metals.

Keywords: Hydrometallurgy, Hydro-pulse crushing, Polymetallic ore, A heat meter gauge, Installation of an elektroimpulse plant

1. Introduction

Currently, in the Republic of Kazakhstan ferrous and non-ferrous metals industry is well-developed; and the subsector of non-ferrous metals has significant reserve deposits. It is commonly known that technological advancements and improvement of polymetallic ores enrichment technology expands the raw material base of the industry taking stocks of new deposits of precious, rare and non-ferrous metals into processing procedure. However, with increasing use of mineral resources the quality of extracted ores deteriorates as the industry changes over from high-grade ores deposits mining to cut-off grade ores mining. In this case, changes in the composition of the raw materials negatively affect the efficiency of the enrichment process technology, in particular during reduction process of the parent stock. This fact points to the need for the development of scientific bases of creation and familiarization of power-engineering equipment and plants, providing optimal progress of production processes of high performance reliability [1-5,11].

In connection with the above, at the laboratory of electrodynamics in E.A. Buketov Karaganda State University, an electropulse plant with an operational assembly designed for crushing mineral ore materials and rocks was developed in order to upgrade the efficiency of valuable metals extraction [6].

2. Experimental part and discussion of the results

For laboratory testing the authors assembled a test bench (Fig. 1). It consisted of the electropulse plant and the crushing-and-reducing assembly (hereinafter referred to as an operational assembly). The middle part of the operational assembly is made of low-alloy structural steel of 10HSND brand. The guide crushing chamber and the insulator are made of fluorine plastic of 4T brand, which increases the reliability and durability of the mechanisms, making for their reliable operation in aggressive environments. Heat resistance and dielectric characteristics of the fluorine plastic provide its radiation hardness and mechanical strength. The bar of the positive electrode is made of austenitic nickel-chromium-based super alloy for use at high temperatures. The positive electrode is made of heat-resistant high-alloy steel of 20H25N20S2 brand. In order to eliminate heat, the transfer channel is filled with transformer oil. The general view of the operational assembly is shown in Figure 1.

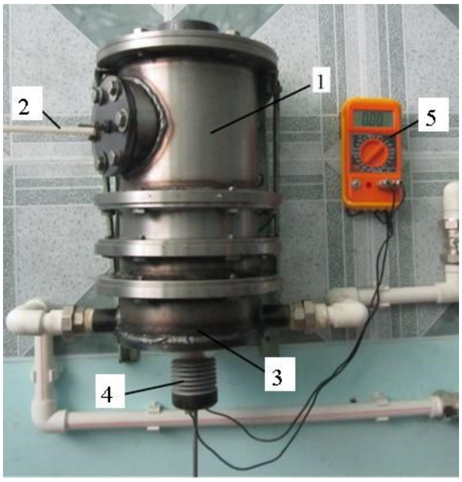

Fig. 1. The general view of the operational assembly: 1 – the operational assembly, 2 – a positive electrode input, 3 – a crushing chamber, 4 – a non-contact heat flow meter, 5 – an electronic temperature recording unit

A linear system of electrodes was installed in the operational assembly. The positive electrode was arranged upright, while the negative electrode was the bottom of a metal chamber of a hemispherical shape. On exposure of a solid to electric pulse impact as the pressure-transmitting medium industrial water was used, since it was the most available, inexpensive and ecologically friendly. The operation principle of the operational assembly was as follows. First, a pulse capacitor is charged by the generator. When the desired voltage is obtained, there is breakdown, and all the energy stored in the capacitor is transmitted through the electrode to the working clearance. When a high power pulse passes through a liquid medium, which is wet ore, there an electrical breakdown occurs, accompanied by a hydraulic shock of high destructive power [7-9]. The resulting from discharge force due to hydraulic impact facilitates self-centering of the electrode; and in the process each discharge is accompanied by electrode wear. During continuous operation the positive electrode runs hot and it is shortened due to erosion, thereby quickly wears out, leading to the destruction of the end part, which markedly influences the efficiency of the plant operation. The wear of the electrode depends on the voltage, the pulse energy and the electrode material.

In this regard, to regulate thermal operational conditions the authors defined temperature regimes of the crushing assembly by a contactless heat flow meter (hereinafter referred to as the meter). The meter consists of a receiver plate 1, a thermoelectric battery heat flow converter 2, a thermoelectric cooler 3, a radiator 4, a temperature registering electronic unit 5 (Fig. 2). The meter is made in the shape of a limited cylinder, one base of which is a working surface, and the other one is in thermal contact with the body which is as warm as an ambient temperature. Built-in heaters make it possible to initiate a heat flow through the thermoelectric sensor in the directions perpendicular to its base. The operation of the sensor does not depend on changes in the environmental conditions [10].

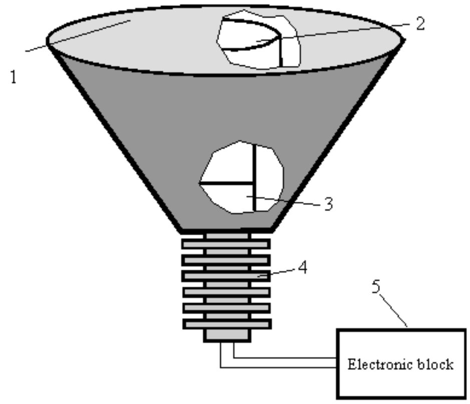

Fig. 2. Schematic representation of the non-contact heat flow meter: 1 – the receiver plate; 2 – the thermoelectric battery heat flow converter; 3 – the thermoelectric cooler; 4 – the radiator; 5 – the signal conditioning and measuring electronics assembly

This meter is arranged in the bottom of the operational assembly (as shown in Fig. 2) and it is set in an elastic rubber pad that eliminates contact thermal resistances. Non-contact measurement of temperature does not affect the operation of the electronic-measuring unit of the device. This fact makes it possible to record quickly the temperature of the operating crushing-and-reducing assembly.

As is well known, the electropulse method shows significant common regulations in the change of energy indicators when varying the parameters of the pulse source, the characteristics of the working chambers, physico-mechanical and electrical properties of the crushed material. In this case the following parameters of the pulse source sufficiently critical to the main energy indicators of the destruction can be distinguished: a pulse energy which can be varied by the value of capacitor capacitance or the value of the discharge voltage; an interelectrode distance, which determines the rate of voltage rise at the object and the duration of energy release in the discharge channel.

Thus, the authors obtained the experimental results at the following geometric and energy operational parameters of the electropulse plant: the interelectrode distance in the forming converter was 12 mm, the capacitance of the capacitor bank was ~ 0.65 μF, and the discharge energy was ~ 292 J.

After actuation of the electropulse plant the energy-efficient parameters of the crushing-and-reducing assembly were defined at different amounts of pulsed discharges (N=500; 750; 1000; 1250; 1500). The temperature of the operational assembly was monitored by the meter. At that, the results were obtained for the clean industrial water (without ore processing) and for slurry (with ore processing). As seen in Fig. 3, when the number of pulsed discharges increases from 1000 to 1500 pulses the temperature of the operational assembly sharply rises from 45^{0}C to 87^{0}C for clean industrial water; and for slurry the temperature rises from 35^{0}C to 74^{0}C. At that, it is noticeable that in the industrial water heating of the operational assembly is more intense, as the water heat transfer is higher than that of the slurry.

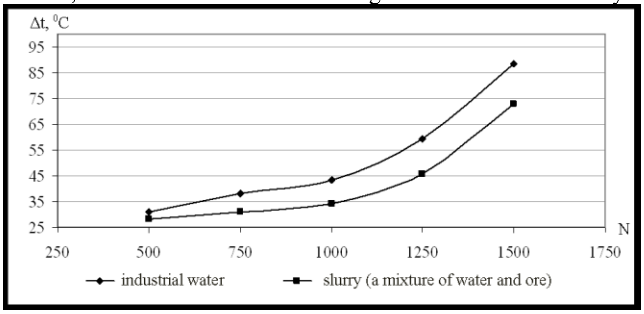

Fig. 3. The dependence of temperature on the number of electrical discharges in different media: 1 – industrial water; 2 – slurry

In subsequent experiments, the authors used the ore from the Akbastau mine in the Republic of Kazakhstan; and the initial diameters of the ore were in the range of 1 to 15 mm (Fig. 4). The used ore of a preset diameter (1, 5, 10 and 15 mm) was subjected to the electric pulse processing, and it was reduced to 0.2 mm at varying amounts of pulsed discharges (from 500 to 1500 pulses).

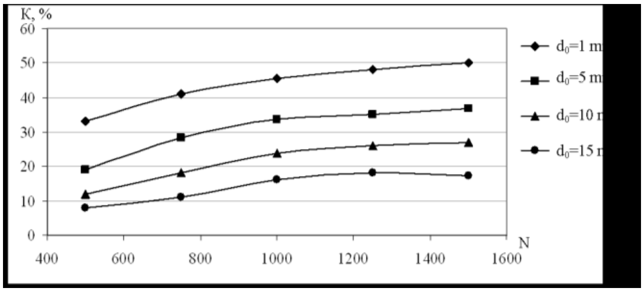

Fig. 4. The dependence of the ore size reduction to the desired fraction (0.2 mm) on the number of pulsed discharges

Fig. 4 shows that the optimum size reduction of the ore solid fraction begins at the number of pulse discharges of 1000 pulses. As can be seen in the figure, the yield of the final product (of the required fraction of 0.2 mm) for ore of the initial diameter of 5 mm, reaches 35%, and for the ore with original diameter of 1 mm it is 46%. With further increase in the number of pulse discharges (up to 1500 pulses.), the yield of the final product stabilizes, however, as can be seen in Fig. 3, the temperature of the operatonal assembly rises sharply. In connection with the above, further experimental work was carried out at preset data of numbers of pulses and at the optimum temperature of the operational assembly of ~35^{0}C.

To obtain comparative data of the ores processed by mechanical and electric pulse methods an initial ore fraction had been previously processed by the gyratory mill VCMD-6. The results of microstructural and elemental analyses, energy-dispersive spectra (Fig. 5) were obtained using a raster electron microscope Philips SEM 515.

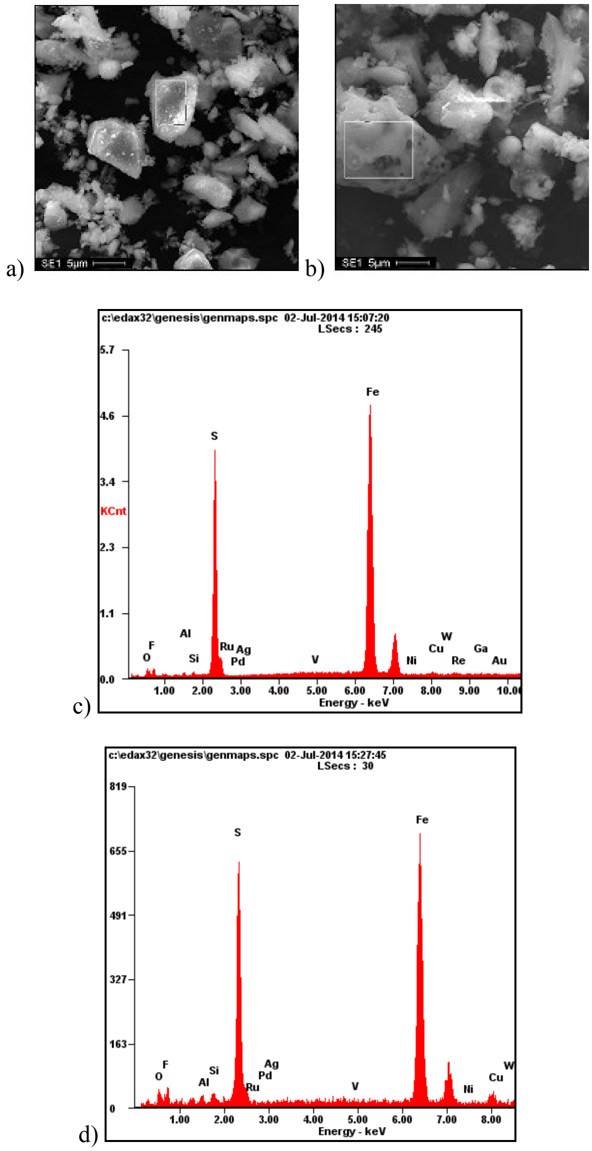

Fig. 5. Microstructures and energy-dispersive spectra of the Akbastau ore: a, c - after mechanical crushing; b, d - after electric pulse reduction

The Fig. 5 (b, d) shows that at the electric pulse reduction, a high selectivity of the destruction of the material takes place, which is manifested in better disclosure of grains of minerals from accompanying rocks. The electropulse reduction and processing of materials due to the softening of particles significantly increases their reactivity and thus the effectiveness of the subsequent hydrometallurgical processing of the material.

The comparative elemental analysis of Akbastau ore also shows (Table 1), that as a result of electropulse reduction in the composition of the ore there was a noticeable by times increase in the metal content: aluminum by 1.9 times, silicon by 2.6 times, vanadium by 3.5 times, copper by 3.8 times, rhenium by 2.9 times, gallium by 1.95 times, gold by 2.7 times. Moreover, tungsten had not been detected before processing, and after processing by the electrpulse method its content was up to 1.73%.

Table 1.
Comparative elemental analysis of the Akbastau ore after mechanical and electropulse reduction

After the mechanical grinding		After the electric pulse processing	
Element	*At%*	*Element*	*At%*
Al	00.88	*Al*	01.57
Si	00.56	*Si*	01.45
S	32.46	*S*	31.63
V	00.08	*V*	00.29
Fe	56.61	*Fe*	42.92
Cu	00.76	*Cu*	02.89
W	00.00	*W*	1.73
Re	00.57	*Re*	01.68
Ga	00.33	*Ga*	00.64
Au	00.46	*Au*	01.24

Thus, we assume that when materials are reduced in a liquid medium by the electro-pulse plant a fast destruction of mineral grains and accompanying rocks takes place along the boundaries. It results in a high degree of release and provides a high percentage of grains ultimately released from accompanying minerals. The electropulse crushing causes incipient cracks, which reduce the strength of the rock. That makes for its enrichment and accelerates the dissolution of grains of metal minerals in the reagents in the hydrometallurgical technologies for their extraction.

3. Conclusions

1. The application of crushing-and-reducing assembly for processing polymetallic ore makes it possible to obtain the slurry of the desired dispersion for the hydrometallurgical extraction of metals. The degree of disintegration of ore raw materials due to the release of metallic minerals from accompanying rocks increases, thus facilitating the enrichment of raw materials.
2. The temperature parameters of the working assembly of the electropulse plant are defined. As a result of tests performed using the non-contact heat flow meter it was found that for optimal operation of the operational assembly the temperature must not exceed 35^0C. In this case the yield of the final product reduced up to 0.2 mm from the original ore with fraction diameter of 1 mm was 46% and that from the ore with initial fraction diameter of 5 mm it was~ 35%.
3. By the example of processing of ore from the Akbastau deposit in Kazakhstan the authors showed that the proposed technology can be used to extract valuable elements from relatively poor polymetallic ores.

References

[1] Bukaeva, A.D. (2012). Production of the non-ferrous metals in the Republic of Kazakhstan. *Theory and practice of social development*. 12, 561-564.

[2] Abramov, A.A. (2004). *Processing, enrichment and integrated use of solid minerals*. (2nd ed.). Moscow: State University Publishing House.

[3] Perov, V.A. (1990). *Crushing, grinding and screening of minerals*. Moscow: Nedra.

[4] Fishman, M.A. (2000). *The practice of enrichment of ores of non-ferrous and rare metals*. Moscow: Nedra.

[5] Samygin, V.D., Filippov, L.O., Shekhirev, D.V. (2003). *Basics of ore dressing*. Moscow: Altex.

[6] Kurytnik, I.P., Nussupbekov, B.R., Khassennov, A.K., Karabekova, D.Zh. (2015). Disintegration of copper ores by electric pulses. *Archives of Metallurgy and Materials*. 60 (4), 2549-2551. DOI: 10.1515/amm-2015-0412.

[7] Yutkin, A.A. (1986). *Electrohydraulic effect and its application in industry*. Leningrad: Mechanical engineering.

[8] Malushevsky, P.P. (1983). *Fundamentals of discharge-impulse technology*. Kiev: Naukova Dumka.

[9] Guliy, G.A. (1990). *Scientific foundations of the discharge-impulse technology*. Kiev: Naukova Dumka.

[10] Nussupbekov, B.R., Kuritnik, I.P., Karabekova, D.Z., Khassenov, A.K., Shaimerdenova, G.M. & Akhmetova, A.K. (2016). Device for the testing of pipelines of thermal networks. *Bulletin of the University of Karaganda*. 82(2), 61-65.

[11] Gawenda, T. *Crushing yesterday, today and tomorrow*. Retrieved January 15, 2018, from www.kieruneksurowce.pl/Resources/art/6170/bmp_5266447eeec39.pdf (in Polish).