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A.K. Khassenov[1*], M. Stoev[2], D.Zh. Karabekova[1], G.A. Bulkairova[1], D.A. Nurbalayeva[1]

[1]*Karaganda University of the name of academician E.A. Buketov, Kazakhstan*
[2]*Neofit Rilski South-West University, Blagoevgrad, Bulgaria*
(*[*]E-mail: ayanbergen@mail.ru*)

Electro-pulse method for obtaining raw materials for subsequent flotation enrichment of ore

The main method of enrichment of polymetallic ores is flotation. The peculiarity of solid mineral processing is the preliminary preparation of raw materials. The essence of this stage is the grinding and sorting of raw materials in order to fully reveal the useful substance from the waste rock. The article is devoted to the study of the effect of electric pulse discharges on the grinding of ore containing non-ferrous metals. This article proposes an electro-pulse method for obtaining raw materials for subsequent flotation enrichment of ore in order to extract valuable components. This method of grinding ores is based on the use of the energy of a pulsed shock wave that occurs as a result of a spark electric discharge in a liquid. An experimental electric pulse unit with a crushing unit is described. When electrohydraulic action on solid particles in an aqueous solution increases the intensity of the grinding process under the influence of additional pressure associated with cavitation. The object of the study was the natural ore of the Akbastau mine. Ore grinding operations were performed at various parameters of the electric pulse plant. The dependences of ore grinding on the electrical and geometric parameters of the electric pulse installation, the value of the interelectrode gap on the switching device, the pulse repetition frequency and discharge energies are determined. It is found that with increasing discharge energies introduced into the discharge channel, the fraction of the crushed fraction increases.

Keywords: ore, flotation, electric pulse installation, working electrode, degree of grinding, crushing, discharge energy.

Introduction

The flotation method is used for the enrichment of most non-ferrous metal ores, in combination with other methods for the enrichment of ferrous metal ores. The wide prevalence of flotation is explained by the universality of the process for the mining industry, associated with the possibility of separating almost any minerals, enriching poor ores with a very thin impregnation of useful minerals.

Flotation in the most general form can be defined as a method of separating relatively small particles of different solid phases suspended in a liquid from each other (or separating solid particles from a liquid) by their ability to adhere to gas bubbles introduced into the suspension, followed by their floating to the surface of the liquid and the formation of foam [1, 2].

To extract valuable components from the waste rock by flotation, the ore is first crushed to the required size. In most cases, the final size of the crushed ore is 0.074 mm. The main purpose of the grinding process is to ensure the release of individual minerals contained in the pieces of the host rock.

Grinding of minerals is carried out in mills, metal rods, balls, and large pieces of the ore itself are used as grinding bodies. In processing plants, cylindrical drum ball or rod mills are mainly used. When using drum mills with steel crushing bodies, the cost of covering the wear of balls, rods and liners is one of the main costs of grinding and reaches energy costs, and sometimes exceeds them. For example, when enriching Kryvyi Rih magnetite quartzites, the cost of rods and balls is 30-35% of the total cost of crushing. During dry grinding, the balls wear out mainly as a result of abrasive action. When wet grinding in aggressive (chemically active) aqueous media, abrasive wear is accompanied by corrosion, in which the metal is destroyed as a result of chemical or electrochemical interaction with the environment. Thus, wear of the balls is a very complex process due to many conditions: the properties of the metal (alloy) made of balls, their size, the abrasive properties of the ground material, its size and the size of the product and the method of grinding (dry or water), aggressive environment (acidic, alkaline), its temperature, the presence of surfactants, high-speed mode of the mill (cascade waterfall), grinding circuit (open or closed cycle), etc. Corrosion wear during wet grinding is the main component of the overall wear, so the loss coefficients are higher than during dry grinding [3, 4].

A radical solution to the problems of complex use of mineral raw materials, increasing the completeness of obtaining minerals with a deterioration in their initial quality in conditions of increasing production and processing volumes can be achieved on the basis of new methods of crushing and grinding, characterized by a high degree of destruction, high selectivity of mineral detection. One of the best methods for grinding solid materials is the electric pulse method. Since the working tool for electric pulse destruction is a spark, there are no problems with contamination of the grinding product with metal, the material of grinding bodies, which is typical for mechanical methods of grinding materials. Therefore, electropulse crushing of highly abrasive materials, especially pure materials, is preferable to mechanical crushing [5-7].

Problem statement and method description

Based on the above problems, the influence of electric pulse discharges on the grinding of ore containing non-ferrous metals is studied in the scientific work. As the conducted experiments show, this method of grinding is economical, environmentally friendly, and easily integrated into any technological chain. The essence and distinctive feature of the proposed technology is that the processing of ore and man-made raw materials using pressure energy released during electrohydraulic action allows you to obtain a product of a given dispersion that is quickly crushed and easily cleaned of undesirable impurities, which can then be used directly for subsequent enrichment [8].

Electropulse crushing is an effective method of grinding various materials, which allows you to obtain a product with a given degree of grinding with a certain granulometric composition and has a high selectivity of crushing. The technological process of electric pulse grinding is easily automated. Maintenance of electric pulse installations does not require a large number of highly qualified workers. In electric pulse crushers, almost any solid material can be crushed and crushed [9]. When working, these devices do not form dust, occupy relatively small production areas and allow them to combine the processes of crushing, mixing and flotation of materials [8].

An electric pulse unit with a crushing unit was developed and assembled to study ore grinding [10]. The electric pulse unit is made in the form of functional blocks (Figure 1), which consist of a control panel, a generator with a spark gap, a protection unit with a capacitor.

Figure 1. Electric pulse installation. 1-control panel, 2-generator with a spark gap (switching device), 3-protection unit with a capacitor.

In the crushing unit there is a cylindrical chamber in which a linear system of electrodes is installed. The positive electrode is located vertically, and the negative electrode is the bottom of the metal chamber of a hemispherical shape. When a powerful pulse passes through a liquid medium, which is a moistened mass, an electric breakdown is created, accompanied by a hydraulic shock of great destructive force.

The water medium in which the high-voltage electric discharge occurs is a transformer of the energy released in the discharge channel, and due to its low compressibility, it leads to a sharp increase in pressure. Under the influence of electrohydroimpulse action, hydrodynamic fluid flows and an acoustic wave occur in the treated medium, and cavitation occurs as a result of a local decrease in pressure in the liquid. In this case, the cavitation bubble, moving with the flow of liquid to the area with a more significant pressure, closes and emits a shock wave. After the collapse of the bubbles, micro-shocks of cumulative jets will form. The mixture, having received acceleration from the discharge channel expanding at high speed, moves away from it in all directions. At the beginning of the process, the discharge channel increases with the maximum speed, at the end of the current flow, the cavity of the discharge channel continues to expand due to the inertia of the medium, reaches the largest size and then begins to contract. The temperature and pressure in it fall during the expansion of the cavity, and increase during compression, i.e., there are damped pulsations of the cavity.

When electrohydraulic action on solids in an aqueous solution increases the intensity of the grinding process as a result of the additional pressure associated with cavitation. Indeed, a cavitation micro-cavity appears on each solid particle, which, collapsing, increases the mechanical effect [7, 11, 12].

The versatility of electric pulse destruction is due to the possibility of large-scale regulation of the nature of the dynamic impact of discharge factors on the material. The peculiarity of electro-pulse grinding is that the area of impact on the material through the discharge channel is localized in a limited volume of the interelectrode interval. This allows you to multi-dimensionally organize the process of destruction and removal of the product in the chamber and, consequently, control the granulometric composition of the crushed product. It is much easier to implement a multi-stage grinding process with electric pulse destruction, including in a single device. In the multi-electronic design of the working chamber, it is possible to influence the granulometric composition of the grinding product by an appropriate ratio of the pulse frequency to the classification ability of the device [13, 14].

Analysis of experimental results

The object of the study was the natural ore of the Akbastau mine with initial diameters (d_0) from 10 mm to 25 mm. Since the energy efficiency of crushing the material depends on the size of the ore particles and the parameters of pulsed discharges, the work on crushing the ore was performed at different values of the discharge energy. The discharge energy W varied depending on the capacity of the energy storage capacitor and the discharge voltage. In addition, the efficiency of the electro-pulse method of grinding the material is characterized by the corresponding frequency of pulse discharges.

Ore grinding operations were performed at various parameters of the electric pulse plant:

– interelectrode gap on the switching device, mm – 8; 10; 12; 14; 16 (Figure 2);
– frequency of pulse repetition, Hz – 1,5; 2; 2,5; 3; 3,5; 4 (Figure 3);
– capacity of the storage capacitor, μF – 0,25; 0,4; 0,8;
– discharge voltage (breakdown voltage of the interelectrode gap on the switching device), kV– 22; 26; 30; 34; 38.

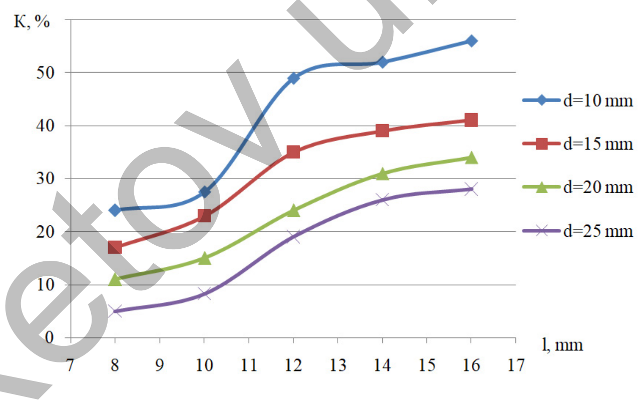

Figure 2. Dependence of the degree of ore grinding on the value of the interelectrode gap on the switching device

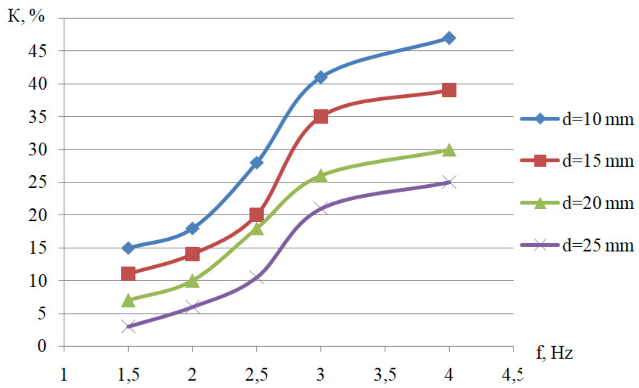

Figure 3. Graph of the dependence of ore grinding on the pulse repetition frequency

The influence of the interelectrode gap on the switching device was carried out with the constancy of other parameters of the installation, which allows you to choose the optimal value necessary for reproducing experiments. According to the results obtained, the optimal interelectrode gap l=12 mm, at which the output was the highest (Figure 2). A further increase in the interelectrode gap stabilizes the output of finished products, but the pulse repetition rate changes. With an increase in the pulse repetition frequency, a uniform grinding is established (Figure 3, the results are obtained at *l*=12 mm). With an increase in the discharge energy ($W=CU^2/2$) introduced into the discharge channel, the fraction of the crushed fraction increases (Figure 4).

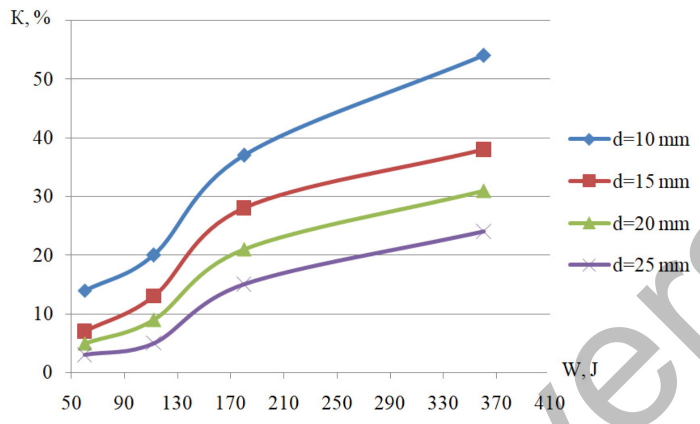

Figure 4. Dependence of the degree of ore grinding on the discharge energy

Given the obtained optimal values of the adjustable parameters (l=12 mm, C=0,4 μF, W=180 J) and duration of treatment 5 minutes to obtained the desired product fraction ≤0.07 mm in the amount of about 37%, 28%, 21%, and 15% for ore initial fraction of 10 mm, 15 mm, 20 mm and 25 mm, respectively. During the experiment, the most optimal value of the interelectrode gap on the switching device is 12 mm, and the diameter of the fractions subjected to the most intense destruction is 10 mm. The degree of grinding increases with an increase in the specific energy introduced into the discharge channel, which is explained by the fact that a network of microcracks is first formed in the structure of the substance on the path of the shock wave, which creates a continuous stress state.

Conclusion

According to experimental data, the prerequisites for regulating the granulometric composition of the processed material during electric pulse grinding are shown. This is due to the possibility of creating favorable conditions for obtaining the necessary product by changing the electrical and geometric parameters of the pulse installation in different ranges. Using the electro-pulse method, raw materials for flotation enrichment were obtained, intended for further extraction of valuable components from ore.

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А.К. Хасенов, М. Стоев, Д.Ж. Карабекова, Г.А. Булкаирова, Д.А. Нурбалаева

Кенді флотациялық байытуға қажетті шикізатты алудың электримульсті әдісі

Полиметалл кендерін байытудың негізгі әдісі флотация болып табылады. Қатты пайдалы қазбаларды байытудың ерекшелігі — шикізатты алдын-ала дайындау. Бұл кезең бос жыныстағы пайдалы затты неғұрлым толық ашу үшін шикізатты ұнтақтау және сұрыптауға арналған. Мақала құрамында түсті металдар бар кеннің ұнтақталуына электроимпульсті разрядтардың әсерін зерттеуге арналған. Авторлар құнды компоненттерді алу үшін кенді флотациялық байытуға қажетті шикізатты алудың электроимульсті әдісін ұсынған. Кендерді ұсақтаудың әдісі сұйықтықтағы ұшқынды электр разряды нәтижесінде пайда болатын импульстік соққы толқынының энергиясын пайдалануға негізделген. Ұсақтағыш түйіні бар эксперименттік электроимпульсті қондырғы сипатталды. Су ерітіндісіндегі қатты заттарға электрогидравликалық әсер ету кезінде кавитациямен байланысты қосымша қысым әсерінен ұнтақтау процесінің қарқындылығы артады. Зерттеу нысаны ретінде Ақбастау кенішінің табиғи кені алынды. Кенді ұнтақтау жұмыстары электроимпульсті қондырғының әр түрлі параметрлерінде жүргізілді. Кенді ұсақтаудың электроимпульсті қондырғысының электрлік және геометриялық параметрлеріне, коммутациялық құрылғыдағы электрод аралығының шамасына, импульстар жиілігіне және разряд энергиясына тәуелділігі анықталды. Арнаға енгізілетін разрядтың энергиясының жоғарылауымен ұсақталған фракцияның үлесі артатыны дәлелденді.

Кілт сөздер: кен, флотация, электроимпульсті қондырғы, жұмыс электроды, ұсақтау дәрежесі, бөлшектеу, разряд энергиясы.

А.К. Хасенов, М. Стоев, Д.Ж. Карабекова, Г.А. Булкаирова, Д.А. Нурбалаева

Электроимпульсный метод получения сырья для последующего флотационного обогащения руды

Основным методом обогащения полиметаллических руд является флотация. Особенность обогащения твердых полезных ископаемых состоит в предварительной подготовке сырья. Сущностью этой стадии являются измельчение и сортировка сырья с целью наиболее полного раскрытия полезного вещества из пустой породы. Статья посвящена исследованию влияния электроимпульсных разрядов на измельчение руды, содержащей цветные металлы. Авторами предложен электроимульсный метод получения сырья для последующего флотационного обогащения руды с целью извлечения ценных компонентов. Данный способ измельчения руд основан на использовании энергии импульсной ударной волны, возникающей в результате искрового электрического разряда в жидкости. Описана экспериментальная электроимпульсная установка с дробильным узлом. При электрогидравлическом воздействии на твердые частицы в водном растворе интенсивность процесса измельчения возрастает под действием дополнительного давления, связанного с кавитацией. Объектом исследования являлась природная руда Акбастауского рудника. Работы по измельчению руды выполнялись при различных параметрах электроимпульсной установки. Определены зависимости измельчения руды от электрических и геометрических параметров электроимпульсной установки, величины межэлектродного промежутка на коммутационном устройстве, частоты следования импульсов и энергий разряда. Установлено, что с увеличением энергии разряда, вводимой в канал разряда, доля измельченной фракции возрастает.

Ключевые слова: руда, флотация, электроимпульсная установка, рабочий электрод, степень измельчения, дробление, энергия разряда.

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