

About Prospects of Enrichment of Mineral Raw Materials and Chemical Activation of Water Suspensions by Electroexplosive Method

S V Bordunov¹, O V Galtseva²

¹Supervisor, Public Corporation Scientific - Innovation Enterprise "Echteh", Tomsk, Russia

²Associate Professor, NDT Institute, Tomsk Polytechnic University, Tomsk
E-mail: bvv@academ.tsc.ru

Abstract. A series of experiments is conducted on laboratory and pilot-production installation for the application of high-voltage pulsed discharge in the processes of enrichment of gold-bearing mineral raw materials with a relatively low energy electrical discharge in the pulse of 120 J. At the same time the conglomerates of clay components are breaking down to micron and submicron sizes completely. Solid minerals such as quartz are simultaneously destroyed by defects and grains and withdrawn from the installation with water, thus increasing degree of enrichment of concentrate. The results of the processing by high-voltage pulsed discharges of building sand from the Ob riverbed are given. Discharge energy is 45 J. Relations of fractions in the original sand and in the sand after electroexplosive process show the uniform crushing of sand particles with splitting off particles with size of less than 0.045 mm. A content of chipped particles is 18 %. The results of particle-size and X-ray structural analyses are shown.

1. Introduction

According to scientific literature 70 % of the gold in the lithosphere is represented by particles with size of 100 microns or less. Thin and fine - grained gold contained in the technogenic placers - dumps of current and long - closed mines. In [1] is reported that the large and the very large gold with size more than 100 microns is produced in Russia. In [2] are shown the data about the gold deposits in the Magadan region, only 5.1 % of this gold with particle size of 50 microns or less is recovered by gravity methods. In [3] is reported about the necessity of disintegration of clay scatterings of gold, and thin gold can be extracted only after removal of clay from these scatterings.

In [4] is presented the method of disintegration of clay, based on the dispersion of clay lumps by rotating water jets with pressure about 150 atmospheres. As a result, the raw material is separated into sludge (clay) fraction with thin gold and crystal fraction with approximately equal gold content. Gold from fractions leached separately. This method didn't allow removing the clay from raw material without loss of gold, as the traditional method of washing out of raw materials from clay in the scrubber-trommels. Therefore, the most important problems in the process of enrichment of raw material are the removal of clay components from raw material and the extraction of thin gold (platinum) with particle size less than 50 microns into concentrate.

According to [5] the clays are composed of clay particles, ultramicrounits, units, grains, inclusions of microfauna and flora, microcrystals and ore minerals. The individual particles form ultramicrounits



and microunits. Ultramicrounits are the strong formations by length from shares of micron to several microns; they are not destroyed by the granulometric analysis. Microunits (size up to several tens of microns) are the associations of clay particles and ultramicrounits, which not disintegrate in water independently at absence of mechanical dispersers.

Interaction of clay particles with elastic grains (minerals and particles of gold) leads to formation of a dense shell-like "coat" on grains; thus, these grains are always submersed in clay mass. The contact between grains takes place only through "coat". The strength of such phase contacts is 10 - 6 N, such "coats" do not lose the strength when wet, and a particle of gold in "coat" not only inaccessible to aqueous leaching solutions, but also loses its essential dignity, used at the gravitational enrichment – high specific weight. Extracting of fine - grained gold into concentrates is mainly by gravity methods based on the difference in the speed of sedimentation of particles with different sizes and density.

The deposition rates of equal-sized particles of gold, pyrite and quartz calculated for laminar mode correlate as 14:3:1; and for turbulent mode correlate as 5:2:1, which is used in most modern devices for obtaining gravity concentrates, and a particle of gold in "coat" is deposited not faster than particles of pyrite. In the literature there are reports about the use of effects of secondary cavitation of ultrasound for dispersing clays, but the effectiveness of this method is small, as well as the efficiency coefficient of energy use.

The most effective tool for dispersing clays with simultaneous destruction of the mineral particle on adhesions, boundaries of section in particles and other defects in the mineral particles, is an electrical discharge in water suspensions. The electric discharge ($E=CU^2/2$) generates the shock waves of compression and extension (up to 60% energy level), ionizes of water with the formation of such reactive products, such as O_2 , H_2 , OH^- , H_2^+ , O_2^+ , O^- , H^+ , secondary volumetric cavitation on particles of suspension, ultraviolet and electromagnetic radiation.

Physical and chemical factors of effect of electric discharge on solid phase of water suspensions are known for a long time. The most publications based on the use of high-voltage pulsed discharges with voltage higher than 110 kV and energy of 10 - 400 kJ, comparable to the explosion energy of industrial explosives. Probably why the industrial electroexplosive installations, the walls of which should be thick enough and durable, were not created.

We were focused on the voltage to 30 kV and the energy in the discharge of up to 120 J, which is allowed to create the technological equipment of sheet steel with a wall thickness of 3 to 4 mm.

2. Experimental

The working laboratory installation is shown schematically in figure 1; it is designed for the primary research of raw materials and determination of the necessary technological modes of processing.

The following tasks are solved with the help of this stand:

- the optimization of energy consumption ($kW \cdot h/t$);
- the speed optimization of water consumption (l/min) required for the maximum removal of "empty" rock from the reactor with the flow of water and increase of gold content in the concentrate.

Further the experiments are carried out at the experimental industrial electroexplosive installation (figure 2) with four electrode pairs [6], which arranged in pairs on opposite walls of the reactor.

The installation operates as follows. The reactors, tank of concentrate and settlement pond are filled with water, which flows through the reactor and is discharged from the settlement pond through the drain with a certain predetermined speed.

The linear speed of the water and suspension "water and raw material" in the reactor is defined as the quotient of the division of the preset productivity of installation by suspension (dm^3) on the cross-sectional area of the reactor (dm^2). The power supply is switched on after filling of the system with water, the frequency of pulse repetition is set and the conveyor of giving of raw materials into reactor turns on. The serve of the initial solid raw materials with natural moisture is carried from the top down to meet the upward flow of water, in which the air can be introduced through the ejector as necessary.

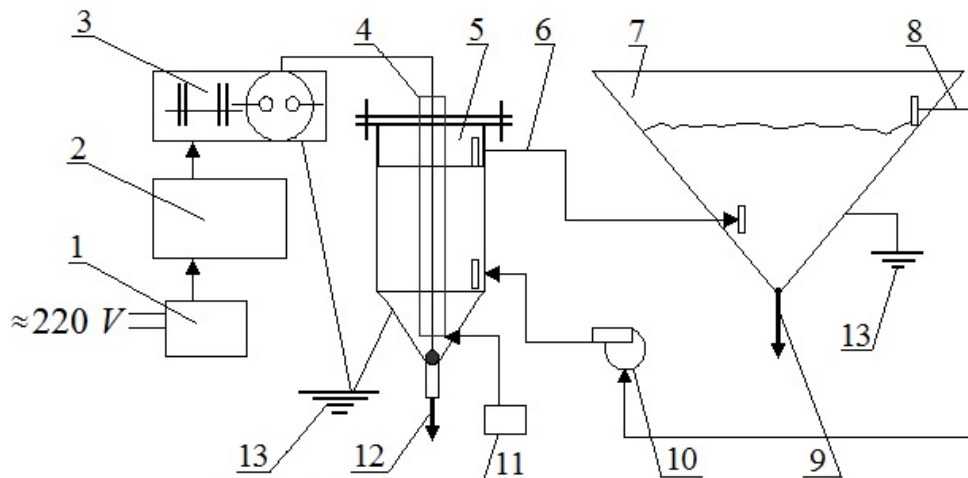


Figure 1. Research electroexplosive installation: 1 – control panel; 2 – high-voltage transformer; 3 – the pulse generator (capacitor, ballast resistors, spark gaps); 4 – insulated electrode; 5 – electro-hydraulic reactor; 6 – line with removal of water from fine-grained rock; 7 – settlement pond; 8 – withdrawal line of clarified water; 9 – line of withdrawal of slurry tailings; 10 – pump; 11 – compressor; 12 – output line of concentrates; 13 – grounding.

At movement of suspension on reactor length the each particle of mineral raw materials should be at least 20 times in the area of the shock waves of four electrodes, sequentially installed in the insulators on the lid of the reactor along its length. Grounded electrodes are the shelves which are installed inside of reactor at an angle of 30 to 45° to the vertical axis of the reactor. There are spring-loaded horizontal supports of shelves.

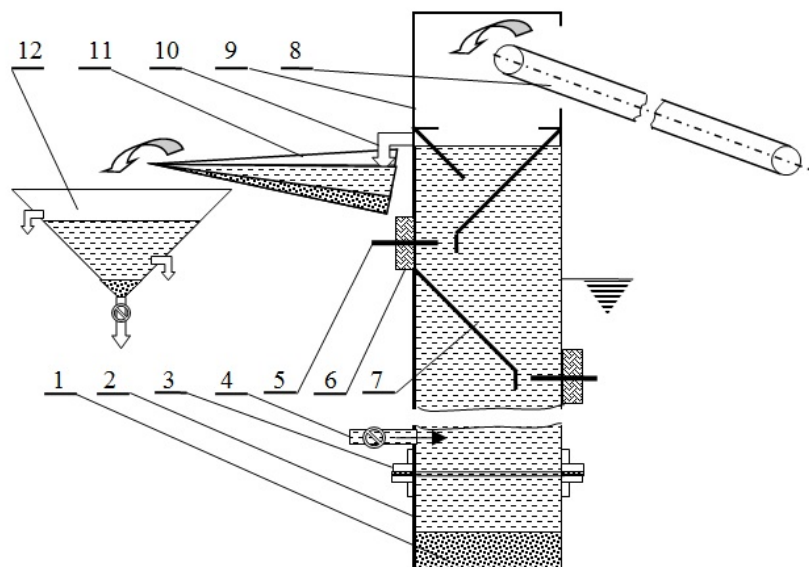


Figure 2. Experimental industrial electroexplosive installation with four electrode pairs: 1 – heavy concentrate; 2 – heavy concentrate bunker; 3 – flanged connection; 4 – water inlet pipe sleeve; 5 – high-voltage electrode; 6 – high-voltage electrode isolator; 7 – landing - ground electrode; 8 – initial raw material transporter; 9 – reactor housing, square in section; 10 – fine slurry outlet pipe sleeve; 11 – fine concentrate trap; 12 – settlement pond.

Thus, in the experiments it is necessary to set the frequency of pulse repetition from power source based on the speed of movement of suspension and the length of zone of action of discharges from

electrodes. In reactor the rock breaking occurs by action of discharges, the crushed clay components entrained with the flow of water into the settlement pond. The removal of particles which are not deposited in the upward flow of water (tailings) is carried out through nozzles in the upper part of the reactor.

The residence time in the reactor increases due to the sliding of solid phase on shelves, the slipping on the shelves of the smallest particles is provided by the vibration of shelves under the action of shock waves and springs. Heavy particles with speed of sedimentation higher than the speed of the upward flow of water fall into tank of concentrate.

The electroexplosive processing of mineral raw materials with size up to 100 mm and the classification of particles of solid phases by size in the tailings and concentrate by the speed regulation of upward flow of water are possible in this reactor. The design of shelves in the upper part of reactor provides the removal of thin suspension of tailings into special chamber without pulsation in the mode close to laminar.

The batcher is switched off after recycling of the batch of raw materials, the water for washing out of the reactor volume from the residue of a solid phase in suspension is served within 5 minutes through the reactor, the power supply is switched off, the voltage of the high - voltage elements of installation is switched off, the water is discharged from the reactor, the concentrate and the tailings from tanks are discharged.

As the clays on the *Prof. Protodyakonov's* scale of hardness rocks is among the least hard rocks, they are almost evenly dispersed to ultramicrounits (3 – 6 μm) at processing by high-voltage pulsed discharge up to 30 kV on installations (figures 1 and 2), the speed of sedimentation of this particles at the laminar mode less than that of gold particles with size of 1 micron.

3. Results and considerations

We studied the possibility of dispersion the clays when exposed to an electric discharge on pieces with size of 10 mm. Samples were taken from the ilmenite placer of Tisulsky district of the Kemerovo region. The experiment showed that pieces of clay are dispersed almost to the colloidal state after 20 discharges with energies up to 120 J. Speed of clarification of column of such clay suspension and accumulation of sediment at the bottom of the cylinder with height of 20 cm is less than 1 cm/day.

The equality of the speed of clarification and sediment shows that there are no harmful factors (the conglutination and the consolidation of clay particles) for the extraction process of fine - grained gold from clay raw material. Stronger rocks are also subject to crushing, mainly, by defects in the structure of the grains.

The results of experiment of electroexplosive process of building sand from the riverbed of the Ob with discharge energy 45 J are shown on figure 3. Changes of relations of fractions in the original sand and in the sand after electroexplosive process show the uniform crushing of sand particles with splitting off particles with size of less than 0.045 mm. A content of chipped particles is 18 %.

X-ray analysis showed that the amount of the crystal phase of SiO_2 increased to 94.9 % after processing by the high-voltage pulsed discharge (90.2 % in the initial sand) in the sand fractions 1 – 7; the amount of tailings decreased to 83 % in the sand fraction 8, but 17 % of Si^* phase appeared. The strength of concrete on compression with filler of sand of fractions 1 – 7 after processing by the high-voltage pulsed discharge on 40 % higher than strength of concrete with filler of initial sand [7].

The effect of grinding of strong rock SiO_2 by discharges with energy of 45 J was tested on tailings of three gold processing plants. The gold content in leaching solution increases by 3 to 6 % after leaching of gold in the Aqua Regia for 24 hours in the sample after processing by the high-voltage pulsed discharge. This is the gold screened within grains of accompanying rock or clay "coats".

High efficiency of processing by the high-voltage pulsed discharge of clay gold-bearing raw material with clay content up to 90 %, which is almost completely removed from the process, the concentrate with weight 8 – 2 % of weight of raw material contains more than 95 % of the initial gold [8].

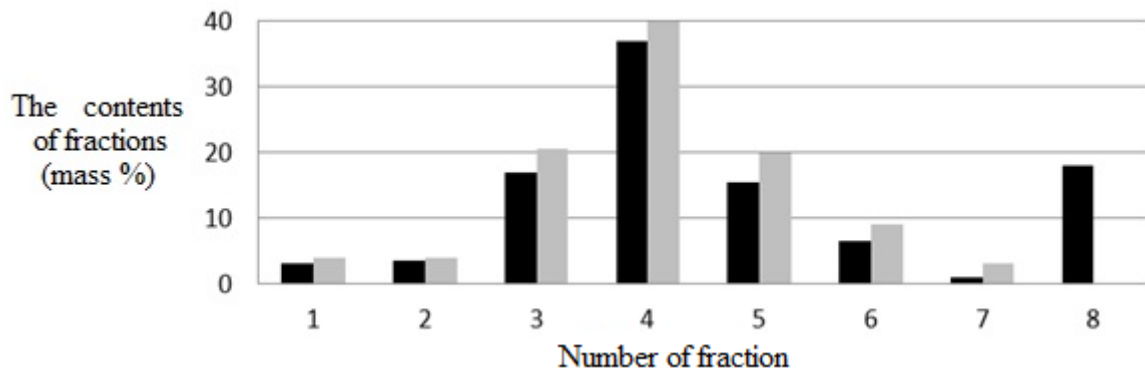


Figure 3. The result of processing of sand from the river Ob by 10 discharges at 45 J, where are ■ – the sand after processing by the high-voltage pulsed discharge and □ – the original sand.

Number of sand fraction corresponds to the following particle size:

- 1 ÷ 5: – 2.5 mm; 2: 2.5 – 2 mm; 3: 2 – 1 mm; 4: 1 – 0.315 mm; 5: 0.315 – 0.2 mm;
6: 0.2 – 0.1 mm; 7: 0.1 – 0.045 mm; 8: 0.045 mm.

4. Summary

Three types of industrial electroexplosive installations with productivity of thin suspension up to 100 m^3/h and of solid raw material up to 10 t/h [6, 8–10] are developed by us on the basis of more than fifteen years of research. The developed technology is characterized by low consumption of electric energy. Depending on the type of processed raw materials the consumption of installation at enrichment of mineral raw materials at processing by high-voltage pulsed discharge is 0.05 – 0.1 $kW \cdot h/m^3$ of suspension (not more than 1.5 $kW \cdot h/t$ of solid raw materials).

Experimental industrial tests showed that the wall thickness of electroexplosive reactors for processing of suspensions with size of particles of the solid phase is less than 0.63 mm, productivity is 100 m^3/h and not more than 4 mm, and the dimensions of the reactor do not exceed 400×800×1200 mm. Technology can be used in utilities in the purification of drinking and waste water [11], hydrometallurgy, enrichment of ores of nonferrous and precious metals, in the construction of buildings and structures made of concrete with high impact strength and compressive strength.

References

- [1] Melamud V S (1999) *Proceedings of 1st International Symposium "Gold of Siberia"* 115–117
- [2] Melnikov M S *et al* (1981) *Proceedings of TsNIGRI* **158** 38–41
- [3] Generalov M E, Naumov V A (1998) *Uralian Geological Journal* **4** 19–56
- [4] Metodi K *et al* (2014) *Gold and Technology* **1** 28–32
- [5] Galtseva O V *et al* 2013 *Electroexplosive equipment for dispersing, chemical activation and mineral processing* (Tomsk, TPU Publishing House)
- [6] Bordunov S V *et al* 2013 RF Patent 2477173 *Byull. Izobret.* **7**
- [7] Bordunov S V and Kulaga I G (2012) *Industrial and Civil Engineering* **4** 58–61
- [8] Bordunov S V *et al* (2008) *Rus. J. Non-Fer. Met.* **9** 24–28
- [9] Bordunov S V *et al* 2012 RF Patent 2470875 *Byull. Izobret.* **36**
- [10] Bordunov S V *et al* (2008) *Rus. J. Non-Fer. Met.* **2** 65–68
- [11] Petrova A Y *et al* (2015) *Technical Physics* **60** (4) 592–594