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Research of electrohydraulic destruction of mineral quartz

In connection with the government's program of import substitution, the possibility of obtaining products based on quartz-containing local raw materials of Kazakhstan has gained relevance. The most popular quartz raw material in the technological processes are easily regenerated quartzites, which ensure a higher rate of chemical transformations. The article presents the results of the investigation of the electrohydraulic method for the destruction and grinding of the natural quartz mineral of the Aktas deposit. Also, the microstructure and energy spectrum of the quartz sample were studied before and after electrohydraulic treatment. Electric discharge in a liquid is the main operating mechanism in many domestic and foreign technologies. From the whole complex complex of phenomena that arise during an electric discharge in a liquid, direct transformation of electric energy into the energy of the pressure of shock waves is used. Application of the electrohydraulic effect for the quartz mineral crushing allows to optimally use the obtained dosage fractions for various industries.

Keywords: natural mineral quartz, crushing and grinding, electrohydraulic effect, discharge channel, shock wave, microstructure, energy spectrum.

The development of industry, as well as the improvement of Kazakhstan's energy security, depend to a large extent on the widespread and effective use of natural resources. Most of the country's regions have huge reserves of industrial minerals. An early organization of mining and mineral processing at the fields of Kazakhstan is needed. The use of crushed mineral in a wide variety of areas will allow to obtain new products with a number of valuable properties, and will contribute to technical progress in a number of industries. Also, the lack of natural minerals in European countries make it possible to treat the mineral as a subject of export.

The most popular quartz raw material in the technological processes are easily regenerated quartzite's, which ensure a higher rate of chemical transformations, but work on the involvement of other types of quartzite's in the technological cycles are known [1].

Quartz is the most common mineral with the chemical composition of SiO_2 (46.7 % — Si, 53.3 % — O_2). In practice, quartz crystals extremely rarely approach this composition, since they usually contain various impurities.

At present, ground quartz is widely used in various industries. For example, in the production of refractories, in metallurgy, in the production of ceramics and glass, in the production of optical fiber, in the production of construction products and filigree development, the production of semiconductor crucibles, combustion chambers, etc. In huge quantities it is used for the production of glass, ceramics, refractories. As a piezoelectric, it is used in optical instruments, in ultrasound generators, in telephone and radio equipment, although it has recently been supplanted by other artificial piezoelectrics. Many varieties are used in jewelry. Quartz is also used to produce pure silicon.

The Republic of Kazakhstan has large reserves of quartz-containing raw materials, but its main part is used in the production of simple building materials, and only small-scale high-tech industries. The largest deposits in the Karaganda region are the Aktas and Nadybay fields, located near the city of Zhezkazgan. Similar deposits exist in Kokshetau and Pavlodar regions.

Known methods of processing quartz mineral and operating industrial plants require high energy costs, do not provide full production of pure quartz are not effective in terms of ecology and labor-saving.

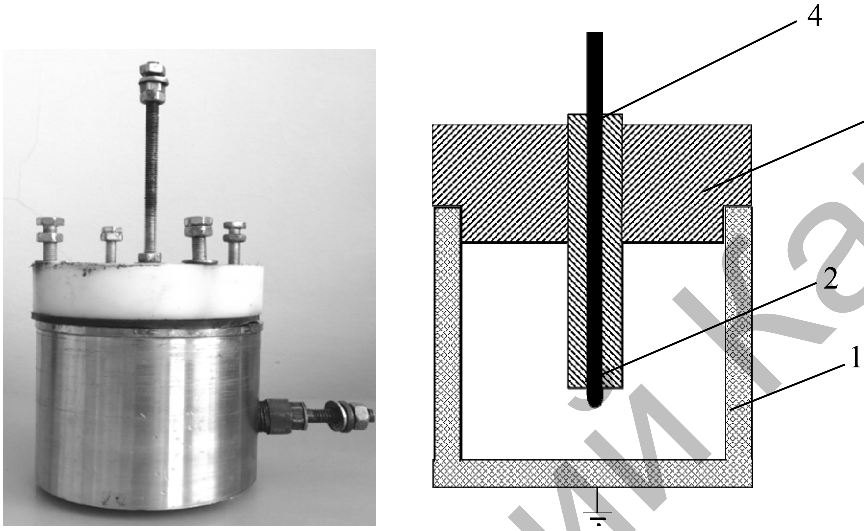
One of the methods are used to crush solid bodies is the electrohydraulic method used as a working tool for the energy of high voltage pulsed electrical discharges within rocks.

The proposed method of grinding quartz is based on the use of the energy of a pulsed shock wave, which arises as a result of a spark electric discharge in a liquid. This method of fragmentation is promising, economical, environmentall clean and easy to integrate into any technological chain.

The electrohydraulic effect [2] is a high-voltage electric discharge in a liquid medium. In the formation of an electrical discharge in a liquid, energy is released in a fairly short time. A powerful high-voltage electric pulse with a steep leading edge causes various physical phenomena. Such as the emergence of ultra-high pulsed hydraulic pressures, electromagnetic radiation in a wide frequency range (under certain conditions prior to X-ray), cavitation phenomena. These factors have different physicochemical effects on the liquid and the bodies placed in it.

Investigation of the effect of the electrohydraulic effect on the degree of crushing and grinding of the quartz mineral were carried out in the electrohydrodynamics laboratory on the Cairt of Thermophysics and Engineering named after Professor Zh.S. Akylbaev at Ye.A. Buketov KSU.

The electrohydraulic unit consists of a control panel, a high voltage pulse voltage generator, a switching device with a protection system and a working area where quartz is crushed and mined. The working section consists of: a cylindrical body, a working electrode, a cover, a caprolan washer (Fig. 1).



1 — cylindrical body, 2 — working electrode, 3 — cover, 4 — caprolan washer

Figure 1. Working area of the experimental stand for crushing the quartz mineral

The space between the electrodes is filled with a multiphase medium with nonlinear electrophysical characteristics, which can be represented as a deterministic nonlinear dynamical system.

When a powerful pulse passes through a liquid medium, which is a moistened ore, an electric breakdown is created, accompanied by a hydraulic shock of great destructive force.

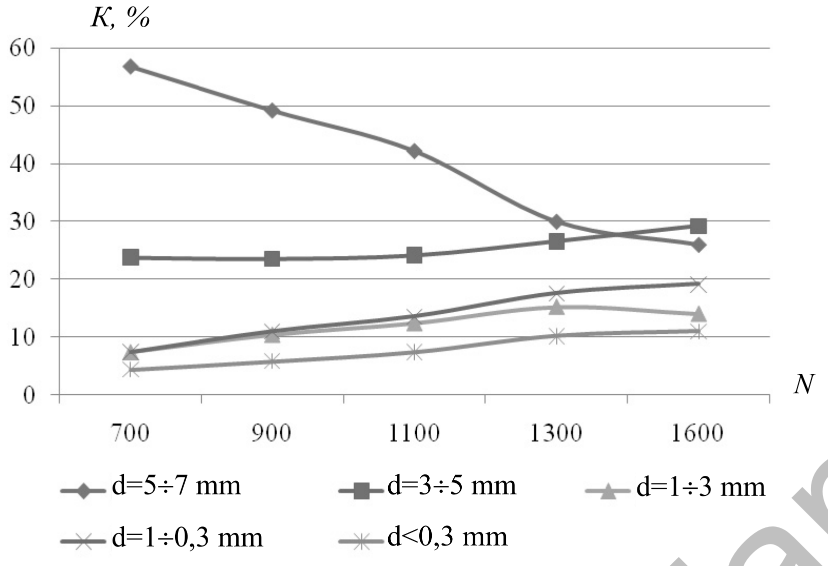
In the experiments carried out the degree of grinding of the quartz mineral increases with the increase in the specific energy introduced into the discharge channel, which is explained by the fact that in the quartz, a network of microcracks is first formed in the path of the shock wave, which creates a continuous stress state. As a result of the action of a series of pulses of duration (10^{-5}÷10^{-4}c) on solid quartz fractions, plastic deformations accumulate at the initial stage, which on the one hand increases its strength, on the one hand, and stresses, destroying the mineral, arise in the zones of defectiveness of structures [3].

Electrohydraulic devices for crushing, in contrast to mechanical crushers, do not have moving parts, they are made of ordinary structural steel, and their body practically does not wear out during operation. When working, these devices do not form dust, occupy relatively small production areas and allow the combining in them of the processes of crushing, mixing and flotation of materials. The working environment in electrohydraulic crushers can be any liquid, most often technical water. All this makes it possible to effectively combine the process of crushing and grinding quartz.

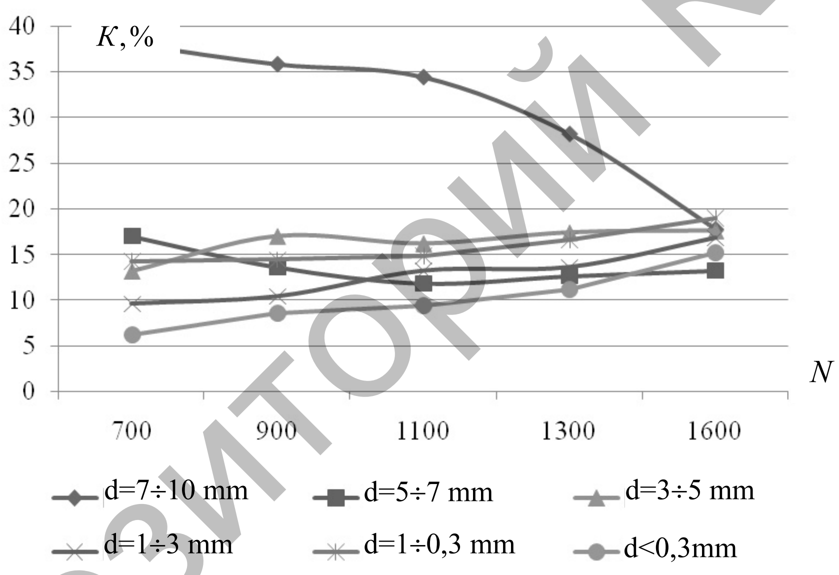
Quartzites of the Aktas field used in the work as the main material are represented by quartz particles of milky white and grayish white colors. In insignificant quantity there are grains with inclusions of light brown color [4].

The experiments were carried out with a capacitance battery of 0.25 mkF, voltage on the switching device up to 19 kV, the interelectrode distance of the working channel of 6 mm, and the length of the discharge gap on the commutating device of 10 mm. The first diameter of the destruction of minerals was 7 mm and 10 mm, and the number of electrohydraulic impulses ranged from 700 to 1600.

Figure 2 shows the dependence of the degree of grinding K of the quartz mineral on the number of electrohydraulic impulses N.



a) $l_e = 7$ *mm,* $C = 0{,}25$ *mkF,* $m_f = 50$ *g*



b) $l_e = 10$ *mm,* $C = 0{,}25$ *mkF,* $m_f = 50$ *g*

Figure 2. Dependence of the degree of grinding of quartz mineral on the number of electrohydraulic impulses

In Figure 2a with the initial fraction of 7 mm in diameter and the number of electrohydraulic pulses N = 700, the degree of coarse fractions is ($d_f = 5 \div 7mm$) 56.8 %, the degree of grinding into small particles ($d_f \prec 0{,}3mm$) 4.4 %, and at N= 1600 large fractions ($d_f = 5 \div 7mm$) decreases to 26 %, fine fractions ($d_f \prec 0{,}3mm$) increases to 11 % of the feedstock.

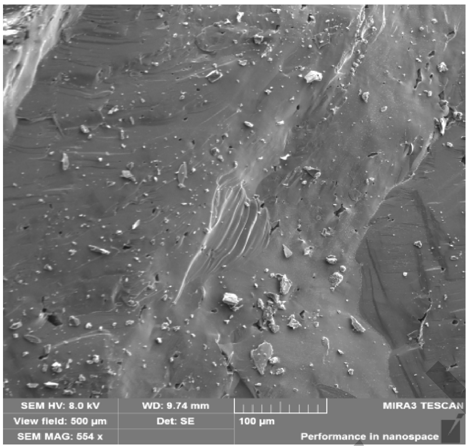
With the initial fraction of 10 mm in diameter and the number of electrohydraulic wave pulses N = 700 (Fig. 2b), the degree of coarse fraction is ($d_f = 7 \div 10mm$) 38 %, fine fractions ($d_f \prec 0{,}3mm$) 6.2 %, and at N = 1600, the coarse fractions ($d_f = 7 \div 10mm$) are reduced to 17.8 %, fine fractions ($d_f \prec 0{,}3mm$) is increased to 15.2 % of the feedstock.

From the above graphs, it can be concluded that when the number of electrohydraulic impulses decreases the size of large fractions and increases the size of the crushed particles.

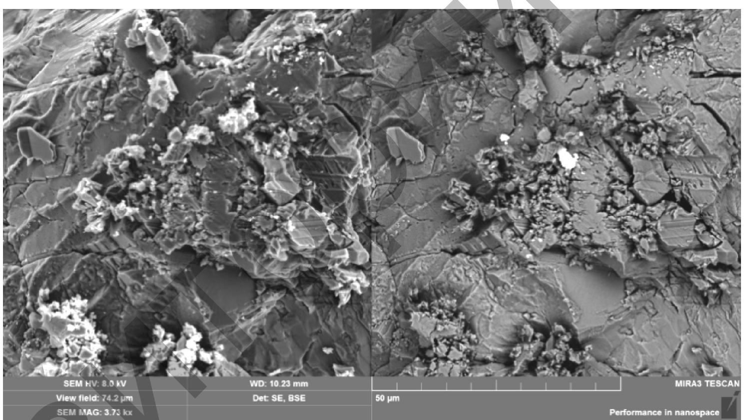
The wide prevalence of the mineral, the ease of diagnosis and the prostate determining the orientation of the optical axis make the microstructural study of quartz accessible and attractive [5,6].

Investigations of the microstructure of the quartz mineral of the Aktas deposit were carried out on a scanning (raster) electron microscope Tescan Mira3, which is used to study fracture surfaces and allows to obtain magnification and depth of field of the image than when using light.

Figure 3 shows electron microscopic images of the quartz sample of the Aktas deposits before and after electrohydraulic treatment.



a) before processing



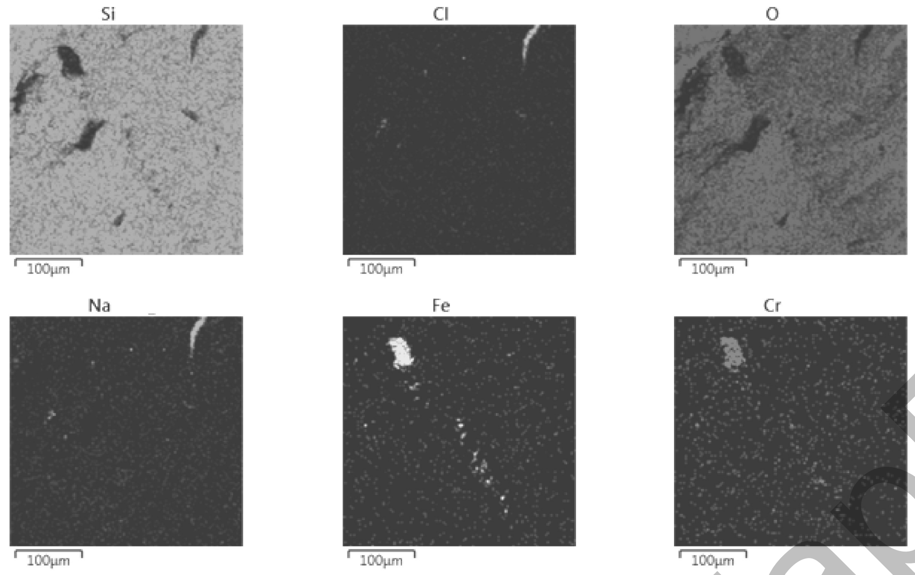
b) after processing

Figure 3. Electron microscopic image of the quartz sample of the Aktas deposit

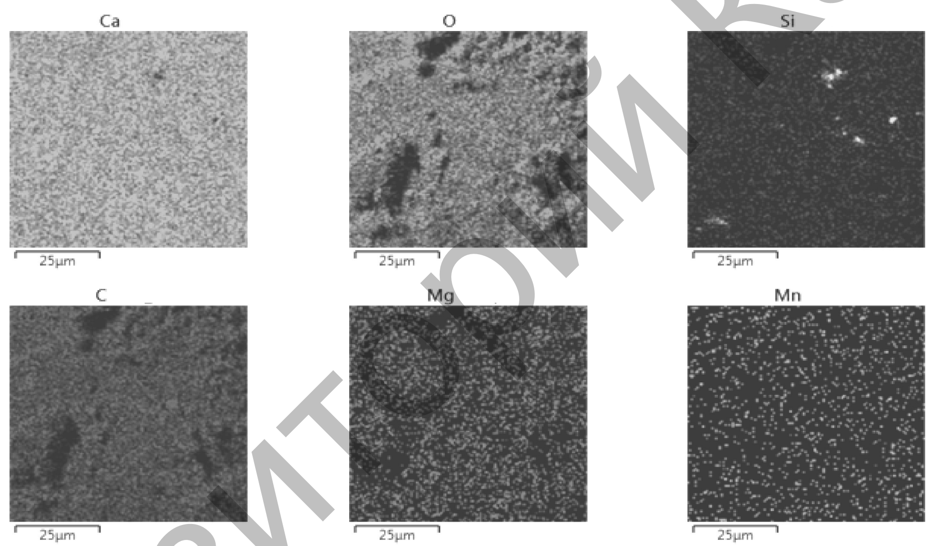
It can be seen from the photographs that the surface of the quartz particle after grinding has become more chopped, and the edges are strongly amorphized, sharp angles and faces are absent. In the areas of cleavage, there is a hummocky surface. The dimensions of the «hillocks» are more or less identical to the same size. In the process of fracture, cracks are formed that close and divide the body of the crystal into three parts. The cracks are formed during the process of force deformation and the destroyed sections are seen in the form of elevated areas of chipped. In some areas it can be seen that the process of destruction is not complete, although the crack has passed, but partial connections are still preserved.

Between the crack and the elevated «tubercle» there are still partial bonds that still bind these three pieces of the crystal to be destroyed. During the passage of the subsequent shock wave, the process of crack formation is completed, as a result of which a complete cleavage of the crystal occurs in three parts. Electrohydraulic action of a given power, crushes and grinds a natural mineral to a certain size in an existing self-similar hierarchy.

Figures 4 and 5 show a multilayer map of energy-dispersive microstructures and the energy spectrum before and after treatment of the quartz sample.

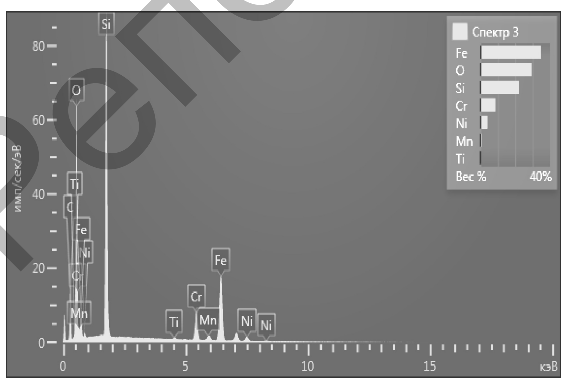


a) before processing

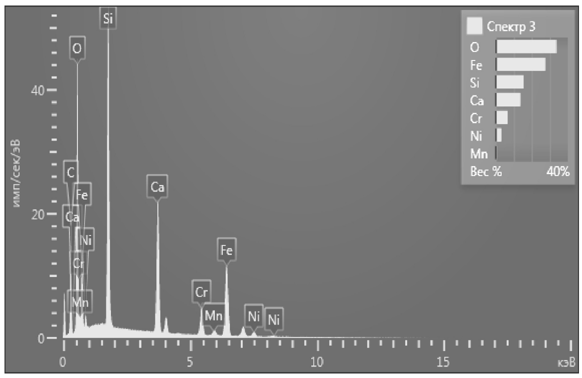


b) after processing

Figure 4. Multilayer map of energy-dispersive microstructures of a quartz sample



a) before processing



b) after processing

Figure 5. Energy spectrum of a quartz sample

During the investigation of the quartz sample of the Aktas field, the results are showed that quartzite contains, besides SiO_2, chemical elements such as Fe, Ca, Cr, Ni. The content of white-gray and milky-white quartzites is mainly due to the high content of impurities. It can be seen that the quartz mineral contained in the composition contains high silica quartzites with low impurities.

Thus, the method and parameters of crushing and grinding proposed by us are the most acceptable under production conditions, they provide intensive crushing and grinding of minerals. The results of these studies have shown that electrohydropulse technology can be useful in developing and creating a new domestic Kazakhstan technology of quartz processing and obtaining high quality materials.

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Г.А. Булкаирова, Б.Р. Нүсіпбеков, Г.Г. Тоқтаболат

Табиғи кварц минералының электргидравликалық бөлшектенуін зерттеу

Үкіметтің импорт алмастыру бағдарламасына байланысты Қазақстанның кварц құрамындағы жергілікті шикізат негізінде өнімдерді алу маңызды болып отыр. Технологиялық үдерістердегі ең танымал кварц шикізаты, химиялық түрленуді жоғары жылдамдықпен қамтамасыз ететін оңай қалпына келетін кварциттер болып табылады. Мақалада «Ақтас» кен орнының табиғи кварц минералының электргидравликалық әдіспен бөлшектенуі мен ұсақталуын зерттеу нәтижелері келтірілген. Сондай-ақ кварц үлгісінің электргидравликалық әдіспен өңдеуге дейінгі және кейін микроқұрылымы және энергетикалық спектрі зерттелді. Сұйықтықтағы электр разряды көптеген отандық және шетелдік технологияларда негізгі жұмыс істеу механизмі болып табылады. Сұйықта болатын электр разряды кезінде туындайтын барлық құбылыстар кешенінен, электр энергиясының соққы толқынының қысымына тікелей айналдыру қолданылды. Кварц минералын бөлшектеуде электргидравликалық әдісті қолдану алынған фракцияларды түрлі өндіріс салаларында тиімді пайдалануға мүмкіндік берді.

Кілт сөздер: табиғи кварц минералы, бөлшектеу және ұсақтау, электргидравликалық тиімділік, разряд арнасы, соққы толқыны, микроқұрылым, энергетикалық спектр.

Г.А. Булкаирова, Б.Р. Нусупбеков, Г.Г. Токтаболат

Исследование электрогидравлического разрушения минерала кварца

В связи с программой правительства по импортозамещению приобрела актуальность возможность получения продукции на основе кварцсодержащего местного сырья Казахстана. Наиболее популярным кварцевым сырьем в технологических процессах являются легко перерождающиеся кварциты, обеспечивающие более высокую скорость химических превращений. В статье приведены результаты исследования электрогидравлического способа разрушения и измельчения природного минерала кварца месторождения «Актас». Исследованы также микроструктура и энергетический спектр кварцевого образца до и после обработки электрогидравлическим методом. Электрический разряд в жидкости является основным действующим механизмом во многих отечественных и зарубежных технологиях. Из всего сложного комплекса явлений, возникающих при электрическом разряде в жидкости, используется непосредственная трансформация электрической энергии в энергию давления ударных волн. Применение электрогидравлического эффекта для дробления минерала кварца позволяет оптимально использовать полученные дозированные фракции для различных производств.

Ключевые слова: природный минерал кварц, дробление и измельчение электрогидравлический эффект, канал разряда, ударная волна, микроструктура, энергетический спектр.

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