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IMPROVEMENT OF PROCESSES OF GRIBING OPERATION AND DESLIMATION OF SYLVINITE ORE BEFORE FLOTATON

The paper studies the problems affecting the degree of extraction of potash ore in the process of its flotation enrichment. It reveals the main directions to improve the process of preparing the ore to flotation. The paper has proposed the construction of a shock-centrifugal mill, in order to improve the quality of ore grinding and has shown the results of its research. A new method of ore desliming prior to flotation as well as the design of the device for its implementation have been presented. The research shows the results of the new classifier studies.

Key words: sylvinite, flotation, grinding mill, desliming, classification.

Introduction. The flotation method of extracting potassium chloride from sylvinite ore is used at three concentrators of "Belaruskaliy". This method is compared with a halurgical one has low power consumption and simpler technology. However, the flotation method has some serious disadvantages: a lower degree of extraction of a target product (KCl) from the ore, the worst quality of the product, deficiency and toxicity of flotation reagents used [1]. Technological and economic indicators of flotation recycling process are deteriorating with the increase of the content of halopelite in the ore (insoluble clay impurities), which is observed in recent years.

Undoubtedly, one of the main indexes of the work of concentrators is a degree of extraction of potash from ore. This index for factories of flotation enrichment of "Belaruskaliy" constitutes a little over 80%, while at similar enterprises of some countries it reaches 96%. The high degree of extraction at these enterprises is assured by introduction in addition to the flotation method of halurgical one of KCl extraction from sludges, as well as improvement of processes of grinding and deslimation of ore before flotation.

Unsufficietly high-degree of KCl extraction at the flotation plants of "Belaruskaliy", in our view, is primarily explained by two main reasons: overgrinding of ore by milling in the drum-rod mills, as well as unsufficiently complete removal of clay sludges (halopelite) from the ore before it is fed to flotation.

The aim of grinding of the ore in the flotation enrichment is its destruction into the grains consisting of individual components (KCl, NaCl, halopelite), and aggregates of these components are not allowed. It is believed that to achieve this goal, the ore of Starobin deposits needs to be ground to the size of less than 0.8 mm. To do this, the primary ore grinding is completed in a hammer crusher, the final one – in a drum-rod mill. In this mill grinding is accomplished mainly due to crushing and attrition leading to excessive grinding of sylvinite. The content of particles with the size less than 0.15 mm in the finished product is 24%. With further deslimation of the ore in hydrocyclones, in which the separation boundary is a grain size of approximately 0.15 mm, a large part of the re-ground ore is in the sludge, which leads to loss of desired product. Properly the design of the mill was developed with the purpose of finely divided grinding of hard rocks, and so there is no reason to use it for crushing of sylvinite ore which hardness on the Mohs scale is not higher than three.

Main part. There are currently a large number of experimental and production data for the enrichment of ore grinding by impact. Thus, in the literature [2, 3], there are the data of sylvinite ore grinding in the rotary crusher, where the impact is predominant. Experiments show [2] that at the optimum and geometric parameters of an optimum rotor speed there can be obtained a product in which the fractions of less than 0.3 mm would be about 2%, and a particle size of less than 0.06 mm are virtually absent. Our experiments of grinding of sylvinite ore [4, 5] in the shock-centrifugal mill [6] also show that under optimum conditions of impact grinding the amount of fines (less than 0.15 mm) can be three times reduced (in comparison with the drum -rod mill). In order to reduce the ore overgrinding many enterprises of Canada perform grinding of sylvinite to flotation size by dry three-stage process in shock crushers such as disintegrators [7]. Thus, in preparation of sylvinite for flotation it is necessary to pass to impact method of grinding. In addition, the impact grinding has other advantages. One of them is that full disclosure of minerals is observed in the case of larger particle sizes. This fact is mentioned by many researchers. So, a well-known specialist in grinding V. I. Revnivtsev [8] indicates that at impact crushing destruction occurs primarily on the splices of crystals. Interesting results of the disclosure of mineral grains in shock grinders were obtained by grinding the copper-zinc ores of the Urals, and copper ores of Amalyk field [9]. So, the introduction of shock-rotary grinders on the copper-zinc ores of the Urals allows to achieve 95% of disclosure of mineral grains during grinding to 85–90% of the class less than 0.3 mm, while in a drum-ball mill, this disclosure index is achieved only during ore grinding to the class of 0.074 mm.

In the study of sylvinite grinding we analyzed the disclosure of the products of grinding. It was established that all particles with a size of less than 3 mm have clean sides and smooth clear, red or grey colour [4, 5]. This once again confirms that during the impact grinding the destruction occurs in the places of splices of crystals, and the entire disclosure of minerals is observed at larger particle sizes. Therefore, during the impact grinding it is not advisable to grind sylvinite ore up to 0.8 mm. The specific size to which it should be ground, will be determined by the flotation process. However, according to data [10], at Canadian enterprises the ore is fed to the flotation with particle size of 1.65 mm.

An important advantage of impact crushing of sylvinite ore is significantly lower energy consumption. Earlier we gave a profound analysis of the energy consumption at various ways of grinding [11] and it was concluded that under shock grinding energy consumption will be minimal. In this work there are the ways of creation of new grinders with low power consumption. Given studies of sylvinite grinding in the mill developed by us [6] indicate that in comparison with the drum-rod mill energy consumption for the drive is reduced at least twice. This is due to the fact that in the drum-rod mill energy is consumed on the rotation of 200 ton drum as well as the ore with solution and constant rising to a certain height of 70 tons of rods. In our mill energy is spent on the rotation of the rotor, which weight in the industrial embodiment is of no more than 150 kg, and also to disperse lumps of ore to a speed not exceeding 30 m/s. The advantages of the new design also include compactness and low metal content, which is ten times lower than that of a drum-rod mill.

Studies on dry milling of sylvinite in a shock centrifugal-mill [4, 5] show that the major influence on shredding fineness has rotor speed, i. e. the impact velocity of ore lumps on a reflective wall. Numerous experiences demostrate that for high productivity of a mill with a minimum overgrinding of ore optimum circumferential rotor speed at the ends of the blades should be 15–17 m/s.

As it was noted earlier, ore grains at shock milling are well revealed. Taking into account the experience of Canada in this matter, we can assume that in this case the ore must be milled to a particle size less than 1.5 mm. Studies show that at grinding of sylvinite in a shock-centrifugal mill with a circumferential rotor speed of 15–17 m/s in the final product there will be 13–15% of particles larger than 1.5 mm. Consequently, after the mill the ore must go for the classification to separate particles larger than 1.5 mm, and a large fraction must go back to a mill for additional grinding. However, the practice shows that the qualitative sorting of dry material with the boundary division of 0.5–2.0 mm at both sieve shaking and air classification is a very difficult task. Taking into account that smaller particles are significantly worse for grinding, it was decided to conduct a study on the regrinding of all sylvinite without sampling fraction less than 1.5 mm. Such studies have been conducted and their results are presented in Fig. 1. The graph shows that for the production of the entire product of grinding with a particle size of less than 1.5 mm sylvinite must be passed through the mill three times. Thus, after the second and third times the amount of particles finer than 0.15 mm increased not more than 1.5%. The total number of particles smaller than 0.15 mm after three times passing a shock centrifugal mill reaches 14%. It should be noted that we have carried out experiments on the ore extracted by a combine held crushing in hammer-mill and containing about 7% of the particles with a size of less than 0.15 mm. In such a case, the use of impact-centrifugal mill instead of drum-rod allows to decrease by 10% the number of over-crushed ore and thereby to increase the degree of extraction of potassium chloride.

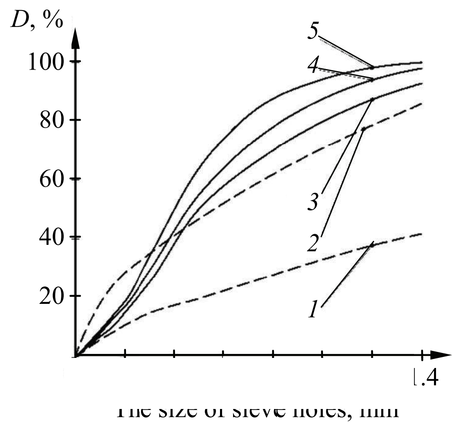

Fig. 1. The particulate composition of the products of sylvinite ore grinding:
1 – initial ore after a hammer crusher;
2 – ore ground in a drum-rod mill; *3* – ore ground in a shock-centrifugal mill (single pass); *4* – ore ground in a shock-centrifugal mill (double pass);
5 – ore ground in a shock-centrifugal mill (triple pass)

Since the installation of three mills in succession complicates technological scheme of ore preparation for flotation we have developed a design of a three-stage mill, which performs the analogous problem. Such a mill is shown in Fig. 2. According to the principle of action it is analogous to the mill described in the patent [6], but three rotors with blades are here mounted on a common shaft and after the first and the second rotors there are cones that allow the material to be subjected to three steps of grinding. The second problem of flotation enrichment of sylvinite ore is unsufficiently complete extraction of the clay sludge from the ore before passing it to the flotation. Sludge is formed in contact of halopelite with liquid. At first halopelite swells and then is dispersed into tiny particles with a size of less than 0.06 mm. The presence in the ground ore finely dispersed clay sludge has a negative influence on the flotation of potassium salts [1]. Used at present time ways of deslimation of ore (hydro-mechanical, i. e. friction separation of sludges followed by removal of fine particles in hydrocyclones and hydroseparators, flotation of sludges, depression of sludges with the help of reagents) do not allow to get rid completely of the sludge, especially at high quantity of halopelite in ore. Therefore it comes to flotation with the content of clay particles of more than two per cent [10], which of course affects the degree of extraction and the quality of desired product.

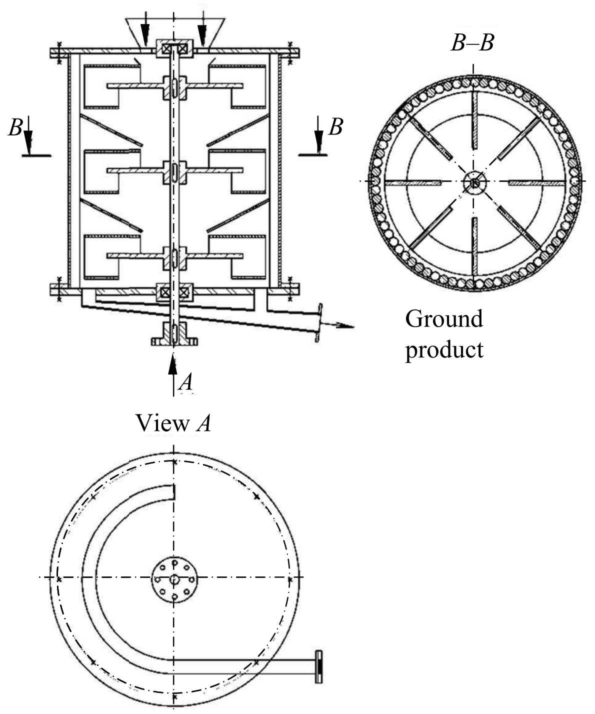

Fig. 2. The three-stage impact-centrifugal mill

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To solve the problem of deslimation is possible, using new methods. One of them is fluid filtration. This method is widely used in the coal industry for the separation of fine dispersed coal from the mineral slurry, as well as in concentrators for the classification of crushed ore. In the majority of cases for the implementation of this method arc screens are used [12]. The design of an arc screen is very simple: a curved sieve is placed in metallic housing, where in the upper part there is a slit device for feeding suspension film on the sieve. Under the screen there is a casing for the collection and removal of the liquid phase. In operation, a suspension with some initial velocity is supplied to the surface of the screen and moving on the curved surface, is affected by centrifugal inertia forces and gravity. As a result of the pressure caused by these forces, a part of a stream rushes through the sieve slots. During the advancement of the film over the screen the amount of liquid phase in suspension decreases. If there are finely dispersed particles in suspension a significant part of them together with the liquid will remove into the underscreen product. Experiments and practice show [12] that through the perforation holes the particles which size is 2 times less than these holes pass. Thus, at Soligorsk concentrators for the classification of products of grinding of sylvinite to isolate particles less than 1 mm thick, arc screens, which size of the slots constitutes 2 mm are used.

To solve the problem of deslimation of sylvinite ore before flotation it is necessary to remove particles of the clay slurry. The bulk of its particles has a size of less than 0.05 mm [1]. Consequently, the size of the slits of the arc sieve should not exceed 0.12 mm. Since the pressure of the suspension film moving over the arc screen surface is very small and sieve slots are small too, then to remove slurry with a liquid it is necessary to have arc screens of huge sizes, and therefore, the use of this construction for deslimation is almost unreal.

Some of the coal and iron ore industries use more compact cylindrical-conical screens [12] or, as they are called, centrifugal water separators. By design, they resemble hydrocyclones but their vertical cylindrical and conical part is perforated. Above the cylindrical part of apparatus a slotted nozzle is tangentially added through which by the film into the machine is given the suspension. Due to centrifugal force the film of suspension is pressed against the perforated surface and spirally moves to the bottom of the unit. At the same time due to the centrifugal force liquid with small particles of slurry is forced through the slits and removed from the apparatus. The practice of exploitation of such devices has shown that due to dehydration the frictional force increases, the rate of it slows down, the twist is reduced, and consequently the velocity of the fluid flowing out of the perforation holes falls [12].

A significant intensification of the process of flow deslimation is possible by acting on the suspension film with whirling air flow. This method is widely used by us while dehydrating polymer suspensions and described in detail in [13]. The design of the flow classifier for deslimation of suspensions is shown in Fig. 3. The classifier consists of a vertical cylindrical chamber 1, which at the bottom becomes conical chamber 2. To the upper part of the chamber 1 is tangentially added the branch pipe 3 of original suspension feed. From above through the lid into the chamber 1 passes the branch pipe 4 of the air supply. At the bottom the branch pipe 4 is plugged and for air to go out of the chamber on its side surface there are tangential slots.

When the classifier works in the branch pipe 4 air is supplied by the fan. At the exit from the branch pipe through the tangential slots it acquires a vortex motion and rotating, enters the perforated working chamber 1. Through the branch pipe 3 into the working chamber suspension is tangentially fed. Getting tangentially to the inner wall of the perforated wall 1 suspension forms a film which rotating spirally descends. Here by tangential stresses it is effected by speed air flow that accelerates the movement of the film. With the increase of the speed of the film the pressure at the perforated wall increases, and therefore, the velocity of the fine suspension outflow is increasing through the perforation holes. With the movement of suspension film down the fine particles of suspension together with the liquid phase are removed from the working chamber. At the exit through the branch pipe of conical shell along with the main stream of air only wide particles and a small amount of liquid are removed. Fine suspension, passed through the perforation holes, is removed from the device.

The verification of capacity for work of developed design of hydrodynamic flow classifier was conducted in a pilot plant with the diameter of a cylinder part of the filter chamber of 100 mm. The investigations were carried out on a water – sand suspension with a particle size of the solid phase of 0.1–2.0 mm.

The concentration of solids in the suspension was 12%. The size of perforation holes of the filter element was 0.5 mm. The air velocity relative to the section of a cylindrical part of a filter chamber, was ranging from 6 to 30 m/s. Research results are presented in Table.

The Table shows that with the increase of air velocity in the working camera the amount of the suspension passed through the perforation holes and the degree of extraction of a fine fraction from the suspension increase. When the air velocity is of 25–30 m/s the extraction of a fine fraction from the suspension reaches 90%, which is a very high index for any method of the classification of suspensions.

Research results

Air velocity on the cross section of the filter chamber, m/s	Extraction degree of the fine fraction from suspension, %	Boundary particle size, passed through the perforation holes, mm	Fraction of suspension passed through the perforation holes, %	Pressure in the working chamber, Pa
6	65	0.3	45	50
10	72	0.3	50	100
15	80	0.25	60	220
20	87	0.2	65	400
25	90	0.2	70	650
30	90	0.3	75	1020

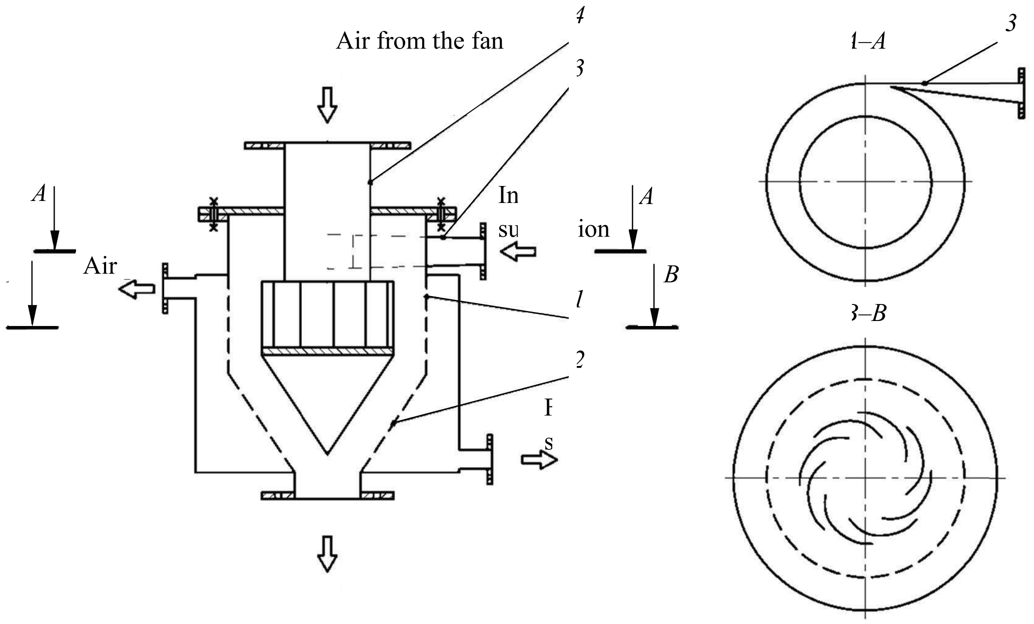

Fig. 3. The scheme of the hydrodynamic flow classifier:
1 – cylindrical chamber; *2* – cone camera; *3* – branch pipe of suspension supply;
4 – branch pipe of air supply

From the experiments it can be seen that the boundary separation of the suspension fractions depends on the gas velocity: at a gas velocity of 6–10 m/s, it was equal to 0.3 mm and at a speed of 20–25 m/s, it was reduced to 0.2 mm. However, with further increase in the speed of 25 m/s the size of particles that have passed through the holes increases.

This is because with the increase of gas velocity the pressure in the chamber increases too, therefore, the velocity of suspension flow through the holes of perforation increases, and larger particles will be trapped by fluid and taken away.

The experiments showed a high capacity for work of a developed classifier. The optimal air speed in it should be 15–25 m/s, and the excess of pressure in the working chamber should be at 200–650 Pa.

Conclusion. The developed constructions of the shock-centrifugal mill and the hydrodynamic flow classifier can significantly increase the degree of extraction of potassium chloride and improve other indexes of concentrators. However in order to move to the industrial inculcation, it is necessary to conduct complex tests of suggested mill and classifier at more consolidated apparatuses with the productivity of ten and more tons per hour.

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