ОБОГАЩЕНИЕ ПОЛЕЗНЫХ ИСКОПАЕМЫХ

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Choosing special methods of selective disintegration and schemes for complex refractory ore

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Abstract

Introduction. *The article highlights a new procedure of choosing special methods of disintegration and schemes for complex refractory ore and develops an integrated approach and criteria to comparing different types of crushers and screens, namely, reduction ratio, grinding degree, slime formation degree, and a new selectivity criterion.*

Research aims *to study a new method and derive an equation to determine the crushing in the layer force and a new selectivity criterion.*

Research methods. *The new methods were tested by comparing Otboynoye deposit tantalum ore, Vishnevogorsky deposit niobium ore, and Zashihinsky deposit tantalum-niobium ore crushing in cone inertial and centrifugal impact crushers and a roller press. The process of crushing in machines was studied in the laboratory and semi-industrial conditions. Different operation modes of crushers and screens were also checked.*

Object of research *is tantalum and niobium ore of different deposits.*

Research results. *The crushing selectivity criterion and reduction ratio comparison demonstrated that centrifugal impact crusher and roller press indexes are lower than the cone inertial crusher (KID) indexes. The reduction ratio for different crushing machines is 10.1 for the centrifugal impact crusher, 10.8 for the roller press, and 14.2 for the cone inertial crusher. The selectivity criterion for the crushing machines is 0.632 units for the centrifugal impact crusher, 0.730 units for the roller press, and 0.848 units for the KID. The KID-300A crusher performed the best for Otboynoye deposit tantalum ore and Vishnevogorsky deposit niobium ore. The KID-300A crusher also has the best slime formation degree criterion. The new method has been tested and approved.*

Summary. *The paper analyses different methods and criteria of selective crushing. A new crushing selectivity criterion was proposed based on optical and electron microscopy data. It describes the ratio of liberation in the crushed product and feed.*

Keywords: *ore preparation; reduction ratio; slime formation degree; selectivity criterion; cone inertial crusher; centrifugal impact crusher; roller press.*

Introduction. Technological schemes for the beneficiation of rare metal ores are complex, energy-intensive and costly. The reasons for this include the multimetal nature of the ores, their volatile material composition and low grade. That is why careful selection of ore preparation circuits is of great importance for minimizing the energy inputs and maximizing the liberation of the valuable minerals. Modern researchers [1] have found out that the most efficient method available to the mineral processing industry are selective disintegration, crushing and grinding, allowing liberation of the mineral particles along the cleavage in the comminution process. These methods are indispensable for the processing of finely disseminated refractory ores prone to slime formation. Many rare metal and nonmetallic ores found in Russia are of this type.

A priori [2] impact crushing, crushing *in the layer* with choked cone crushers, vibro-inertial crushing, and crushing in roller press are classified as special selective ore disintegration methods of 3–4 stages [3]. These processes can be modeled using software such as JkSimMet or Rocky [4]. However, this ignores the selectivity of crushing, since no effective and simple selectivity criterion has been proposed. It is known from the scientific works [5] that it was proposed to assess the selectivity of disintegration on the basis of the subsequent concentration performance with the determination of the concentration grade, and also as the ratio of the effective intergrowth surface of the mineral particles in the feed to the sum of the intergrowth surfaces in the disintegration products [6]. The proposed selectivity criteria have never been widely used because of the impossibility and complexity of reliable estimation of the proposed indicators.

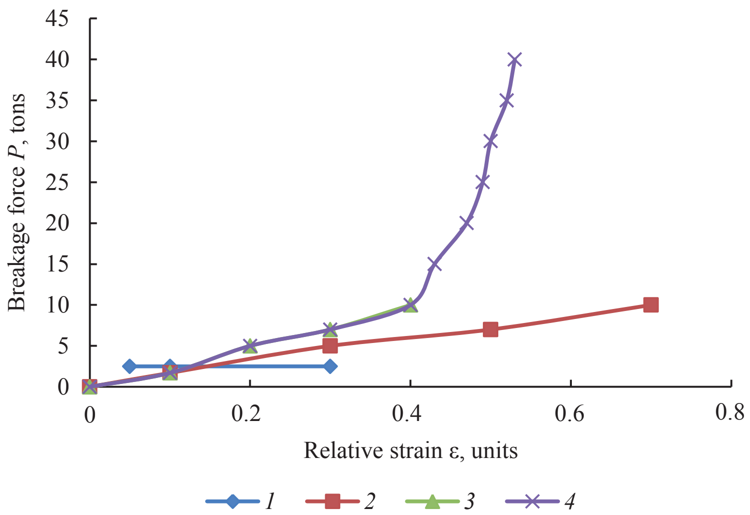

Figure 1. Relationship between the compressive force applied to the material disintegrated of single pieces with the lining and *in the layer*:
1 – zone of disintegration of single pieces; *2* – same – zone of compression; *3* – breakage in the layer, (matrix) – force 20 tons; *4* – same – force 40 tons
Рисунок 1. Зависимость усилия сжатия материала от относительной деформации при разрушении методами «кусок о броню» и «в слое»:
1 – зона разрушения при дроблении «кусок о броню»; *2* – то же – зона прессования; *3* – разрушение «в слое» (матрица) – усилие 20 т; *4* – то же – усилие 40 т

The goal of this study was to develop a modern method for selecting special disintegration methods for finely disseminated refractory rare metal (and nonmetallic ores, such as niobium, tantalum ore, using the new effective selectivity criterion of the disintegration process and to experimentally verify the proposed method.

The research task was to study the processes of crushing *in the layer* defining its effectiveness, and to create a new criterion for the disintegration selectivity based on the use of technological mineralogy data.

Materials and methods. Tantalum ore of Otboynoye deposit (Siberia), tantalum-niobium ore of the Zashihinsky deposit (Central Siberia), niobium ore of Vishnevogorsky deposit (South Ural) were the objects of the experimental research.

The studies were conducted in laboratory and semi-industrial conditions at JSC Uralmekhanobr (Russia). The following theoretical, analytical, and experimental methods and equipment were used:

– theoretical and experimental analysis of forces acting on the ore under disintegration in a cylindrical matrix measuring 75 × 75 mm,

– experimental studies on the liberation of the valuable minerals in the ore feed and crushed products, applying process mineralogy methods with the use of the optical microscope Axio Imager (Carl Zeiss, Germany), the software product Mineral C-7 (Russia), the electronic scanning microscope EVA-MA 15 (Carl Zeiss, Germany), and the software suites INCA and AZtec (UK). Substantiation and selection of an effective criterion measuring the selectivity of disintegration,

– experimental verification of the various special selective crushing processes under different operating conditions. Comparing the slime formation degree of the ore (50.5 μm) in a selective crushing circuit using the laser granulometer Helos (Germany).

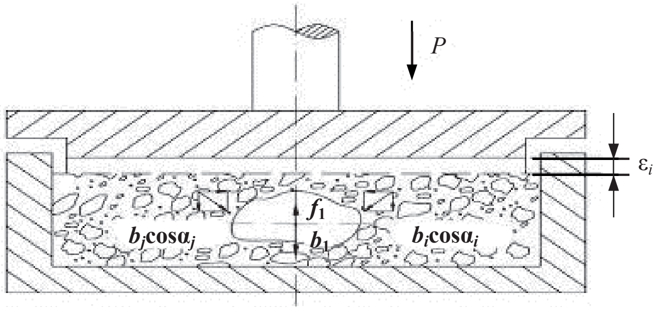

Figure 2. Forces acting on the feed under disintegration *in the layer*
Рисунок 2. Силы, действующие на кусок материала при дроблении «в слое»

Experiments to test various methods of selective crushing were carried out on semi-industrial and industrial equipment – the cone inertial crusher KID-300A (NPK Mekhanobr-Tekhnika, St. Petersburg) and the centrifugal impact crusher DC-05 (NPO Center, Belarus) and with the help of physical modeling of the grinding process in roller press (LABWAL). The study sequence was as follows: the particle size distribution by size class of the initial ore sample was determined using 25 to 0.050 mm sieves. The liberation of the valuable mineral in the initial sample was found for each size class; experiments were conducted to find the operating parameters of the crusher KID-300A: eccentric mass position (change of the angle of rotation by 0, 60, and 120 degrees and peripheral rotational speed of the cone (1,136 and 1,420 r/min). Specific power input was measured directly by connecting an electric meter to the power mains of the crusher drive; experiments were conducted by varying the rotational speed of the accelerator of the crusher DC-05 using the integrated frequency converter. The speeds [6] were 1,000 and 1,400 r/min. Specific power input was measured directly in each experiment; experiments were conducted in roller press (LABWAL), using following operating parameters (as recommended by the vendor): roller speed is 12.5 r/min; peripheral speed is 0.16 m/s, the power consumption was measured; the selective crushing products after all experiments were divided by size classes to find the liberation of the valuable mineral; based on the experimental data, the proposed crushing selectivity criterion, the reduction ratio of the ore, and the slime formation degree degree of the crushing product were determined to select the optimal selective crushing process and the optimal operating parameters of the crusher. Specific energy input values were compared between the selected methods.

Results. *Theoretical and experimental studies of in the layer disintegration processes.* In 1977, Prof. C. Schonert at Clausthal University (Germany) [7] patented the principle of selective crushing in roller press. The same principle is used in choked cone crushers and in inertial crushers. It is the most effective principle, both in terms of minimizing the energy costs and in terms of maximizing the liberation of the valuable minerals. Figure 1 shows the relationship between the compressive force applied to the material and the relative strain for tantalum ore.

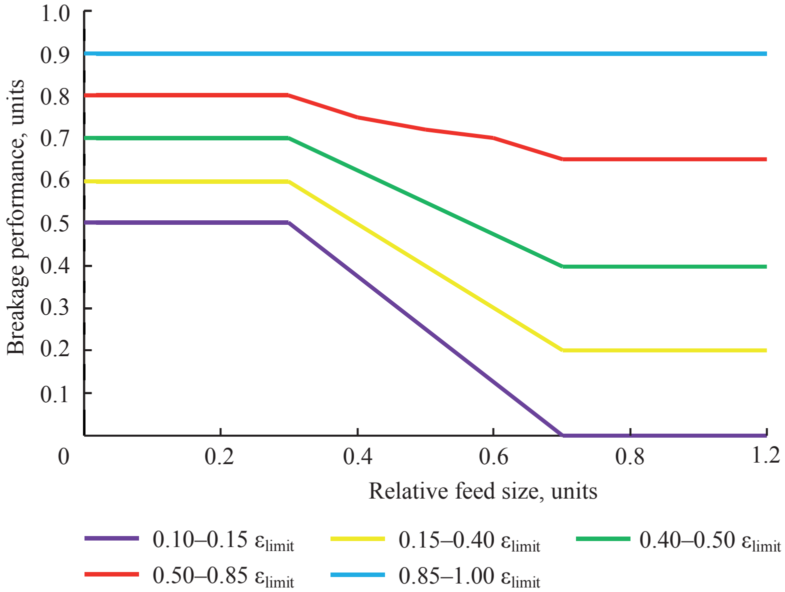

Figure 3. Breakage performance of the size class *i*, crushing *in the layer*
Рисунок 3. Эффективность разрушения кусков руды при дроблении «в слое»

The study compared two methods — the conventional uniaxial crushing of single pieces of ore and crushing *in the layer* (matrix). Experiments have shown that, under disintegration of single pieces, the piece of ore is gradually exposed to a load of up

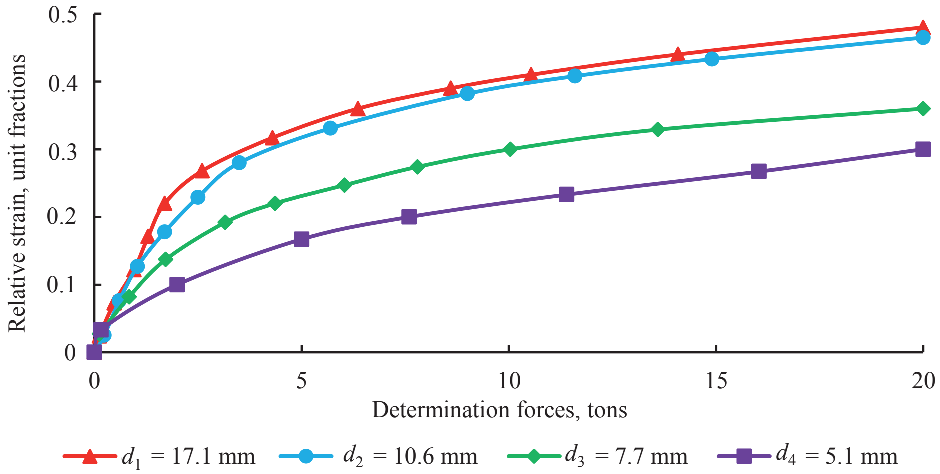

Figure 4. Determination of the relative strain from forces acting for the different size of mineral particles. Tantalum-niobium ore of the Zashihinsky deposit
Рисунок 4. Зависимость относительной деформации от усилия разрушения для различных средних диаметров смеси

to 15 tons. The relative strain varies from 0.05 to 0.76. Under disintegration *in the layer*, to obtain a much finer product, the loading force has to be increased to 40 tons at a limiting relative strain of 0.53. In the case of uniaxial static compression under disintegration of single pieces, the required crushing force is equal to the product of the cross-sectional area of the piece of ore by the compressive strength and by the strain ratio, and the sectional area of the piece of ore is equal to its thickness to the power of 1.5.

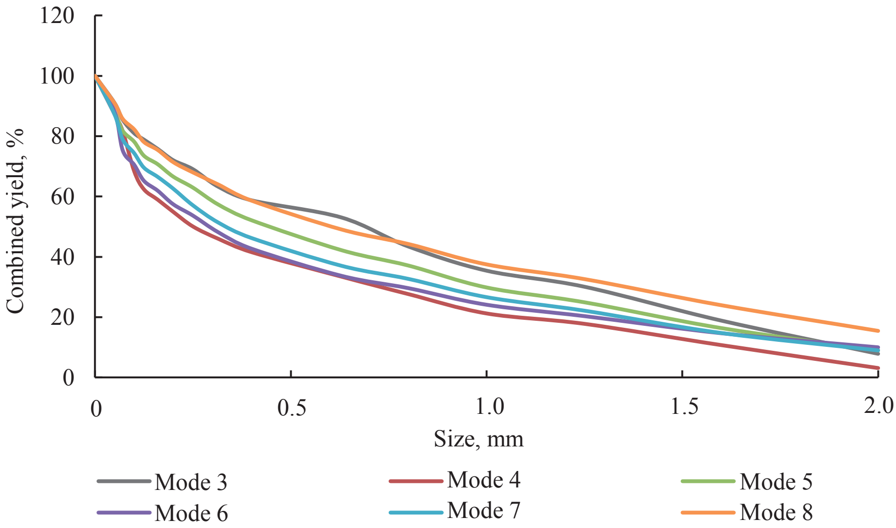

Figure 5. Size class distribution of the crushed product
Рисунок 5. Гранулометрические характеристики по + продуктов дробления

Forces acting on the piece of ore crushed *in the layer*, are shown in Figure 2.

Figure 2 shows that, in addition to the specific compressive force applied by the crushing member b_1, under crushing *in the layer*, multiple specific compressive forces of

Table 1. Content of free mineral grains and intergrown mineral grains in the initial sample of the niobium ore of Vishnevogorsky deposit
Таблица 1. Содержание свободных зерен минералов и зерен минералов, находящихся в сростках, в исходной пробе ниобиевой руды Вишневогорского месторождения

Size class, mm	Pyrochlore		Other minerals	
	Free grains, %	Intergrowth with other minerals, %	Free grains, %	Intergrowth with pyrochlore, %
–0.050	100	–	100	–
+0.05–0.2	90	10	100	< 1
+0.2–0.8	82	18	100	< 1
+0.8–2.0	42	58	100	< 1

the contacting pieces b_i and the respective strains are added. Thus, the required resultant crushing *in the layer* force P_c can be found from equation:

$$P_c = P_1 + \left(c^{1.5} \cdot \int_{i=1}^{n} \int_{\alpha j}^{\alpha m} \left(b_i \cos\alpha_j \partial b \partial a \right) \left(\varepsilon_i - f_1 \right) \right), \quad (1)$$

where P_1 is uniaxial compressive force; b_i is specific pressure exerted by a single contacting piece *in the layer* on the given piece (with i from 1 to n); α_{mj} is the elementary angle at

Table 2. Content of free mineral grains and intergrown mineral grains in the crushed samples of the niobium ore of Vishnevogorsky deposit

Таблица 2. Содержание свободных зерен минералов и зерен минералов, находящихся в сростках, в пробах дробленых продуктов ниобиевой руды Вишневогорского месторождения

Sample	Size class, mm	Pyrochlore		Other minerals	
		Free grains, %	Intergrowth with other minerals, %	Free grains, %	Intergrowth with pyrochlore, %
Centrifugal, 1400 r/min	–0.050	100	–	100	–
	+0.05–0.2	100	< 1	100	< 1
	+0.2–0.8	94	6	100	< 1
	+0.8–2.0	72	28	100	< 1
Centrifugal, 1000 r/min	–0.050	100	–	100	–
	+0.05–0.2	100	< 1	100	< 1
	+0.2–0.8	92	8	100	< 1
	+0.8–2.0	69	31	100	< 1
LABWAL, Mode 4	–0.050	100	–	100	–
	+0.05–0.2	100	< 1	100	< 1
	+0.2–0.8	95	5	100	< 1
	+0.8–2.0	79	21	100	< 1
KID, Mode 3	–0.050	100	–	100	–
	+0.05–0.2	100	< 1	100	< 1
	+0.2–0.8	94	6	100	< 1
	+0.8–2.0	74	26	100	< 1
KID, Mode 5	–0.050	100	–	100	–
	+0.05–0.2	100	< 1	100	< 1
	+0.2–0.8	97	3	100	< 1
	+0.8–2.0	71	29	100	< 1
KID, Mode 6	–0.050	100	–	100	–
	+0.05–0.2	100	< 1	100	< 1
	+0.2–0.8	95	5	100	< 1
	+0.8–2.0	66	34	100	< 1
KID, Mode 7	–0.050	100	–	100	–
	+0.05–0.2	100	< 1	100	< 1
	+0.2–0.8	95	5	100	< 1
	+0.8–2.0	77	23	100	< 1
KID, Mode 8	–0.050	100	–	100	–
	+0.05–0.2	100	< 1	100	< 1
	+0.2–0.8	97	3	100	< 1
	+0.8–2.0	81	19	100	< 1

which the contacting piece acts on the given piece; ε_i is relative strain *in the layer* at the current time of compression; f_1 is specific resistance *in the layer*, c is thickness of the piece of ore. From Figure 2, P_1 is 15 tons, the second term of equation (1) is 40–15 = 25 tons. In addition, an analysis of equation (1) and Figure 1 shows that, for the ore under study,

Table 3. Crushing performance of the niobium ore of Vishnevogorsky deposit in the crushers DC, KID and LABWAL

Таблица 3. Результаты определения показателей дробления ниобиевой руды Вишневогорского месторождения в дробилках ДЦ, КИД и ИВВД

Mode	DC, 1	LABWAL	KID, Mode 3	KID, Mode 8
Criterion L_o	0.874	1.709	1.73	1.755
Disintegration degree	6.5	9.2	10.0	10.2
Slime formation degree	11.20; 2.69	29.20; 8.70	28.00; 7.50	27.30; 7.20

the crushing force *in the layer* is 2.67 times greater than the uniaxial compressive force in crushing single pieces. To assess the process of crushing *in the layer*, the disintegration performance E_i was assessed of the size class i:

$$E_i = \frac{(\gamma_{\text{feed}i} - \gamma_{\text{cr}i})}{\gamma_{\text{feed}i}},$$

where $\gamma_{\text{feed}i}$ is the yield of the size class i in the feed, %; $\gamma_{\text{cr}i}$ is the yield of the size class i in the crushed product, %. Figure 3 presents a graphical analysis of the breakage performance of different size classes under crushing *in the layer*. The relative grain size of the class is defined as:

$$d_{\text{relative}} = \frac{d_{eff}}{d_{\max}},$$

where d_{eff} – effective diameter; $d_{\max}$ – maximum diameter.

With single pieces disintegration, the disintegration performance of the size class does not depend on the share of other size classes in the feed. With disintegration *in the layer*, the disintegration performance of a single particle depends on the share of other size classes and strain *in the layer*. At a strain close to the limit value, 0.85–0.9 $\varepsilon_{\text{limit}}$, the breakage performance of all size classes in the feed is virtually identical at 0.9. As the relative strain of the layer decreases, the disintegration performance of the size classes decreases and, at a strain of 0.4–0.5 of the limit value, it is 0.7 for finer classes and 0.4 for coarser ones. At low strain, 0.1–0.15 of the limit value, coarse size classes are not disintegrated and act as grinding media. Based on the analysis of the presented experimental results, the mechanism of crushing in the layer becomes clear, involving not only compression of the ore piece by the active crushing members, but also compression by contacting pieces of ore and larger pieces acting as grinding media.

It was found out that the mixture size has a grade influence on forces acting in selective disintegration (Figure 4). The research results indicate that with an increase in the size of the initial product, the force required to disintegrate the mixture of particles to a certain value of the relative deformation decreases. As the layer of material passes through the crushing chamber, the average diameter of the mixture decreases, and the smaller the average diameter of the mixture becomes, the more energy is required for its disintegration.

Criterion of selectivity. Based on examination of rare metal ore studies by process mineralogy methods, a simple and effective criterion was proposed for assessing the selectivity of the disintegration process, applicable to any crushing and grinding process and any equipment, according to the formula given below [8]:

$$L_o = Y_i \frac{N_{ik}}{N_{i0}}, \qquad (2)$$

where N_{i0} is the content of free grains of the valuable mineral in the given size class of the feed; N_{ik} is the content of free grains of the valuable mineral in the given size class of the crushed or ground product; i is the given size class (–2(3) + 0 mm); Y_i is the yield of the size class i in the crushed product. If necessary, the size classes are summed. This formula is meant to find the change in the specific mineral intergrowth surface based on an estimate of the change in the content of free mineral grains in the respective size classes.

Table 4. Crushing performance of Otboynoye and Zashihinsky ore in crushers DC (MD-7), KID, and LABWAL

Таблица 4. Результаты определения показателей дробления руд Отбойного и Зашихинского месторождений в дробилках ДЦ (MD-7), КИД и ИВВД

Mode	DC, 1	LABWAL	MD-7	KID
Otboynoye				
Criterion L_o	0.632	0.730	–	0.848
Disintegration degree	10.1	10.8		14.2
Slime formation degree	15.2; 9.5	22.3; 12.3	–	20.1; 10.2
Zashihinsky				
Criterion L_o	–	1.3	1.15	1.42
Disintegration degree	–	6.5	7.5	8.3
Slime formation degree	–	15.3; 7.0	9.0; 2.0	13.7; 6.7

Pilot tests. Figure 5 presents the size class distributions of the crushed products of KID, DC, and LABWAL under different operating modes when processing the niobium ore of Vishnevogorsky deposit. Tables 1 and 2 show the liberation of pyrochlore, the principal mineral in these products. The crushing selectivity criterion (L_o) was calculated by formula (2) for the combined size class finer than 2.0 mm. The input data for the calculation were taken from Table 1 and 2 (N_{i0} and N_{ik}) and Figure 5 (Y_i). The results for the optimal operating parameters are given in Table 3.

Table 3 also compares the reduction ratio and slime formation degree degree of the products.

A comparison of the selectivity criterion of the different crushers examined – KID, DC, and LABWAL – demonstrated that DC has a lower selectivity criterion than KID and roller press. For DC, the criterion L_o is 0.874, while for KID, it is 1.73–1.755, and for LABWAL, it is 1.709. The highest disintegration degree, 10.2, was observed in KID under following operating conditions: eccentric mass angle is 120°, circumferential rotation speed of the cone is 1420 r/min. Selectivity, reduction ratio, and slime formation degree parameters for tantalum ore of Otboynoye deposit and tantalum-niobium ore of the

Zashihinsky deposit are presented in Table 4. The data confirmed the conclusions drawn from the studies of Vishnevogorsky ore.

Table 5 compares the energy efficiency of the studied equipment under the optimal crushing modes of Vishnevogorsky and Otboynoye ores.

Estimation of screening procedure on screens Kroosh and GIL. The objects of experimental research were niobium ore of Vishnevogorsky deposit.

Effectiveness of screening were estimate on cycle experiments scheme with Kroosh, GIL and selective centrifugal mill – ZOM. Screening was dry and stable [9–11].

Table 5. Specific energy inputs when using selective crushing in KID, DC, LABWAL compared to Bond index, (kW · h)/ton

Таблица 5. Удельные расходы электроэнергии при использовании селективного дробления в КИД, ДЦ, ИВВД в сравнении с индексом Ф. Бонда, (кВт · ч)/т

DC	KID	LABWAL	IW crushing
Vishnevogorsky niobium deposit			
8.02	6.99	5.15	19.6
Otboynoye tantalum deposit			
7.40	4.99	4.50	9.8

Procedure of screening is: for Kroosh:

– specific productivity for row material (q = 4 t/(h · m^2);

– sieves size (b = 0.2 mm);

– acceleration of screen surface ($a_{s.s}$ = 360 m/s^2);

– slope angle surface of screen (a = 5 degrees).

Table 6. Procedure of screening for GIL

Таблица 6. Техническая характеристика наклонного инерционного грохота легкого типа ГИЛ

Size of surface of screen:	
Width, mm	500
Length, mm	750
Quantity of sieves, pcs	2
Max particle size in row material, mm	50
Slope angle surface of screen, grad.	10–25
Vibrating motor shaft speed, min^{-1}	900; 1000
Productivity, ton/h	1
Electric motor power, kW	2

Procedure of screening for GIL are given in Table 6.

Effectiveness of screening was estimated by the following formula [12–15]

$$E = \varepsilon_{-0.2} - \varepsilon_{+0.2}, \quad (5)$$

where $\varepsilon_{+0.2}$ is recovery size class +0.2 mm in the screen throughs; $\varepsilon_{-0.2}$ is recovery size class –0.2 mm in the screen throughs.

Particle size distribution of screen throughs are shown in Table 7.

A comparison of the effectiveness of screening, screen throughs sizing of different screens and the slime formation degree shows that the Kroosh is better than GIL. Kroosh effectiveness of screening is 80% opposite 78% of GIL.

Table 8 presents the effectiveness of screening and particle size distribution of underground products in screen tape Derrik after rod mill. Sieves size was 0.2 mm.

A comparison of the effectiveness of screening, screen throughs sizing of different screens and the slime formation degree shows the Kroosh is better then Derrik.

Table 7. Result of screening on GIL and Kroosh
Таблица 7. Результаты грохочения на грохотах ГИЛ и Kroosh

Particle size, mm	Kroosh		GIL	
	Part yield, %	Summary yield, %	Part yield, %	Summary yield, %
–0.200+0.160	15.58	15.58	11.64	11.64
–0.160+0.125	22.26	37.85	13.98	25.61
–0.125+0.100	10.66	48.50	18.24	43.85
–0.100+0.071	18.52	67.03	11.15	55.00
–0.071+0.050	13.00	80.02	19.78	74.78
–0.050+0.000	19.98	100.00	25.22	100.00
	100		100	
q, ton/m^2, h	3200		620	
Effectiveness of screening	80%		78%	

Kroosh effectiveness of screening is 80% opposite 78% of Derrik.

Proposed technological scheme of disintegration of tantalum ore of the Otboynoe deposit and niobium ores of the Vishnevogorsky deposit is given below (Figure 6).

Table 8. Particle size distribution of screen throughs in Derrik
Таблица 8. Гранулометрическая характеристика подрешетного продукта грохота Derrik

Particle size, mm	Derrik	
	Part yield, %	Summary yield, %
–0.200+0.160	25.5	25.5
–0.160+0.125	20.3	45.8
–0.125+0.100	10.6	56.4
–0.100+0.071	8.5	64.9
–0.071+0.050	10.0	74.9
–0.050+0.000	25.1	100.00
	100	
Effectiveness of screening	78%	

Discussion. The proposed criterion of selectivity is simple and accurate for comparison and selection of equipment for selective disintegration without significant energy losses. Its definition is based on the generally accepted mineralogical analysis to determine the liberation of useful minerals. However, it should be noted that this criterion should be applied only together with such criteria as the degree of crushing and the slime formation degree.

It should be noted that in the case of selective crushing, Bond index exceeds the specific energy input by 2–3 times. Based on the experimental data, roller press like KID are the most energy-efficient technology for the crushing of the examined ores.

It should be noted that both crushers, roller press, and KID, belong to equipment operating on the principle of destruction *in a layer*, and as theoretical studies have shown, they work effectively in a mode when large pieces of the mixture act as crushing bodies.

A prerequisite for choosing an effective selective crushing scheme is the choice of a fine screening apparatus from the point of view of its efficiency and the slime formation degree of the crushed product. The slime formation degree is determined by two size classes – 50 and 5 microns.

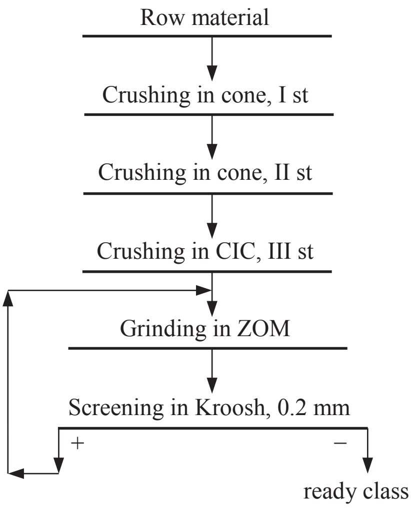

Figure 6. Proposed technological scheme of disintegration
Рисунок 6. Предлагаемая технологическая схема дезинтеграции

Conclusions. The development of concentration circuits for rare-metal refractory ores requires the use of special selective disintegration methods, of which the most efficient is disintegration *in the layer* in roller press and choked inertial cone crushers.

A theoretical analysis of the forces acting on a piece of ore in the process of disintegration *in the layer* showed that, in this case, uniaxial compression is complemented by the specific compressive forces of the contacting ore pieces resulting in corresponding changes in strain, as described by the proposed formula. Analysis of the disintegration performance of different size classes under crushing *in the layer* showed that, at low strain, 0.1–0.15 of the limit value, the coarse size classes remain intact acting as grinding media. This mechanism ensures the selectivity of crushing *in the layer*.

The paper contains an analysis of different methods and criteria of crushing selectivity. A new criterion L_o of crushing selectivity was proposed based on optical and electron microscopy data, describing the ratio of liberation in the crushed product and feed.

A comparison of the selectivity criterion L_o under various crushing modes in the examined crushers, namely inertial cone crusher (KID), centrifugal crusher (DC), and roller press (LABWAL), in a pilot test on the niobium ore of Vishnevogorsky deposit, tantalum ore of Otboynoye deposit, and tantalium-niobium ore of the Zashihinskoy deposit in Russia showed that DC has the lowest selectivity criterion, which is much lower than that of KID and LABWAL.

A comparison of the specific energy inputs of the examined rare metal ore crushing processes revealed that the most energy-efficient is selective crushing *in the layer* in roller press, and that the widely used Bond index is an improper performance indicator for selective crushing, since it increases the energy inputs by a factor of 2–3.

A comparison of the effectiveness of screening, screen throughs sizing of different screens and slime formation degree shows the Kroosh is better than Derrik and GIL. Kroosh effectiveness of screening is 80% opposite 78% of Derrik and GIL.

The developed methodology has been approved by the Ministry of Natural Resources of the Russian Federation.

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Выбор специальных методов дезинтеграции и схем для комплексных труднообогатимых руд

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Реферат

Введение. *Статья посвящена новому подходу к выбору специальных методов дезинтеграции и схем для труднообогатимых комплексных руд. Предлагается комплексный подход и критерии для сравнения различных типов дробилок и грохотов. Критерии следующие: степень дробления, степень измельчения, степень ошламования и новый критерий селективности.*
Целью исследований *является изучение нового метода и вывод уравнения определения усилия дробления «в слое» и критерия селективности.*
Методы исследований*. Проверка предложенного нового метода осуществлялась при сравнении дробления танталовых руд Отбойного месторождения, ниобиевых руд Вишневогорского месторождения и тантало-ниобиевых руд Зашихинского месторождения в конусной инерционной, центробежно-ударной дробилках и роллер-прессе. Исследования дробления в аппаратах проводились в лабораторных и полупромышленных условиях. Также проверялись разные режимы работы дробилок и грохотов.*
Объектом исследований *являлись танталовые и ниобиевые руды разных месторождений.*
Результаты исследований*. Сравнение критерия селективности и степени дробления показали, что центробежная ударная дробилка и роллер-пресс имеют более низкие показатели по сравнению с конусной инерционной дробилкой КИД. Степень дробления для*

дробилок следующая: для центробежной ударной дробилки – 10,1; для роллер-пресса – 10,8; для конусной инерционной дробилки – 14,2. Критерий селективности для центробежной ударной дробилки составляет 0,632 ед., для роллер-пресса – 0,730 ед., для дробилки КИД – 0,848 ед. Дробилка КИД-300А показала наилучшие результаты для танталовой руды Отбойного месторождения и ниобиевой руды Вишневогорского месторождения. Кроме того, критерий степени ошламования также наилучший у дробилки КИД-300А. Новый метод проверен и апробирован.
***Выводы**. Статья содержит анализ различных методик и критериев оценки селективного дробления. Предложен новый критерий оценки селективности дробления, который базируется на данных, полученных с помощью оптического и электронного микроскопов, и описывает отношение степени раскрытия минералов в дробленом продукте к исходному.*

***Ключевые слова:** рудоподготовка; степень дробления; степень ошламования; критерий селективности; конусная инерционная дробилка; центробежно-ударная дробилка; роллер-пресс.*

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