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FEATURES OF RARE - METAL ORE ENRICHMENT IN A CENTRIFUGAL FIELD

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ОСОБЛИВОСТІ ЗБАГАЧЕННЯ РІДКІСНОМЕТАЛЕВОЇ РУДИ У ВІДЦЕНТРОВОМУ ПОЛІ

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ABSTRACT

Purpose. The target is to study in a centrifugal field the features of recovery of heavy minerals (pyrochlore, zircon) from rare-metal ore which contains minerals of intermediate density.

Methods. Laboratory and bench research.

Finding. The article is devoted to the problem of dressing of finely disseminated rare-metal ore in free-flow centrifugal concentrators. It is shown low efficiency of the dressing of the ores containing mineral of intermediate density in addition to the light and heavy minerals. To raise the contrast of separated mineral grains we proposed preliminary magnetic separation of minerals extraction intermediate density - aegerine, biotite, etc. before the separation of heavy and light minerals in the centrifugal field. But the complete absence of the intermediate density grains in the concentrating milling ore is also negative.

Originality. We investigated the patterns of the recovering heavy minerals from rare-metal ore of domestic deposits with different content intermediate mineral density in the centrifugal field. It is shown that for this type of ore the optimal intermediate density mineral content is 4,8-5,2%.

Practical implication. The study of the magnetic properties of the minerals helps to determine the technical parameters of the magnetic field, which is provided for the required content in the ore minerals of intermediate density.

Keywords: *rare-metal ore, centrifugal concentration, magnetic separation, recovery*

1. INTRODUCTION

The general trend of poor rare-metal raw materials processing and reducing the size of the disseminative components requires to solve the problem of the processing of finely disseminative ores and dump dressing products accumulated over a long period of dressing plants preparation.

Rare-metal ores are often poor and fine-disseminative. Traditional gravity dressing methods for such ores do not provide a sufficiently high metal recovery into concentrates. Thus, long-term research of the dressing of rare-metal ore of Mazurovskoe deposit, which is unique in Ukraine, carried out by different research organizations with the purpose to develop effective dressing technology have not lead to positive results. The recovering of most valuable mineral - pyrochlore - at best did is not more than 35-40% [1-2].

These days at some foreign dressing plants for tantalum-niobium raw materials processing there is the usage of dressing devices of new generation - non-pressure centrifugal concentrators. In such devices different specific gravity acceleration is provided to the grains of minerals, as a result the minerals with a high specific weight are concentrated at the wall conical bowl, and lighter grains are pressed out. The last ones are falling into the tails spout of centrifugal concentrator.

The crushed finely disseminative ore and products of their dressing as well as sand of alluvial deposits that have not processed natural hydraulic classification are the most suitable material for the dressing of centrifugal machines. Such devices have proven themselves in the dressing of gold the specific weight of which is several times more than the specific gravity of the rock. Differences in the density of mineral grains of valuable components and rock for rare-metal ores are less significant than the gold-containing ore. Given this into account it is appropriate for dressing of rare-metal ore to process a preliminary extraction of minerals of intermediate density - aegerine, biotite, goethite / ferrohydride and others - using one of the known methods of dressing. Based on the general laws of gravity separation it would lead to an increase in the degree of contrast mineral grains separated.

The problem of the separation efficiency of mineral grains in the centrifugal field of gold –containing materials have been considered and largely solved [3-5]. It is known that the efficiency of extracting valuable components from ore particle size is determined by grain light and heavy minerals (their ratio), their density and content of heavy minerals. Heavy grains are removed in centrifugal concentrator with a higher efficiency than grains of smaller grain density [6].

In [7-9] studied the effect of rotational speed of the rotor hub, pulp density and water flow onto the recovery of fine gold.

Rare metal ores contain significant proportion of intermediate density heavy grains. In [10] observed that dressing of these materials is low efficiency. In [11-12] states that the complete absence of red beans benefication intermediate density is also unfavorable. So, for each type of ore beneficating fine-grains rare-metals regime should be reasonable technological parameters of centrifugal concentrator.

The target is to study in a centrifugal field the features of recovery of heavy minerals (pyrochlore, zircon) from rare-metal ore which contains minerals of intermediate density.

2. MAIN PART

For the research the technological sample was prepared. The sample is the complex of niobium-zirconium ore of nepheline syenites from Mazurivskiy deposit, composed of some core samples taken from three specifically made the for this purpose wellings, crossed the first and the second ore deposits. Fragments of cores are composed of small- and medium-nepheline syenite, a small amount of fragments are composed of aegerine nepheline-pegmatites. Preparation of the sample before technological research consisted in crushing and grinding stages and flashy selection of the material for the chemical, mineralogical studies and experiments on dressing.

For doing research of material composition were used known methods for determining the chemical composition of the X-ray fluorescence and chemical analysis, optical microscopy study in heavy liquids fractionation (bromoform), quantitative mineralogical analyzes, magnetic and electromagnetic separation.Technological sample consisted mainly of nepheline, microcline and albite small amount, lepidomelane (biotite) and aegerine. For mineral composition the sample corresponds to nepheline syenite.

Table 1.The physical characteristics of the material

Mineral	Chemical composition	Specific gravity, g / sm3	Specific magnetic susceptibility, m3 / kg * 10-^{8}
Pertyt / microcline	(Na, K)Si_3O_8	2,55 – 2,65	Non-magnetic
Albite	Na,Al,Si_3O_8	2,6	Non-magnetic
-Nepheline	Na,Al,SiO_4	2,45 - 2,55	Non-magnetic
Sodalite		2,13-2,29	Non-magnetic
Kankrynit		2,3-2,5	Non-magnetic
Calcite		2,72	0,4-0,6
Egiryn (pyroxene)	Na,Fe$(SiO_3)_2$	3,4-3,5	3-11
Lepidomelan (Fe- biotite)	$K_2(Mg,Fe)_2(OH)_2Al,Si_3O_{10}$	3,1	4-12
Iron hydroxides (goethite / ferohidryt)	FeO,OH	3,8	20-30
Apatite		3,1-3,2	0,1-0,4
Fluorite		3,15	0,10-0,36
Zircon	$ZrSiO_4$	4,6	0,15
Pyrochlore	Nb/Ta/Fe/Ca Complex	5,27	0,6-0,7
Magnetite		5,1	25-50
Ilmenite		4,6	30-120
Pyrite		5,1	0,5-1,0

Mineral composition of the technological sample (%):

light minerals (<2.9 g / cm3): nepheline - 18.5; microcline - 36.8; albite - 30.2; sodalite - 0.3; kankrynit - 0.6; carbonate - 1.33;

minerals of intermediate density (2,9-3,6 g / cm3): lepidomelane

(biotite) - 4.8; aegerine - 4.2; apatite - 0.1; fluorite - 0.1; goethite / ferohidryt - 2.2;

heavy minerals (> 3.6 g / cm3): zircon - 0.38; pyrochlore - 0.13; magnetite - 0.15; ilmenite - 0.11; sulphides (pyrite) - 0.10.

Some physical properties of the minerals of Mazurivskoe deposit are shown in the Table. 1.

The multiple mineralogical studies of the material show that during the grinding to −1 mm zircon can be sufficiently recovered and can be removed effectively by existing gravity separation methods. Pyrochlore, by contrast, opening only partially and mainly in the smaller size than 0,063 mm.

That is why for technological research on dressing the sample was crushed to −0.2 mm (Table. 2). But with such a small majority of grinding material (66.0%) remained in classes larger than 0.063 mm. It is still almost 60% of the total number of Nb_2O_5 and 72% of ZrO_2. The content of Nb_2O_5 in these classes is at the level of its original content in the ore or little lower, and kept mainly as inclusions in the rock-forming minerals pyrochlore. The size yield smaller than 0,063 mm is 34%, including 11.98% of slime. They considerably enriched with Nb_2O_5 and they concentrated about 43% of the total amount. Zirconium oxide is evenly graded to all classes both when grinding to −1 mm, and to −0.2 mm. Unlike when pyrochlore zircon are sufficiently released in the class −1+0.5 mm.

The physical properties analysis of the minerals of the ore of Mazurivske deposit showed that the preliminary extraction of intermediate density minerals by magnetic separation is promising method.

Certainly the magnetic properties of minerals from different deposits are substantially different. From the preliminary studies [13] it is known that the pyrochlore of Mazurivskij deposit is characterized with magnetic properties due to thick black ore "shirt" on the surface of the grains.

Table 2. The content of components in class size of ground technological sample

Class size, mm	Yield, %	Content, %		Distribution, %	
		Nb_2O_5	ZrO_2	Nb_2O_5	ZrO_2
Grinding to –1,0 mm					
–1+0,5	39,56	0,10	0,55	35,74	33,73
–0,5+0,25	19,32	0,10	0,82	17,60	25,50
–0,25+0,125	14,53	0,11	0,82	13,99	18,42
–0,125+0,063	11,41	0,11	0,72	11,55	12,57
–0,063+0,032	6,15	0,13	0,64	7,22	6,06
–0,032	9,03	0,17	0,34	13,90	4,72
Base ore	100,00	0,11	0,65	100,00	100,00
Grinding to –0,2 mm					
+0,2	0,72	0,08	0,47	0,53	0,51
–0,2+0,125	30,81	0,10	0,70	27,01	35,03
–0,125+0,063	34,45	0,10	0,65	30,18	36,44
–0,063+0,032	15,55	0,13	0,70	17,75	17,52
–0,032	6,49	0,17	0,50	9,65	5,25
TOTAL: sand	88,02	0,117	0,71	85,12	94,75
Slime	11,98	0,15	0,27	14,88	5,25
Base ore	100,0	0,12	0,62	100,0	100,0

The determining factor for magnetic separation of rebellious ore of rare metals is release level of raw materials and components, which in turn depends on the size of crushing ore.

As we have shown in [14], the release of pyrochlore grains - the most valuable component of the ore - occurs mainly during the grinding of ore to 0,1-0,09 mm (60-70% of the class content of -0.074 mm). But while the significant amount of slime, efficient recovery of valuable components of which is impossible.

That is why magnetic separation of such raw materials is proposed to be start not from the specified optimal size, and that which is already characterized by a sufficient number of pyrochlore grains released.

Thus, the raw material for the magnetic separation was a highly classified material from the particle size from 0 to 0.2 mm, which has about 60% released pyrochlore grains. Identifying the initial and final size of magnetic separation was carried out on the recommendations [15].

Most of rare-metals ores refers to low magnetic. The mineral composition of the ore of Mazurivskiy deposit is complex mineral raw. It found about 20 minerals, which necessitates obtaining a wide range of products. It is possible to get concentrates of main components: niobium and tantalum (pirohloroviy), zirconium and hafnium (Zirconium)from the ore. In addition, it is advisable to obtain concentrates (products) with the associated minerals - feldspar, magnetite, ilmenite, ehirynovoho, biotite, and others.

In this regard, was done the detailed study of magnetic properties of all minerals that make up the rebellious rare-metal ore. The research was conducted in the laboratory of NSU on Faraday installation (limit of detection of the magnetic susceptibility of 10-12 m3 / kg). The monomineral fractions of ore components obtained by classification in heavy solutions were served as the material for the study.

Table 3. The results of magnetic fractionation of original ore −0.2 mm, deslimed in class −0.032 mm

Product	Outcome, %	Content of minerals of intermediate density, %			Content of heavy minerals, %		
		aegerine	biotite	goethite	pyrochlore	zircon	magnetite, ilmenite
Magnetic fraction 1 H=3,0 кЕ	1,45	-	-	-	-	-	27,58
Non-magnetic fraction 1	98,55	4,26	4,87	2,23	0,132	0,36	-
Magnetic fraction 2 H=4,5 кЕ	4,92	23,57	19,72	35,16	-	-	-
Non-magnetic fraction 2	95,08	3,1	3,9	0,5	0,138	0,377	-
Magnetic fraction 3 H=6,0 кЕ	12,56	21,97	22,85	16,16	-	-	-
Non-magnetic fraction 3	87,44	1,5	2,0	0,2	0,150	0,41	
Magnetic fraction 4 H=7,5 кЕ	25,18	16,12	18,55	8,64	-	-	-
Non-magnetic fraction 4	74,82	0,2	0,2	-	0,176	0,48	
Magnetic fraction 5 H=9,0 кЕ	27,8	15,32	17,52	-	0,023	-	-
Non-magnetic fraction 5 H=9,0 кЕ	72,2	-	-	-	0,174	0,50	-
Original ore –0,2 мм	100,0	4,2	4,8	2,2	0,13	0,38	0,4

The ranges of the values of variations of the ore minerals magnetic susceptibility are higher in the table. 2. As you can see, intermediate density minerals such as aegerine, biotite, goethite – which content in the ore is high enough - have a significant magnetic susceptibility and belong to the class of weakly magnetic materials. In the relevant industrial magnetic field separator they can be removed from the ore.

Other intermediate density minerals - apatite and fluorite - is nonmagnetic. But their content in the ore is quite small, and therefore a large effect on the separation of the minerals in the centrifugal field will be shown.

Heavy minerals - magnetite and ilmenite - have high magnetic susceptibility and can be removed in the magnetic fraction. Their content in the ore is also low; these minerals before extraction separation in the centrifugal field not affect substantially to the results of the separation of heavy and light minerals.

Magnetic fractionation of the products was conducted in magnetic separation with increasing magnetic field to obtain magnetic and non-magnetic fractions, which were subjected to X-ray fluorescence analysis.

The experiments were performed on a dry roller separator SE-138 with the lower feed material and a maximum value of the magnetic field of 16.4 kE. Preliminary the original ore was crushed to -0.2 mm and deslimed in -0.032 mm class when subjected to magnetic separation in magnetic field of 3.0 kE to extract magnetite and ilmenite.

From the non-magnetic product at magnetic field of 4.5 kE, 6.0 kE, 7.5 kE and 9.0 kE four sample material (non-magnetic fraction) were obtained, which then were investigated for dressing in the centrifugal field.

The results of magnetic fractionation ore output are in Table. 3.

Fig. 1 shows the dependence of content of intermediate density minerals in nonmagnetic fraction from the value of the magnetic field.

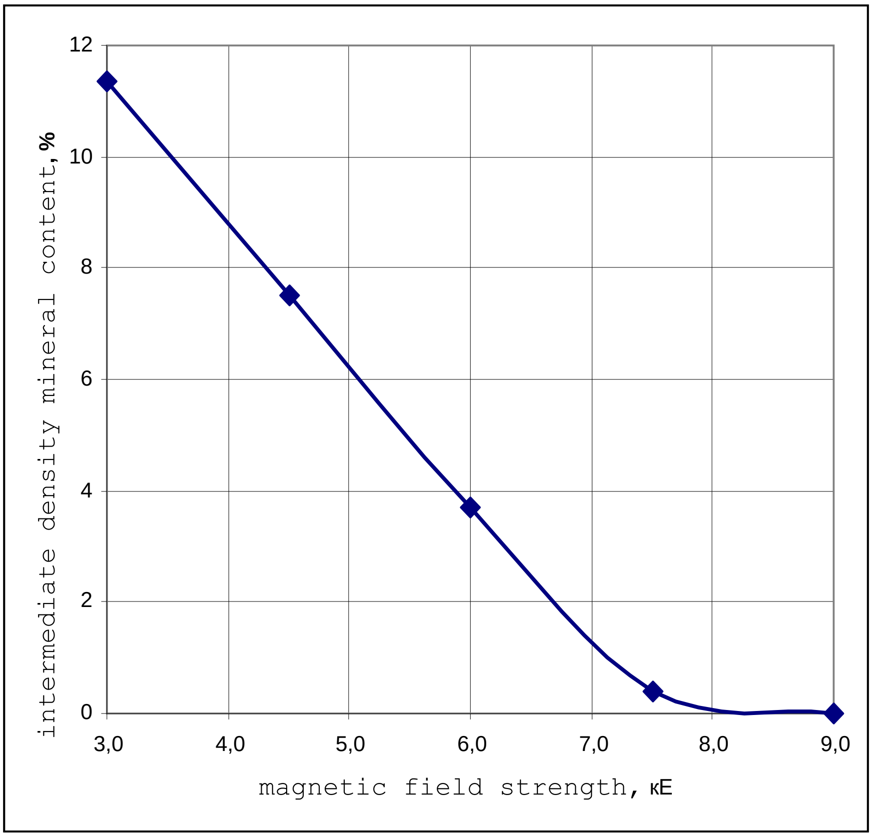

Fig. 1. Characteristic curve of intermediate density mineral content in the nonmagnetic fraction (aegirine, biotite, goethite) and the magnitude of the magnetic field

Established that the pyrochlore goes to the magnetic fraction when the magnetic field is 8,0 ÷ 8,5 kE.

For the research of the ore was used a centrifugal concentrator KNELSON KC-MD3, which provides the same efficiency dressing in a laboratory as more productive machines in industrial conditions. Productivity separator for solid - 45 kg / hr., by liquid - up to 660 l / h. Pulp density power - up to 25% of solid. Water consumption for washing - 660 ÷ 900 l / h.

The material in the form of slurry from the mixer is fed through a central tube to the inner cone (bowl) with a diameter of 3 inches.

Thus the vertical (from top to bottom) pulp flows are created using water supplied through the holes in the cone.

The heavy fraction accumulates due to centrifugal force in the grooves of the cone and periodically while stopping device, unloaded by removing the cone and its washing.

The light fraction is discharged through the upper edge of the bowl into the draining. Water pressure is supported to bestable within 276 - 690 kPa.

The frequency of the rotor is supported to be stable - 1460 rev / min.

The adjustment of dressing modes is carried out by changes in water pressure, which is going into the bowl.

The water pressure for each sample was chosen experimentally.

We studied four samples of the material with different content of minerals of intermediate density that were obtained by magnetic separation of the sample of original ore.

Each sample (about 20 kg) was passed through the concentrator of Nelson getting heavy and light fractions. After drying and weighing out the release dressing products was determined.

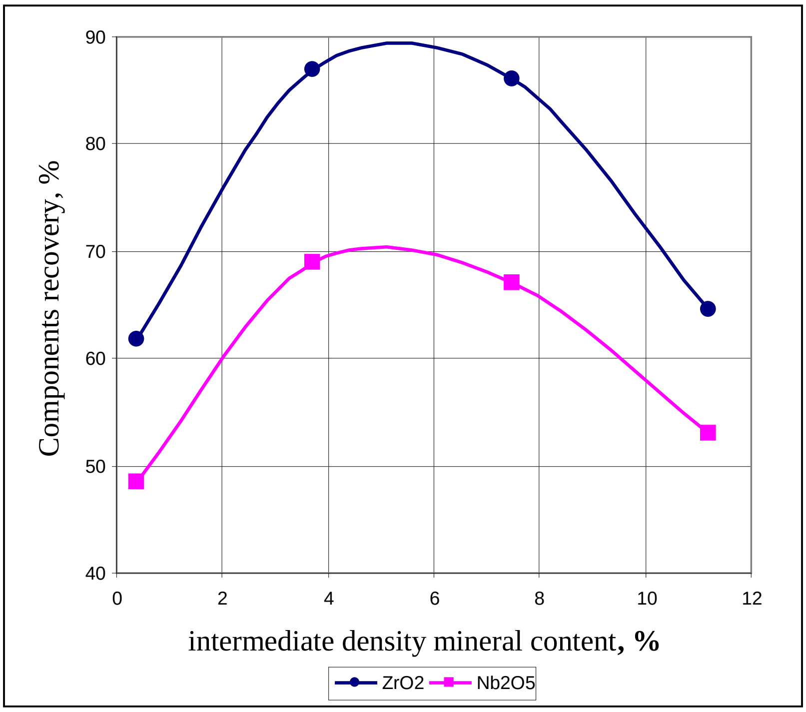

Fig. 2. Characteristic curve of Nb_2O_5 and ZrO_2 recovery level and heavy fraction of intermediate density mineral content in the ore

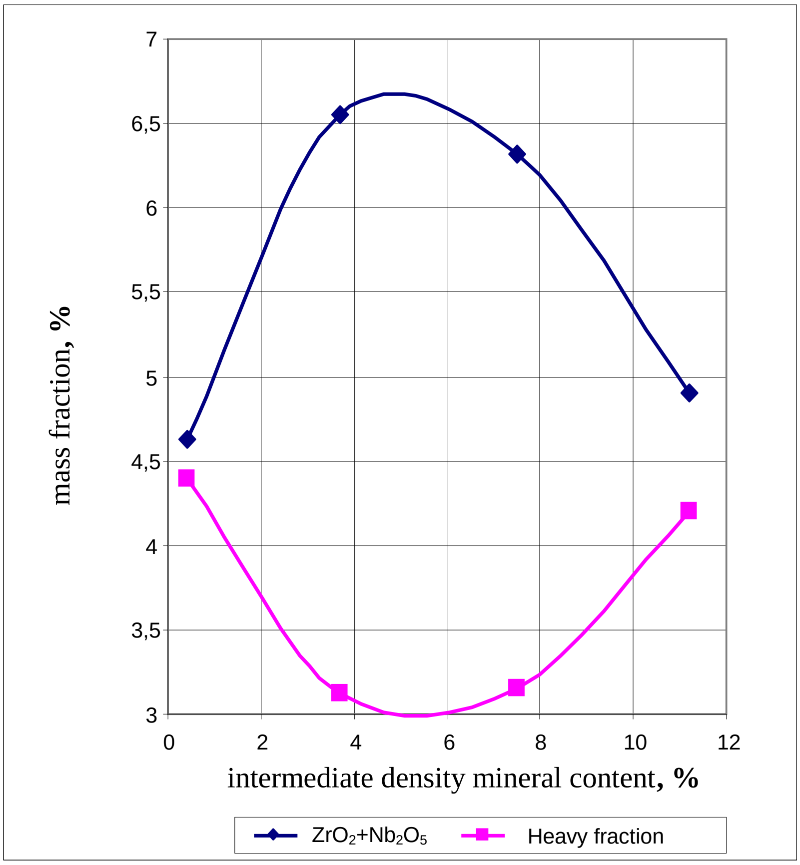

Fig. 3. Characteristic curve of the mass content of zirconium and niobium oxides and outcome of heavy fraction (pyrochlore + zircon) and the intermediate density mineral content in the ore

From each product was selected the sample of 50-100 g for chemical and mineralogical analyzes. We determined the content of pyrochlore, zircon, and Nb_2O_5 and ZrO_2. Evaluation of the dressing of the ore samples carried out in the concentrator of Nelson was done according to the chemical and mineralogical analyzes.

Fig. 2 shows the characteristic curve of the extraction level of Nb_2O_5 and ZrO_2 in heavy fraction; Fig. 3 - mass fraction of ZrO_2 + Nb_2O_5 in heavy fraction and heavy fraction release (zircon + pyrochlore) depending on the content of intermediate density minerals in the ore.

3. CONCLUSIONS

The most appropriate indicators of the dressing of the ore of Mazurivskiy deposit in free-flow centrifugal concentrator (withdrawal Nb_2O_5 and ZrO_2, mass fraction (ZrO_2 + Nb_2O_5, achieved when the content of intermediate density minerals (biotite, aegerine, goethite) in the ore is at 4,8-5,2 %.

The content of intermediate density minerals (biotite, aegerine, goethite) at 4,8-5,2% is provided by the preliminary magnetic separation of ore, grinded to a particle size less than 0,2 mm, in the magnetic field 5,4-5,5 кЕ.

The magnetic fractionation of finely disseminative ore is a promising technological operation, which improves the efficiency of recovery of heavy minerals - pyrochlore and zirconium - in centrifugal field.

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ABSTRACT (IN UKRAINIAN)

Мета. Метою роботи є вивчення особливостей збагачення у відцентровому полі рідкіснометалевої руди, що містить важкі мінерали (пірохлор, циркон), та мінерали проміжної густини (егірин, біотит).
Методи. Лабораторні та стендові дослідження.
Результати. Статтю присвячено проблемі збагачення дрібнодисперсної рідкіснометалевої руди у відцентрових концентраторах. Показана низька ефективність збагачення руд з високим вмістом мінералів проміжної щільності. Для підвищення контрасту мінеральних зерен, що розділяються, нами запропоновано до розділення важких і легких мінералів у відцентровому полі, проводити попереднє вилучення магнітною сепарацією слабомагнітних мінералів проміжної щільності - егірину, біотиту і т.д. Але повна відсутність зерен проміжної щільності в збагачувальній руді також негативно позначається на результатах збагачення.
Наукова новизна. Встановлені закономірності вилучення у відцентровому полі важких мінералів з рідкіснометалевої руди вітчизняного родовища з високим вмістом мінералів проміжної щільності. Показано, що для цього типу руди оптимальний вміст мінеральних речовин проміжної щільності становить 4,8-5,2 %.
Практичне значення. Вивчення магнітних властивостей мінералів допомагає визначити технічні параметри магнітного поля, за яких забезпечується оптимальний вміст в руді мінералів проміжної щільності, при якому досягається максимальне вилучення важких мінералів.

Ключові слова: *рідкіснометалева руда, відцентрова концентрація, магнітне поле, розділення.*

ABSTRACT (IN RUSSIAN)

Цель. Целью является изучение особенностей обогащения в центробежном поле редкометаллической руды, содержащей тяжелые минералы (пирохлор, циркон), а также минералы промежуточной плотности (эгирин, биотит).
Методы. Лабораторные и стендовые исследования.
Результаты. Статья посвящена проблеме обогащения мелкодисперсной редкометаллической руды в центробежных концентраторах свободного истечения. Показана низкая эффективность обогащения руд, содержащих минералы промежуточной плотности. Для повышения контраста разделяемых минеральных зерен мы предложили до разделения тяжелых и легких минералов в центробежном поле, проводить предварительное выделения в магнитном поле слабомагнитных минералов промежуточной плотности – єгерина, биотита и т.д. Но полное отсутствие зерен промежуточной плотности в обогащаемой руде также отрицательно отражается на результатах обогащения.
Научная новизна. Установлены закономерности извлечения в центробежном поле тяжелых минералов из редкометаллической руды отечественного месторождения с високим содержанием минералов промежуточной плотности. Показано, что для этого типа руды оптимальное содержание минеральных веществ промежуточной плотности составляет 4,8-5,2%.
Практическое значение. Изучение магнитных свойств минералов помогает определить технические параметры магнитного поля, обеспечивающие оптимальное содержание в руде минералов промежуточной плотности, при котором достигается максимальное извлечение тяжелых минералов.
Ключевые слова: *редкоземельная руда, центробежная концентрация, магнитное поле, разделение.*

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