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STUDY OF GRAVITY PRETREATMENT OF REFRACTORY GOLD-BEARING ORE FROM AKTOBE DEPOSIT

Extraction of gold from refractory gold-bearing ores in processing with combined flow charts is higher if more gold is extracted by gravity methods before flotation and hydrometallurgical circuits. The article presents the results of gravity beneficiation of refractory gold-bearing ore from the Aktobe deposit with the cyanidation-recoverable gold content of 46.47%. Assessment of the gravity separation efficiency used the GRG-test which found that 35.93% of gold could be extracted in centrifugal concentration. Two flow charts of gravity concentration of ore in the grinding circuits with jigging and centrifugal concentration were tested. The studies find out that the main amount of Aktobe gold has a size less than 0.1 mm, and it is recommended to recover such gold by combining grinding and centrifugal concentration in the integrated processing circuit.

Keywords: *Aktobe deposit, gold, gold-bearing ore, recoverability by gravity*
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Introduction

At present the world gold mining industry due to depletion of easily dressable mineral resources is forced to master technologies of processing of refractory gold-bearing raw materials characterized by fine dispersion of gold in sulphide minerals, which complicates direct cyanidation of beneficiation products. Processing of refractory gold-bearing ores has a variety of technological schemes, the choice of which is influenced by many factors. The main influences are: the chemical composition of initial ore, the location and distribution of gold in ore, the properties of accessory minerals, the presence of other components that complicate beneficiation. In addition, the presence of adhesive films and coatings on the surface of gold significantly worsens the process of gold recovery.

Modern experience of refractory gold-bearing ore processing is based on the combination of gravity separation and flotation technologies with cyanidation of gold-containing concentrates.

One of the refractory gold-bearing deposits is the Aktobe deposit explored in 2017 by Mynaral Gold and Mynaral Resources, which holds 4.7 tons of gold according to the JORC system estimate, is located in the Zhambyl region of Moyinkum district and is a part of the Mynaral ore field [1].

In connection with the above-said, it is impossible to use ready-made technical solutions on enhanced gold recovery, and it is required to improve processes and high-efficiency technologies via physical and chemical treatment of mineral raw materials. Remoteness of deposits, reduction of quality of extracted materials leads to the necessity of preliminary concentration of valuable components [2].

The review of the work of gold extraction plants show that the total recovery of gold from ores in combined processing schemes is higher when more gold is separated by gravity methods before the main circuits.

This takes place because neither flotation nor cyanidation provide recovery of all forms of free gold.

So flotation fails to recover:

1. Rounded coarse gold of 0.2 mm;
2. Gold covered with films of iron and manganese hydroxides;
3. Gold covered with oxide films of copper, silver and silicate;
4. Rolled-up gold (covered with small particles of rock minerals embedded in the surface layer of gold particles during grinding).

Cyanidation misses:

1. Densely coated gold particles (dense sulphide and silicate films);
2. Coarse gold particles of 0.2 mm (which have no sufficient time to dissolve).

For gravity extraction of gold, the most common processes are sedimentation, concentration on tables, centrifugal separators, enrichment in screw and cone jet separators, as well as on sluice devices of various kinds [3–5].

Gold recoverability by gravity is estimated using the GRG-test (Gravity Recoverable Gold Test) improved by Nelson (Knelson) company in centrifugal concentrators [6–14].

This article is devoted to the study of gravity concentration of refractory gold-bearing ore of Aktobe deposit in order to develop a rational technology of its processing.

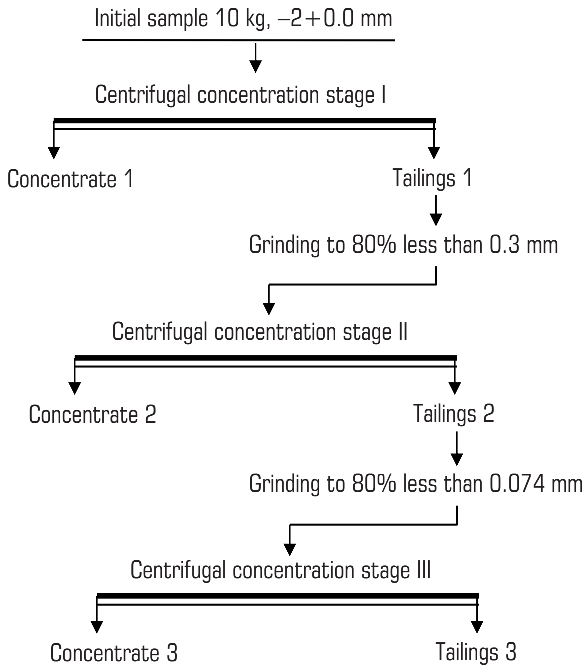

Fig. 1. The GRG-test with vibrating centrifugal concentrator

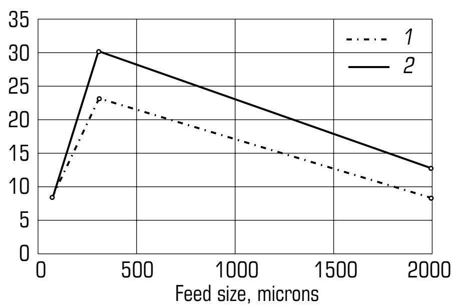

Fig. 2. Dependence of gold recovery and quality of GRG-test concentrate on feed size:
1 – extraction of gold into a gravity concentrate, %; *2* – gold content in the gravity concentrate, g/t

Table 1. Phase analysis of gold and silver in ore sample from Aktobe deposit

Description	Au content, g/t	% Au, (relative)	Ag content, g/t	% Ag, (relative)
Au, Ag free and in open aggregates	0.73	46.47	16.40	38.59
Au, Ag covered with oxide films	—	—	13.12	30.87
Au, Ag in arsenic minerals (except arsenopyrite and), lead-containing minerals	—	—	0.08	0.20
Au, Ag in iron or manganese oxides	—	—	0.15	0.34
Au, Ag in sulphides	0.59	37,61	11.76	27.67
Au, Ag thinly disseminated in quartz, carbonaceous matter, etc.	0.25	15,92	0.99	2.33
Total	1.57	100.0	42.50	100.0

Table 2. The GRG test results

Product	Output		Content, g/t		Extraction, %	
	g	%	Au	Ag	Au	Ag
Stage I, ore coarseness –2+0.0 mm						
Concentrate 1	105.3	1.05	12.85	92.46	8.62	2.29
Tailings 1	9894.7	98.95	1.45	41.97	91.38	97.71
Ore	10 000	100.00	1.57	42.50	100.00	100.00
Stage II, 80% feed size less than 0.3 mm						
Concentrate 2	109.5	1.11	30.25	147.32	23.09	3.88
Tailings 2	9785.2	98.89	1.13	40.79	76.91	96.12
Feed (tailings 1)	9894.7	100.00	1.45	41.97	100.00	100.00
Stage III, feed size 80% less than 0.074 mm						
Concentrate 3	115.1	1.18	8.47	142.56	8.82	4.11
Tailings 3	9670.1	98.82	1.04	39.58	91.18	95.89
Feed (tailings 2)	9785.2	100.00	1.13	40.79	100.00	100.00
Cumulatively						
Concentrate 1	105.3	1.05	12.85	92.46	8.62	2.29
Concentrate 2	109.5	1.10	30.25	147.32	21.10	3.80
Concentrate 3	115.1	1.15	8.47	142.56	6.21	3.86
Total concentrate	329.9	3.30	17.10	128.15	35.93	9.95
Tailings 3	9670.1	96.70	1.04	39.58	64.07	90.05
Ore	10 000	100	1.57	42.50	100.00	100.00

The authors set the following tasks:

— to investigate gravitational beneficiation of refractory gold-bearing ore from the Aktobe deposit by the GRG-test method;

— to carry out gravity concentration in the circuit of grinding with the grinding–jigging–concentration table and grinding–centrifugal concentration flow charts, with the tailings of this circuit to be send for the subsequent flotation.

Object and methods of research

The object of research is gold-bearing ore from the Aktobe deposit, the material composition of which is studied and given in the article [1], from which it follows that:

— the main host mineral of the sample is quartz, and potassium feldspar, calcite and mica are also present;

— the ore minerals are pyrite up to 6%, limonite up to 0.5%, galena 0.15–0.2%, sphalerite 0.17–0.2%;

— harmful impurities in the form of arsenic and antimony are practically absent, and copper content is minimal;

— the microscope examination of the samples reveals that the ore is represented by nested disseminated aggregates of galena–sphalerite–pyrite composition. The main ore mineral — pyrite — is observed in the form of anhedrals and phenocrysts, individual idiomorphic grains, ranging from 0.02 to 1.5 mm in size, in association with sphalerite and galena, developing mainly along fractures. Nugget gold is found in a void in brecciated, intensely leached rock represented by limonite and iron hydroxides. The grain is elongated, 0.035×0.01 mm in size, straw-yellow in color, with high reflection;

— the main commercial value components in Aktobe ore are gold with the content of 1.57 g/t and silver with the content of 42.50 g/t.

Assessment of gravity beneficiation of gold-bearing ore by the GRG-test method was carried out on a vibrocentrifugal concentrator [15] under the following conditions: centrifugal acceleration — 60G; solid throughput — 1 kg/min; solid content in the pulp fed to gravity concentration — 25%.

GRG-test

The test simulates staged beneficiation. At the 1st stage ore is crushed to 100% of –2 mm size and is passed through the vibrocentrifugal concentrator. The tailings of the first beneficiation stage are ground to 80% content of the size less than 0.3 mm and are passed through the vibrocentrifugal concentrator, too. The tailings from the second stage of beneficiation are ground to 80% content of the size less than 0.074 mm and are again passed through the vibrating centrifugal concentrator. At all stages of the test, the samples are taken from the tailings for the assay analysis and process balance. The scheme of the GRG-test is shown in **Fig. 1**.

Accumulation of the gravity concentration tailings in the grinding circuit with the grinding–jigging — concentrating table flow chart was carried out at the following parameters of jigging: frequency of pulsations — 350 pulses/min, amplitude of pulsations — 6–4 mm, height of artificial bed — 40 mm, material of artificial bed — steel shot with diameter 3–4 mm, size of grid holes — 2 mm, flow rate of subgrate water — 2 m^3/t, specific productivity — 25 t/h-m^2 of grid; and the grinding–centrifugal concentration flow chart used the regimes from the GRG-test.

Results and discussion

Refractory properties of the test gold-bearing ore are confirmed by the phase analysis of gold and silver (**Table 1**).

The phase analysis reveals that 46.47% of gold is free and in open intergrowths (recoverable by cyanidation), the remaining gold is in sulphides (37.61%) and is thinly disseminated in waste rock (15.92%). The GRG-test results are summarized in **Table 2**.

The analysis of the GRG-test results shows that from the ore of the Aktobe deposit, centrifugal concentration can extract 35.93% of gold into gravity concentrate. It should be mentioned that the main amount of gold recoverable by centrifugal concentration is observed at a coarseness of 80% less than 0.3 mm (**Fig. 2**).

In stage III GRG-test, at the feed size of 80% less than 0.074 mm, the obtained gravity concentrate has the lowest quality of 8.47 g/t, and indicates that the remaining gold is thinly disseminated and is impossible to be dissociated at this size of grinding [13–15].

On the basis of the collected information, it is recommended to add the developed technological processing circuit for Aktobe ore with gravitational processes. The results of gravity concentration are described below.

Gravity concentration in the flow charts of grinding–jigging–concentration table and grinding–centrifugal separation

The experimental flow charts are depicted in **Figs. 3** and **4**.

The recommended flow charts for gravity gold recovery in the grinding circuit with jigging and centrifugal concentration are similar, with the objective of recovering dissociated gold. The initial sample was ground to the size of 2 mm, which corresponded to the discharge of the first stage of grinding, and was fed to gravity concentration. Tailings of the first stage of gravity concentration were classified at a size of 0.1 mm, the sand fraction went to the second stage of grinding, where it was further ground to the size of 0.3 mm. The milled product from the second grinding stage was fed to stage II gravity concentration. The concentrates, if jigging is used, are joined and re-cleaned on a concentration table, if centrifugal concentration is used, the concentrates represent the finished product. The gravity concentrator tailings and the classification drain form the gravity concentrator tailings meant for the further flotation beneficiation and analysis.

The results of gravity concentration of initial ore are summarized in **Table 3**.

From the practice of concentration, it is known that jigging effectively extracts gold 0.1 mm in size and more, and centrifugal concentrators effectively extract gold 0.03 mm in size and more. The accomplished research shows that the main amount of gold from the Aktobe deposit has a size less than 0.1 mm and it is recommended to use the grinding–centrifugal concentration flow chart for such gold recovery.

Conclusions

The GRG-test results prove that refractory gold-bearing ore from the Aktobe deposit can be enriched on centrifugal concentrators.

Two flow charts of gravity concentration in the grinding circuit of ore processing with jigging and centrifugal concentration are tested. The results show that the main amount of gold from the Aktobe deposit has a size less than 0.1 mm, and it is recommended to use the grinding–centrifugal concentration flow chart in the processing circuit developed to recover such gold.

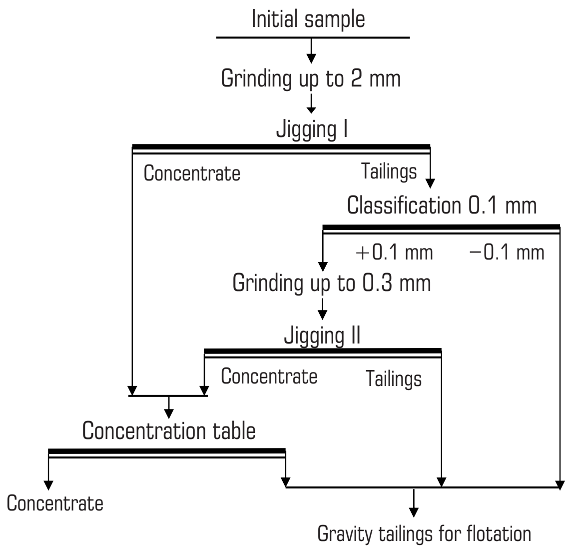

Fig. 3. Grinding–jigging–concentration table

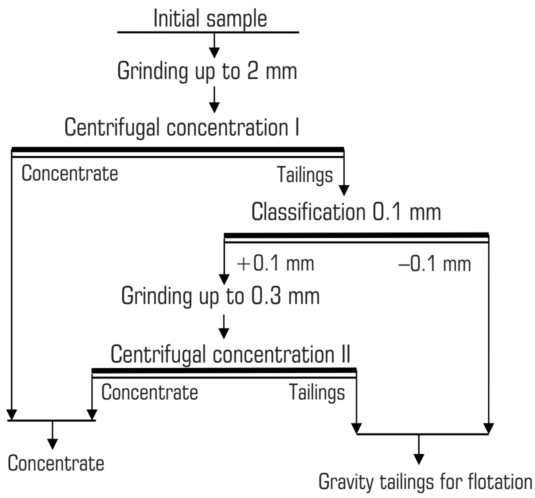

Fig. 4. Grinding–centrifugal concentration

Table 3. Results of gravity concentration of initial ore

Product	Output, %	Content, g/t		Extraction, %	
		Au	Ag	Au	Ag
Gravity beneficiation with jigging–concentration table					
Concentrate	1.20	21.35	125.23	16.11	3.60
Tailings	98.80	1.35	40.71	83.89	96.40
Ore	100.00	1.59	41.72	100.00	100.00
Gravity concentration with centrifugal concentration					
Concentrate	1.24	36.62	145.00	28.74	4.20
Tailings	98.76	1.14	41.48	71.26	95.80
Ore	100.00	1.58	42.76	100.00	100.00

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THE USE OF MINING AND METALLURGY WASTE IN MANUFACTURE OF BUILDING MATERIALS

This article describes R&D connected with the technology of production of building materials using waste of the mining and metallurgical industry.

The subject of research are mill tailings, as well as backfill and reinforcement mixtures with and without addition of tailings. The object of research are physical and mechanical properties, and features of curing of the test mixtures in the conditions of natural humidity.

The characteristics of the initial materials, compositions of backfill and reinforcement mixtures, and their physical and mechanical properties were determined using standard techniques, and the physicochemical properties were identified from the X-ray diffraction analysis and infrared spectroscopy. Phases were specified on diffraction device DRON-3M, and the chemical analysis used X-ray fluorescent spectrometer EDX-8000. The granulometry was determined using three methods: sieve analysis by multifrequency screener MSA W/D-200 Kroosh Technologies Ltd.; diffraction analysis by laser particle size analyzer Helos-KR with Quixel add-on; dispersion analysis by a dry powder dispersion unit.

Toward the industrial and ecological safety, the qualitative and quantitative characteristics of waste from some large mines in Kazakhstan are described, and the environmental damage of the mining industry waste is investigated and taken into account. Mill tailings of a processing plant of a mining company in the Republic of Kazakhstan are analyzed. Some technologies are proposed to manufacture dry building mixtures and aerated concrete using mineral processing waste. The use of manmade mineral feedstock in manufacture of dry building mixtures and aerated concrete allows total substitution of carbonate and silica components, and saves consumption of Portland cement. The technical and economic effect of application of the developed compositions as masonry, finishing and polymeric materials for the building industry of Kazakhstan totals 329–2700 Tenge/m^3 of mixture. The technology of no cement porous concrete manufacture uses a binder represented by burnt and ground lime from furnacing of carbonate-bearing waste. The binder is used jointly with a silica component – tailings of rare metal and complex ore processing, containing silicon dioxide. The technology of manufacture of aerated concrete using tailings is aimed at achieving: required thermal–insulating properties at the average dry density not higher than 500 kg/m^3, structural–thermal–insulating properties at the average dry density of 500–900 kg/m^3 and structural properties at the average dry density of 900–1200 kg/m^3.

Keywords: *mining and metallurgy waste, ecological risks, mineral mining, open pit, underground mine, concentration plant, jointing, fractures, rock falls, reinforcement, mining waste, building materials*

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Introduction

The sector of mining and metallurgy in the Republic of Kazakhstan has accumulated a massive amount of overburden, mill tailings and slag for the long years of operation. The greater percentage of waste is the waste of nonferrous metal mining and metallurgy, with the biggest volume of rejects concentrated in tailings ponds (**Table 1**). The tailings represent a fine material that needs no additional milling before utilization, which allows reduction in economic costs. For another thing, processing of such material ensures its chemical and mineralogical uniformity.

Operating mines emit millions of tons of toxic substances in the atmosphere and discharge hundreds of millions of cubic meters of contaminated effluents in water basin. This entails severe economic, social and ecological consequences. By present-day estimates, Kazakhstan's mining sector has accumulated over 50 Bt of waste which occupies vast overall area (more than 150 km^2). Amount of industrial waste grows annually by 1.5 Bt while the use of solid mining waste is currently at a rather low scale [1].

Table 1. Manmade waste at large mining and processing plants

Mining and processing company	Waste, kt	
	Overburden dumps	Tailings ponds
Achpolimetal JSC	–	142 570.1
Belaya Gora GOK	24 406.0	10 067.8
Donskoi GOK	81 447.7	38 280.4
Kazakhmys	973 114.7	1 674 691.5
Zhairem GOK	6354.8	3188.8
Tekeli GOK	15 723.9	40 360.5
Kazzinc	–	373 147.1
Zhezdy GOK	89.7	3173.2
Kostanai Minerals JSC	–	2038.3