UDC 622.765

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PILOT ASSIMILATION OF FLOTATION TECHNOLOGY FOR PROCESSING OXIDIZED FERRUGINOUS QUARTZITES



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In magnetite ore mining and processing, oxidized ore makes 10–30% out of which 90% is lost with tailings.

Processing of oxidized ferruginous quartzites is a promising and economic source for growth of concentrate production without increase in magnetite ore output.

At present, under the order of Inguletsky Mining-and-Processing Integrated Works, Ukraine, RIVS has performed the research and pilot trial aimed at estimation of feasibility of oxidized quartzites processing.

In view of the fine dissemination of Inguletsky oxidized quartzites (average size of hematite grains is 10–50 μm, quartz — 50–70 μm), the objective of the laboratory research was to determine the optimized processing method. As magnetic and gravity concentration of fine-disseminated ore is low-effective, the solely method of dressing is flotation.

Hematite quartzites are currently not extracted but considered as a raw material for the Krivoi Rog Oxidized Ore Mining-and-Processing Integrated Works and processing plants in Krivbass.

As a result of the performed research, the technology of magnetite ore processing has been developed and pilot trialed.

Key words: *oxidized ferruginous quartzites, flotation, pilot trials, amines.*

Iron ore deposits are discovered in 98 countries of the world. The explored reserves make 464.24 Bt and the demonstrated reserves are 206.9 Bt. Majority of the reserves are low- and medium-grade ores with iron content of 16–40% that make 87.5% of the explored reserves. Russia's possession of high-grade ore with iron content of 60% and above (no beneficiation required) is merely 12.5%.

In black iron ore mining and processing, the portion of oxidized ore reaches 10–30% out of which 90% are lost in tailings and dumps. Processing of oxidized ferruginous quartzites is the most promising and efficient source of increase in production of concentrates.

Various countries of the world have adopted different methods of dressing feebly magnetic, mainly hematite, ore.

By texture and structure characteristics, hematite ores are grouped into fine-, medium and coarse-disseminated ore. Separation of metals and nonmetals uses gravity, magnetic and flotation concentration, as well as combinations of these processes. Based on iron content, these ores are divided into low-grade ore (iron content to 40%) and high-grade ore (iron content of 50–60% and above). The high-grade ores are coarse- and medium-disseminated, and low-grade ores are fine-disseminated (**Fig. 1**).

Against the order of Inguletsky Mining-and-Processing Integrated Works, Ukraine, RIVS has assessed feasibility of industrial processing of oxidized quartzites. The developed flotation process allowed iron mass fraction of 66.5% in the concentrate at the recovery of 84.5%.

In the research laboratory of IVS company, various concentration methods were tested on a representative sample of Inguletsky oxidized quartzites: float-and-sink, jigging, gravity separation on concentration table and in spiral separators, dry and wet magnetic separation, direct and reverse flotation, as well as the combination gravity-magnetic and magnetic-flotation technologies [1].

For each of the listed methods, the tests determined optimized size of the ore disintegration and parameters of the process based on the separation criterion conforming with the characteristics of milling (**Fig. 2**).

Based on the mineral composition, ferruginous quartzites from the discussed deposit are mainly fine-disseminated type (**Fig. 3**) where iron minerals are represented by feebly magnetic kinds: hematite in the form of martite and micaceous iron oxide, ferric hydroxides (goethite, hydrogoethite) and ferrous silicates.

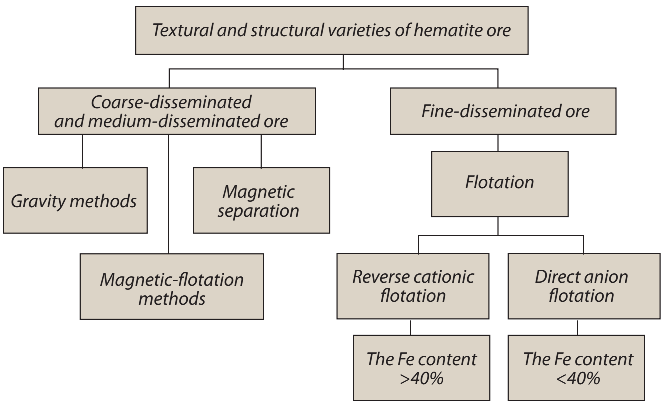

Fig. 1. Selection criteria for separation characteristics in ferruginous quartzite processing

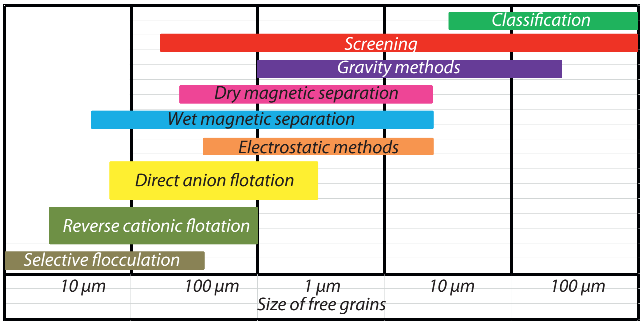

Fig. 2. Size range of mineral particles governing the choice of a processing method [after Khan (1985)]

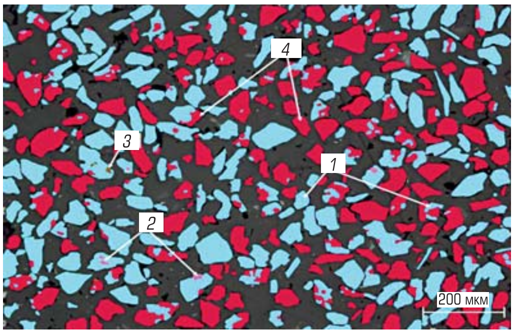

Fig. 3. Hematite concentrates of Inguletsky ore. Phase chart (scanning electron microscope):
1 — hematite; *2* — magnetite, *3* — goethite, *4* — nonmetals

The sample of Inguletsky hematite quartzites contains hematite (39.81%), magnetite (3.6%), iron hydroxides (2.53%), quartz (46.4%), silicates (4.9%) and carbonates (2.6%).

Iron distribution in the minerals shows that iron is mainly associated with hematite (82.98% relative), magnetite (7.76% relative) and iron hydroxides (4.76% relative). Some iron is contained in iron-bearing nonmetals: ankerite, dolomite (1.19) and various composition amphiboles (3.28%).

Dissociation of metals is only achieved in fine grinding of ore up to 75–85% content of size grade –44 µm. Relative percentage of free grains of hematite is 83.96 out of which 41.26% relative are in the size grade –10 µm. Relative percentage of dissociated nonmetals is 76.68 where 83.95% relative belong in the size grade –10+40 µm favorable for cationic flotation. Thus, the feature of this type ore is complicated extraction of hematite due to its fine dissemination. Morphology of quartz grains is beneficial for flotation.

Coarse-disseminated hematite is successfully dissociated from barren rock under magnetic separation in high-intensity magnetic field. This method is inapplicable for fine-disseminated ore due to a few essential shortcomings: weak difference between magnetic properties of metals and nonmetals as a consequence of large amount of aggregates after coarse grinding; weak selectivity of magnetic separation of fine-ground ore; instability of magnetic separation due to variability of material constitution and impregnation of oxidized quartzites. The presence of magnetite adds more difficulty in the process of separation.

One of the promising methods for dressing of oxidized quartzites is flotation widely used in mineral processing in the world (for example, Samarco and Brucutu processing plants in Brazil) and allowing production of high quality concentrates.

The analysis of the material constitution and dressability of the chosen ore type showed the highest performance characteristics in stage-wise flotation circuit with tailings subjected to disposal after each stage of grinding.

Floatability of quarts and the other silicate minerals differs much and depends on chemical composition of a mineral, water phase of flotation pulp and on grain-size composition of the mineral [2]. Any kind mica is readily floated even in the form of large flakes, whereas quarts can usually be floated if its particles are under 0.1 mm in size. Optimal recovery of quartz is achieved with its particles within the size range of 0.075–0.005 mm.

The IVS specialists pilot-trialed the technology developed in September–November 2013 at Krivoi Rog Oxidized Ore Mining-and-Processing Management (KROOMPM), Dolinskaya town, Ukraine.

The pilot trials included two ore grinding charts. The choice of the optimal grinding chart, ensuring the required dissociation of metals and nonmetals, was based on the comprehensive analysis of the grinding products.

In the first chart, one-stage grinding used a ball mill and double classification in classifier and cyclone up to 88.65% content of size grade –44 µm. The main metals of hematite and magnetite in the cyclone discharge were dissociated by

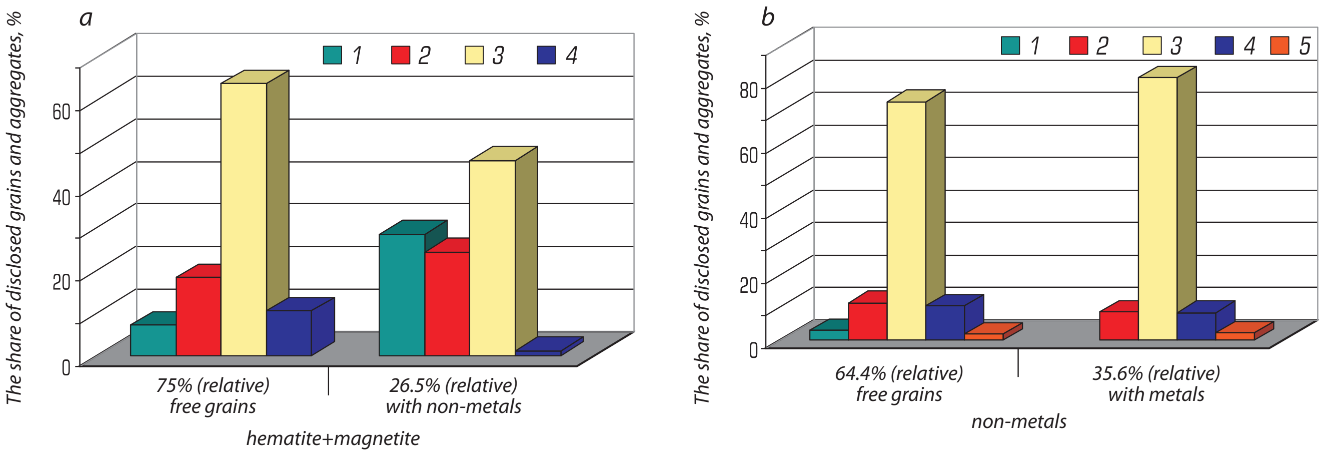

Fig. 4. Dissociation of metals and nonmetals with grinding circuit variant I:
1 — <5; *2* — (–10+5); *3* — (–40+10); *4* — (–100+40); *5* — >100

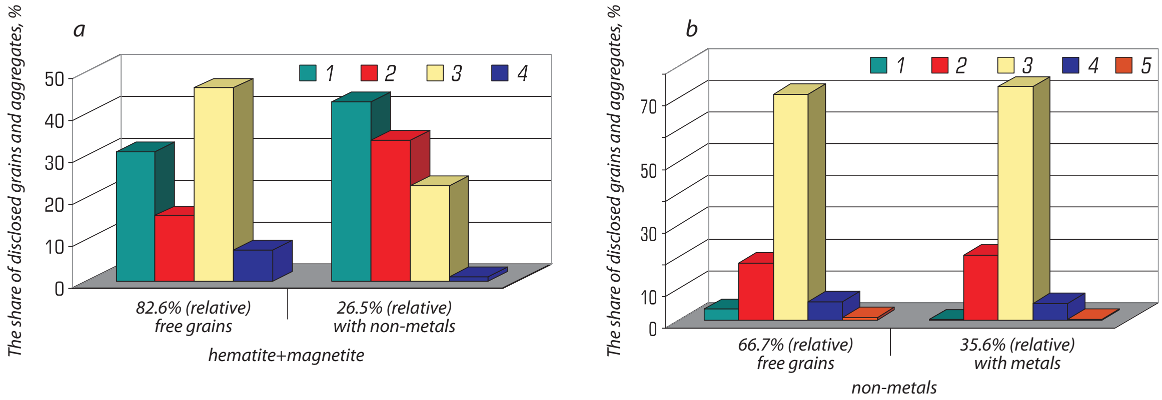

Fig. 5. Dissociation of metals and nonmetals with grinding circuit variant II:
1 — <5; *2* — (–10+5); *3* — (–40+10); *4* — (–100+40); *5* — >100

73.50% relative of the typical size grade -40 µm. In aggregates with nonmetals, hematite and magnetite are represented by grains under 40 µm in size. Relative percentage of metals in size grade –5 µm was 7.1. Nonmetals were dissociated by 64.4% relative, where 85% were in flotation size grade –40 µm. Aggregates of metals and nonmetals mostly (over 90%) occurred in the size grade larger than 10 µm (**Fig. 4**).

In the second chart, two-stage grinding used a ball mill at stage I and vertical mill Vertimill at stage II up to 91.6% content of size grade –45 µm in the final product. In stage II cyclone discharge, metals were heavily overground. Relative percentage of their dissociation was 82.60, and more than 90% of free grains were in size grade –40 µm, where 30% belonged in the size grade –5 µm. In aggregates of metals and nonmetals, hematite and magnetite were represented by grains smaller than 40 µm, out of which 40% relative were in the size grade smaller than 5 µm. Nonmetals were dissociated by 70% relative, and major portion of free grains belonged in the size grade from 10 to 40 µm. Aggregates of nonmetals and hematite and magnetite are 95% grains smaller than 40 µm in size (**Fig. 5**).

After the comparison of dissociation performance, the one-stage grinding chart with double classification in classifier and cyclone was chosen for the pilot trial as it ensured the required milling and dissociation of mineral at the minimum slime formation (**Fig. 6**).

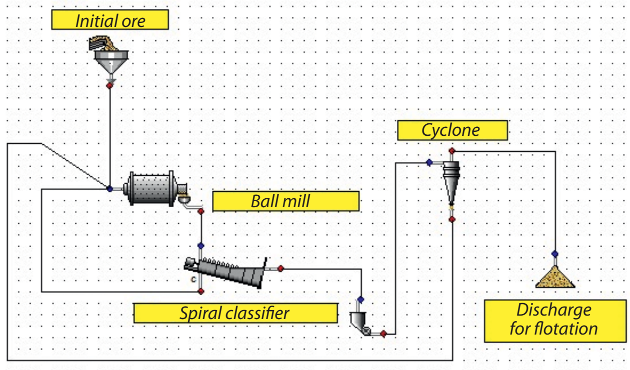

Fig. 6. One-stage ore grinding circuit under pilot trial

The flotation test (**Fig. 7**) had two stages because of:

- the requirement to thicken recleaner flotation I concentrate in order to produce the preset density product before attritioning;
- the insufficient number of flotation cells.

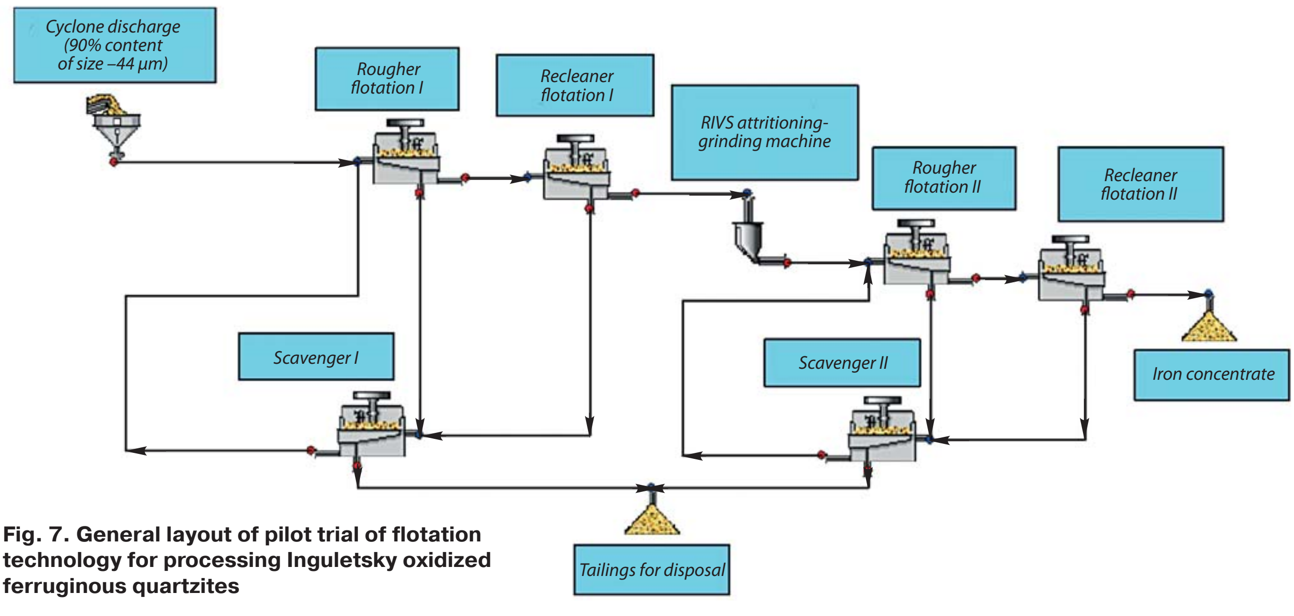

Fig. 7. General layout of pilot trial of flotation technology for processing Inguletsky oxidized ferruginous quartzites

Table 1. Pilot trial production data

Description	Yield, %	Content, %		Recovery, %	
		Fetotal	SiO_2	Fetotal	SiO_2
Tailings for disposal	59.7	12	82.26	21.35	96.75
Hematite concentrate	40.3	65.5	4.09	78.65	3.25
Ore	100	33.56	50.76	100	100

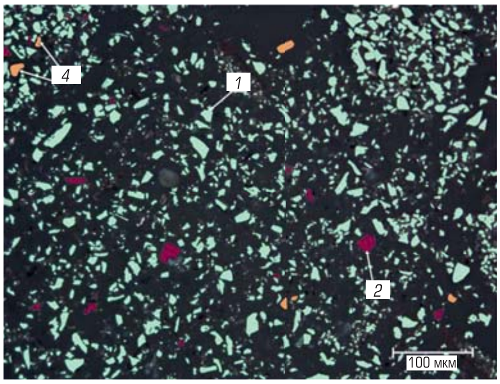

Fig. 8. Hematite concentrate. Reflected light, parallel nicols, dark-colored with no relief — compound
1 — hematite, *2* — magnetite, *3* — goethite, *4* — nonmetals

Table 2. Pilot press-filter production data

Experiment no.	Initial ore, %	*S*, m^2	Compression, atm	Blowing, atm	*T*, s	Filtrate volume, l	Cake weight, kg	Moisture content, %
1.	50 (1630)	0.309	7	7	90	13.6	19.8	14.8
2.	54 (1730)	0.309	10	10	120	16.2	18.29	4.5
3.	51 (1655)	0.268	12.5	—	95	6.4	6.510	3.2

The trials were carried out in a continuous mode for 72 h, with water rotation based on Inguletsky Mining-and-Processing Works recycled water. Quartz flotation used a collecting agent based on primary monoamines ester; depression of galena used hydrolyzed starch.

As a result of the pilot trial under continuous operation conditions at stage I for 32 h and at stage 2 for 2 days, the flotation concentrate was produced with the iron mass fraction of 65.5% at the recovery of 78.65%. Silicon dioxide content of hematite concentrate was 4.09% (**Table 1**).

Hematite concentrate (**Fig. 8**) produced using the developed technology contained 94.97 of actual percentage of metals, which implies high quality. Nonmetals were quartz, amphiboles, feldspars, micas and hydromicas, as well as carbonates. Most of aggregates of nonmetals and hematite belonged in the size grade –40 µm.

The specific surface area measured in accordance with the RF State Standard 21043-87, on NOVA12900e analyzer made 3.701 m^2/g.

Coralina Engineering and IVS carried out joint pilot trial of hematite concentrate press filter on a patent design pilot plant. The trial included varied operating parameters of the press-filter and produced cake with the moisture content from 4 to 9%, which enabled eliminating the stage of drying the concentrate (**Table 2**).

Aimed at estimation of ecological impact of the technology using Clariant flotation agents, the content of the agents in solid, water and air media was analyzed.

According to the project, the hematite ore flotation pulp will be disposed in the same tailings storage as the magnetite ore processing tailings with the dilution of the former by the latter by 121.7. The pulps of the both types of tailings were mixed in laboratory. The spectrophotometric analysis showed that Flotigam ED concentration in water phase of the mixed pulp was 0.082 to 0.09 mg/l in 10 min after mixing and 0 mg/l (absence) in two hours of mixing.

The research and experimental investigation of concentration of oxidized ferruginous quartzites is a technological breakthrough in the area of iron-bearing mineral processing and can be practiced by the similar plants in Russian Federation and in near and far abroad.

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