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MINERAL DRESSING

Dressability of Abagas Hematite-Magnetite Ores

V. I. Kilin[a], E. K. Yakubailik[b], L. P. Kostenenko[b], and I. M. Ganzhenko[c]

[a]*EVRAZRUDA,*
prospect Kurako 49a, Novokuznetsk, 654027 Russia
[b]*L.V. Kirensky Institute of Physics, Siberian Branch, Russian Academy of Sciences,*
Akademgorodok, Krasnoyarsk, 660036 Russia
[c]*Siberian Federal University,*
Svobodny prospekt 79, Krasnoyarsk, 660041 Russia

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Abstract-A number of magnetic separation processes are used to study preparability of two main hematite-magnetite and magnetite- muscovite ore types extacted it the Abagas iron ore deposit. The dry magnetic separation results were judged as acceptable for the rough processing stage, while the products of the wet magnetic separation were the high-grade iron ore concentrates. The two-stage beneficiation tests on complex hematite-magnetite ores demonstrated much higher cumulative iron recovery from the test ore.

Keywords: magnetite, hematite, ilvaite, dry, wet, high-gradient magnetic separation, jigging

INTRODUCTION

Abagas iron ore deposit was discovered 300 km away of the Teisk iron ore deposit in Khakasia in 1931, and has been well explored since then. The high feebly magnetic mineral content in Abagas iron ore as compared to the mineral composition of the Teisk ore was the main source of heavy iron loss in tailings after PBS-type machine separation.

Since 1996 surface mining is carried out at the ore body VI known as “Yuzhny-2.” Abagas run-of-mine ore was transported to Teisk crushing-and-preparation plant for one-stage beneficiation of 0-16 mm ore feed in up-dated separators PBS 90/250 and 2PBS 90/250 capable to generate magnetic field of higher strength.

The laboratory analysis of dressability of Abagas iron ore, variable in its mineral composition, was undertaken with the aims at increase in the ore production and its beneficiation, and to estimate the economical parameters and the grade of final concentrated products. The present studies can be considered as an extension of the previous work initiated at EVRAZRUDA since 2005 to assess preparation characteristics of Abagas iron ore [1].

L.V. Kirensky Institute of Physics, SB RAS, fulfilled the test material preparation: crushing, grinding, classification, measurements of magnetic parameters and magnetic separation. The jigging separation was executed by the Mineral Processing Department, and the mineralogical studies were carried out by the Geology, Mineralogy and Petrography Department, both departments being subdivisions of the Siberian Federal University. The chemical analysis of Abagas initial and prepared ore specimens was performed by the Central Technological Laboratory, EVRAZRUDA.

1. MATERIAL CONSTITUION AND MAGNETIC PROPERTIES OF ABAGAS IRON ORE

The study objects were four specimens of Abagas iron ore: three cores nos. 60061, 60073, 60115, hereinafter nos. 61, 73, 115 in the abbreviated form, drilled in the Northern wing, one bulk sample no. 1 drilled in the Southern wing of the deposit.

The core samples of the initial ore specimens– 0.07 mm in size and products of their wet separation in different magnetic fields are taken for the mineralogical analysis.

The ore specimens are separated into two groups by the content of basic minerals. Three samples nos. 61, 115 and 1 can be classified as a hematite-magnetite ore. The magnetite-muscovite sulfide-rich ore sample no. 73 should be studied individually.

According to the mineralogical analysis, the mineral composition of the study samples is: magnetite/hematite content is 56%/4.7% for sample no. 73, 30%/4.5% for sample no. 115, 25%/ 21.5% for sample no. 61, and 22%/ 6% for sample no. 1. The goethite content is low, within 0.5-2%, and pyrite amounts to 14% in sample no. 73.

Sample no. 1 is distinguished for 23% content of rather rare mineral ilvaite-iron-calcium silicate with ~41% of feebly magnetic iron. The information on this mineral is scarce. The fine intergrowth of 0.4×0.1 mm ilvaite grains with ore and barren minerals made it practically impossible to recover a monofraction of this mineral for research purposes.

The initial ore was subjected to multi-stage crushing: down to $-5+0$ mm size in a jaw crusher with screening at 10 and 5 mm meshes, then a portion of $-5+0$ mm product was fed to a roll crusher with 1 mm discharge slot and screened at 1 mm sieve. The final crushed product was of two size classes: $-5+0$ mm for dry separation and $-1+0$ mm for classification and wet separation.

To study the granulometric composition and size distribution of iron as the main valuable, each sample was classified into seven size classes from $-5+0$ mm to -0.07 mm.

Disregarding the complete chemical analysis of all the classes and mesh characteristic of $-1+0$ mm class, we should emphasize in brief that:

—The proper dependence of iron content on size class is not observed in the experimental ore samples. The values Fe_{total} in different size classes of samples nos. 73, 1, 115 differ insignificantly, for sample no. 61, it is 5% “burst” in -0.07 mm class. From the analytical data the magnetite iron content is maximum in sample no. 73 and twice less in the rest samples.

—Close sizing of $-1+0$ mm class indicated the dominating presence of coarse particles, while the content of less than 0.1 mm fine particles amounted to 15-18% in the test samples.

The specific magnetization σ_S of the two test fractions, $-1+0$ mm and -0.07 mm in size, was measured in the field $H = 800$ kA/m. Magnetic properties of ore were estimated in a vibration magnetometer. Magnetization and iron content mass values of the initial samples are given in Table 1.

The chemical analytical results are correlated relative to the specific magnetization of the test samples since the magnetite content governs specific magnetization of an ore specimen. Thus, high σ_S values for sample no. 73 are due to rather high magnetite content ~56%. This interaction can garble an actual mineral balance in the case of the complex multi-phase iron oxide composition.

The magnetic properties comply with mineralogical analysis data as well. From the mineralogical and chemical analyses and measurements of the specific saturation magnetization σ_S, we can make a conclusion, crucial for beneficiation of Abagas iron ore, that the ore samples contain two types of magnetic minerals: high-magnetic magnetite and feeble-magnetic hematite, goethite, and ilvaite.

Table 1. Chemical analysis and magnetic measurement data on Abagas iron ore samples

Sample no.	Size, mm	Content, %		σ_s, Am^2/kg
		Fe_{total}	Fe_{mag}	$H = 800$ kA/m
73	$-1+0$	51.1	40.5	63.0
	-0.07	50.2	39.0	58.0
61	$-1+0$	34.0	17.8	21.0
	-0.07	39.2	19.1	23.0
1	$-1+0$	29.9	15.2	19.0
	-0.07	29.8	15.5	22.0
115	$-1+0$	30.5	21.3	27.0
	-0.07	30.1	21.1	24.0

2. LABORATORY MAGNETIC SEPARATION TESTS

The magnetic separation was mainly accomplished in the laboratory tests of the Abagas iron ore specimens, because this process is the principal beneficiation method at the Teisk crushing and preparation plant and the Abagursk preparation-and-agglomeration plant. The magnetic separation is executed by two methods, “wet separation” in analyzer 25T and a pilot high-gradient separator based on electromagnet FL and “dry separation” in centrifugal semi-commercial separator PBSTs 63/50.

2.1. Wet Magnetic Analysis

The tests were performed on 100% fraction of – 0.07 mm class at two magnetic field intensities: $H = 80$ kA/m, close to a working magnitude of PBM separators, taking into account the high content of feebly-magnetic minerals, and $H = 480$ kA/m.

The average iron content in final products and the separation parameters obtained in three tests are summarized in Table 2.

The lack of the field dependence of the magnetic fraction yield γ_m draws attention as in the field conditions we have $H = 80$ kA/m and all the magnetite is recovered into the magnetic product, what is declared by high values of magnetite iron recovery and the mineralogical analysis.

The magnetic product yield is maximum or ~65% for sample no. 73, twofold less, 25-33%, for “mixed” ores nos. 61, 1, 115, and Fe_{total} is from 82 to 47-68%. The high grade concentrate contains 62-64% Fe_{total}, iron loss in tailings ranges from high (29%) to acceptable (14%). Sample no. 73 is characterized by high sulfur content: 2.8% in the concentrate and ~15% in tailings.

The values of the specific saturation magnetization σ_S for initial specimens and – 0.07 mm final fractions at $H = 80$ kA/M for all four samples in Table 2 confirm the above statement.

Table 2. Results of the wet magnetic separation of Abagas iron ore and magnetization of separation products: numerator is magnetic fraction and denominator is non-magnetic fraction

Sample no.	H, kA/m	Yield γ, %	Content, %		Recovery, %		σ_S, Am²/kg
			Fe_{total}	Fe_{mag}	Fe_{total}	Fe_{mag}	
73	80	65.6/34.4	62.7/26.4	58.6/2.2	81.9/18.1	98.5/1.5	86.0/3.25
	480	65.1/34.9	63.4/25.3	59.6/1.3	82.2/17.8	99.5/0.5	—
	Initial	100.0	50.2	39.0			58.0
61	80	28.4/71.6	64.5/29.5	61.7/1.4	46.7/53.3	91.7/8.3	83.0/1.8
	480	30.2/69.8	63,8/28.1	59.7/0.7	49.1/50.9	94.4/5.6	—
	Initial	100.0	39.2	19.1			23.0
1	80	24.5/75.5	62.7/19.3	61.6/1.0	51.5/48.5	97.4/2.6	90.0/1.6
	480	24.8/75.2	63.4/18.8	62.0/0.4	52.8/47.2	99.2/0.8	92.0/1.0
	Initial	100.0	29,8	15.5			22.0
115	80	33,1/66.9	62.2/14.0	60.9/1.3	68.4/31.6	95.5/4.5	84.0/2.0
	480	32.9/67.1	63.7/13.6	62.7/0.6	69.6/30.4	97.8/2.2	108.0/1.4
	Initial	100.0	30.1	21.1			24.0

Table 4. HGMS results: numerator is magnetic fraction and denominator is non-magnetic fraction

Sample no.	Yield γ, %	Content, %		Recovery, %	σ_S, Am^2/kg
		Fe_{total}	Fe_{mag}	Fe_{total}	
61	$\frac{32.0}{68.0}$	$\frac{51.3}{18.4}$	$\frac{4.0}{0.1}$	$\frac{55.6}{44.4}$	$\frac{3.63}{0.5}$
1	$\frac{37.0}{63.0}$	$\frac{27.8}{14.4}$	$\frac{2.9}{0.1}$	$\frac{53.3}{46.7}$	$\frac{3.6}{0.8}$
115	$\frac{32.4}{67.6}$	$\frac{20.2}{11.7}$	$\frac{4.5}{0.1}$	$\frac{46.7}{53.3}$	$\frac{1.9}{0.52}$

The laboratory polygradient separator is based on FL electromagnet, where a copper cassette with a ferrofiller (steel balls of $d = 5$ mm in our case) is placed between flat pole tips located at $d = 26$ mm. The magnetic field in the electromagnet gap is ~960 kA/m. Ore pulp portions were poured out through magnetized balls.

HGMS was used to re-clean –70 µm nonmagnetic fraction tailings of the conventional wet separation in the magnetic field $H = 80$ kA/m for samples nos. 61, 115 and 1 (Table 4).

Re-cleaning of the nonmagnetic conventional separation product of sample no. 61 produces 32% of concentrate with 51% iron content. The grade of re-cleaning products for samples nos. 1 and 115 is much lower. It is explicit because the iron content in tailings was 30% for sample no. 61, ~19% for sample no. 1, and only 14% for sample no. 115.

From the mineralogical analysis the magnetic fraction of HGMS re-cleaning of tailings of sample no. 61 contains 2-2.5 times higher hematite content than in nonmagnetic fraction and almost four times higher ilvaite content in re-cleaning of tailings of sample no.1.

In total, using HGMS, approximately 30% (of the feed mass) of the magnetic product with rather high iron content was produced from tailings of sample no. 61. In other words, the two-stage flow-sheet provided the increase in the cumulative magnetic fraction up to ~51% and the total iron recovery up to ~77%.

3. JIGGING OF ABAGAS IRON ORE

The simple economic jigging was used to process feeble magnetic iron raw materials in a series of tests. This process has been successfully used to beneficiate the complex ores in the Krivoi Rog Basin [3].

Sample no. 1 was separated into fractions: –3+0 mm and –3+0,5 mm by a laboratory diaphragm two-chamber jig machine. The test time is 5 min, water consumption is 8.4 l/min for both chambers for size –3+0 mm; 15 and 6.6 l/min for size fraction –3+0.5mm.

The yield is ~42% concentrate with iron content from 38% (fraction –3+0 mm) to 43% (fraction –3+0.5 mm), ~22% in tailings and ~52% recovery.

The mineralogical analysis of the jigging tailings showed that the tailings contain 20-22% of iron minerals: ilvaite (13-17%) and magnetite hematite (5-7%) as inclusions in barren minerals.

The treatment of the jigging concentrate of –70 µm fraction with ~38% iron in the analyzer gave the ~37% magnetic product with more than ~63% Fe_{total} content, ~24% loss and ~61% recovery.

CONCLUSIONS

The laboratory assessment of the dressability of the main hematite-magnetite Abagas ore specimens made it possible to conclude on the following.

1. Ores in samples nos. 73, 61, 1 and 115 are treated by the dry magnetic separation at separators PBSTs, –5+0 mm fraction with the yield of 39-85% concentrate at 42-54% iron content. It is obvious that a bit worse results are obtained in the treatment of the courser fraction in separators PBS.

2. The wet magnetic separation provides the yield of 24-33% concentrate from the complex ores and 65% concentrate of 62-64% iron grade from sample no. 73.

3. The researchers implemented the two-stage flowsheet of iron ore processing with the recovery of magnetite in a weak field in the first stage and the recovery of feeble magnetic minerals in the high-gradient field in the second stage, namely, the re-cleaning of non-magnetic fraction of an analyzer by the high-gradient magnetic separation of the complex hematite-magnetite ores: samples nos. 61, 1 and 115. The second stage contributes greatly to the higher cumulative iron recovery from sample no. 61. From the experimental data it is explicit that the re-cleaning of tailings is reasonable if the tailings contain at least ~ 30% iron.

4. The jigging tests on sample no. 1 gave "average" results: ~42% concentrate yield with 38-43% iron content, but the economical efficiency of the process should be taken into account.

The obtained results are helpful as the basic data in the processing profitability analysis for Abagas iron ores, that has been analyzed in the present article.

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