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MINERAL DRESSING

Magnetic Characteristics of Primary Concentrates Supplied as a Feedstock to Abagur Enrichment-Agglomeration Plant

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Abstract—The article presents basic magnetic characteristics of nine primary concentrates produced from Siberian magnetite ore and a lightly oxidized iron ore and supplied as a feedstock to Abagur enrichment-agglomeration plant. The best magnetic properties belong to the primary concentrate produced from the magnetite ore mined at Abaza, Irba and Kaz deposits; the weakest properties characterize the lightly oxidized ore from Izykh-Gol and Krasnokamensk; the magnetic characteristics are proportional to magnetite content in a primary test specimen. Considering this, the integrated processing of lightly oxidized and magnetite ore is recommended to lower magnetite loss in tailings of Abagur plant.

Key words: Primary concentrate, magnetite ore, lightly-oxidized ore, magnetic properties.

INTRODUCTION

The iron ore feedstock, supplied to Abagur enrichment-agglomeration plant, is mainly the intermediate products of the dry magnetic separation of magnetite ore, mined at Gornaya Shoria mines, the Kemerovo region, Khakasia, and the Krasnoyarsk Territory. The primary concentrates produced from Siberian ores differ in the material constitution, and firstly in the ferromagnetic component type and its content, the texture-structural attributes, among which the magnetic mineral grain size ranks as the most important one. Such a variety of material characteristics explains a wide range of magnetic parameters of primary concentrates.

It is well known that the magnetic characteristics of minerals govern the behavior of magnetic particles in the magnetic field. Thus, to design an optimal wet magnetic separation process requires knowing basic magnetic parameters of the primary intermediate ore products.

The magnetic characteristics of products, produced by the dry magnetic separation from Siberian ores were studied earlier. The most comprehensive information on five iron ore deposits; Sheregesh, Kaz, Tashtagol, Abakan, and Teya is dated 1974 in [1]. The more recent information on the magnetic parameters of Abagaz concentrates, Abakan deposit is reported in [2, 3].

In view of the urgent need in the systemized investigation into specifications of the feedstock supplied to Abagur plant, the target of the present research is to study the basic magnetic characteristics of primary concentrates, currently supplied to Abagur plant.

Classification of the primary ore materials and measurements of magnetic parameters are fulfilled by L.V. Kirensky Institute of Physics, SB RAS. The chemical analysis of primary and test ore specimens was executed by the Central Technological Laboratory, EVRAZRUDA JSC.

1. MESH ANALYSIS AND COMPOSITION OF PRIMARY ORE CONCENTRATES

1.1. Granulometric Characteristics of Study Products

Abagur enrichment-agglomeration plant, EVRAZRUDA JSC, presented nine averaged primary concentrate specimens of $-1 \div +0$ mm size from Teya, Izykh-Gol, Irbin (K42 and K45), Krasnokamensk, Kaz, Sheregesh, Tashtagol (K42), and Abakan (K45) deposits for investigation. In agreement with the Engineering department of the plant the primary test concentrates were separated into three size classes: $-1 \div +0.28$ mm, $-0.28 \div +0.07$ mm and less than 0.07 mm for mesh analysis and evaluation of the iron mineral size distribution in test specimens. The mesh analysis data are summarized in Table 1.

Table 1. Mesh characteristics of primary concentrates

Specimen	Yield, %, in size class (mm)				
	+ 1	– 1 ÷ + 0.28	– 0.28 ÷ + 0.07	– 0.07	Total
Teya	3.5	52.8	26.9	16.8	100.0
Izykh-Gol	1.3	42.5	37.7	18.5	100.0
Irba, K42	1.0	42.7	36.3	20.0	100.0
Irba, K45	1.7	42.1	33.1	23.1	100.0
Krasnokamensk	2.0	43.4	30.9	23.7	100.0
Kaz	2.5	44.5	31.0	22.0	100.0
Sheregesh	2.0	43.5	27.4	27.1	100.0
Tashtagol, K42	1.9	37.3	31.1	29.7	100.0
Abakan, K45	0.3	34.7	34.9	30.1	100.0

Table 2. Chemical analysis of primary concentrates

No.	Specimen	Size class, mm	Content, %			
			Fe_{total}	Fe_{mag}	FeO	Fe_2O_3
1	Teya	– 1 + 0.28	39.8	36.2	16.31	38.77
2		– 0.28 + 0.07	38.7	34.9	15.58	37.98
3		– 0.07	36.0	32.1	14.83	35.09
4	Izykh-Gol	– 1 + 0.28	46.6	38.3	14.33	50.71
5		– 0.28 + 0.07	50.3	42.8	14.84	55.41
6		– 0.07	41.2	30.9	10.48	47.23
7	Irba, K42	– 1 + 0.28	42.7	38.7	18.29	40.78
8		– -0.28 + 0.07	49.1	45.1	20.55	47.40
9		– 0.07	44.9	40.8	18.53	43.64
10	Irba, K45	– 1 + 0.28	45.8	41.9	19.18	44.26
11		– 0.28 + 0.07	50.4	47.1	20.50	49.30
12		– 0.07	45.0	40.9	17.82	44.60
13	Krasnokamensk	– 1+0.28	40.6	34.2	16.37	39.86
14		– 0.28 + 0.07	44.9	40.1	17.10	45.17
15		-0.07	38.9	31.9	15.15	38.85
16	Kaz	– 1 + 0.28	45.9	39.8	25.49	37.30
17		– 0.28 + 0.07	48.6	43.3	26.44	40.21
18		-0.07	47.1	42.4	26.62	37.87
19	Sheregesh	– 1 + 0.28	42.2	39.1	18.93	39.32
20		– 0.28 + 0.07	44.5	41.5	19.55	41.91
21		– 0.07	41.2	38.2	18.33	38.57
22	Tashtagol, K42	– 1 + 0.28	41.1	36.8	17.07	39.79
23		– 0.28 + 0.07	46.5	43.3	19.63	44.74
24		– 0.07	41.4	37.3	17.27	40.07
25	Abakan, K45	– 1 + 0.28	43.6	38.0	22.44	37.45
26		– 0.28 + 0.07	46.1	40.1	22.55	40.92
27		– 0.07	50.9	46.0	24.81	45.29

In agreement with the Engineering department of the plant the primary test concentrates were separated into three size classes: $-1 \div +0.28$ mm, $-0.28 \div +0.07$ mm and less than 0.07 mm for mesh analysis and evaluation of the iron mineral size distribution in test specimens. The mesh analysis data are summarized in Table 1.

From the analytical data in Table 1 the course particle content in the test specimens is comparatively higher; moreover, the course size content is higher in lightly oxidized ores-the maximum value for Teya specimen, while fine particle content is higher in magnetite ore specimens, the maximum being for Abakan primary concentrate.

1.2. Iron Content in Primary Test Specimens

Table 2 presents the chemical analysis data on three size classes of the test primary concentrates. The greatest content of Fe_{total} and Fe_{mag} in -0.07 mm class is ~51 and 46% in Abakan, ~47 and 42% in Kaz, ~45 and 41% in Irba concentrates, while the least content of the said components is 36 and 32% in Teya intermediate lightly-oxidized ore concentrates and ~39 and 32% in Krasnokamensk ore specimens, respectively.

The general relationship between variations in iron content and a particle size has not been established. The content of total and magnetite iron is solely higher in a fine size class in Abakan specimens. Alternatively, Teya intermediate product exhibits higher iron content in a course size class.

In seven products the maximum iron content is observed in $-0.28 + 0.07$ mm medium size class. The difference in iron content between "medium" and "fine" size class ranges for Fe_{total}: from 1.5% for Kaz specimen to 9.1% for Izykh-Gol specimen and for Fe_{mag}: from 0.9% for Kaz specimen to 11.9% for Izykh-Gol specimen.

According to the evidence reported in [4] iron content in Abagur first-circuit concentrate increases from 53.4% Fe_{total} and 50.7% Fe_{mag} in $-1 \div +0$ mm class up to 60.5 and 59.1%, respectively in -0.05 mm class; namely, the primary concentrates from different deposits are averaged to produce the so-termed "abakan" dependence of iron content on material size.

The results of the chemical analysis confirmed that the iron quantity in intermediate products of magnetite ore is more than 10% higher as compared to that in lightly oxidized ores.

2. MAGNETIC PARAMETERS OF PRIMARY CONCENTRATES

The basic magnetic characteristics of strong magnetic iron ores and minerals, which govern the behavior of magnetic particles in the magnetic separator field and affect the separation process, are saturation magnetization σ_s, residual magnetization σ_r, coercive force H_c [5].

The specific saturation magnetization σ_s, residual magnetization σ_r, coercive force H_c, as well as specific magnetization σ in field $H = 80$ kA/m (close to a separation field value) were calculated for two classes of primary concentrates ($-1 + 0.28$ mm and -0.07 mm).

The specific magnetic susceptibility χ, being a member of the expression for specific magnetic force f_m acting on a grain is also considered as a main parameter of the magnetic treatment.

The measurements were made at an automated vibration magnetometer in magnetic fields up to 800 kA/m. The procedure for measurement of magnetic properties with a vibration magnetometer is described in [6], and the measurement data are cumulated in Table 3.

The primary concentrates of -0.07 mm class can be classified into two groups by the specific saturation magnetization σ_s: magnetite ores and lightly oxidized ores. The specific saturation magnetization σ_s and residual magnetization σ_r for lightly oxidized ores from Teya, Izykh-Gol, and Krasnokamensk are lower than those for magnetite ores from Abakan, Irba, Kaz, etc. Values σ_s and σ_r for magnetite ores from Abakan, Irba, Kaz are close and amounts to 56-47 Am^2/kg for σ_s and within 4-3 Am^2/kg for σ_r. Dependence of σ_s and σ_r on a particle size is not traced.

Table 3. Magnetic characteristics of primary specimens

No.	Specimen	Size class	σ_s, Am^2/kg	σ_r, Am^2/kg	H_c, kA/m	$\sigma_{H = 80\ kA/m}$, Am^2/kg
1	Teya	– 1 + 0.28	38.68	2.76	4.54	25.40
2		– 0.07	39.76	5.57	4.96	26.60
3	Izykh-Gol	– 1 + 0.28	33.09	3.41	9.02	19.93
4		– 0.07	26.57	2.87	10.56	14.93
5	Irba, K42	– 1 + 0.28	53.65	2.22	2.58	37.40
6		– 0.07	48.00	2.87	4.09	32.10
7	Irba, K45	– 1 + 0.28	53.80	2.55	2.93	36.57
8		– 0.07	47.07	3.18	4.68	31.40
9	Abakan, K45	– 1 + 0.28	52.93	4.34	5.70	34.42
10		– 0.07	56.93	3.92	4.53	38.50
11	Tashtagol, K42	– 1 + 0.28	51.13	2.02	2.42	35.26
12		– 0.07	45.28	2.04	3.15	30.42
13	Sheregesh	– 1 + 0.28	42.44	1.72	2.48	29.25
14		– 0.07	48.73	2.56	3.47	33.25
15	Kaz	– 1 + 0.28	56.10	3.08	2.74	40.25
16		– 0.07	48.91	3.19	4.26	33.30
17	Krasnokamensk	– 1 + 0.28	35.41	1.73	4.06	22.20
18		– 0.07	33.81	2.42	6.02	20.45

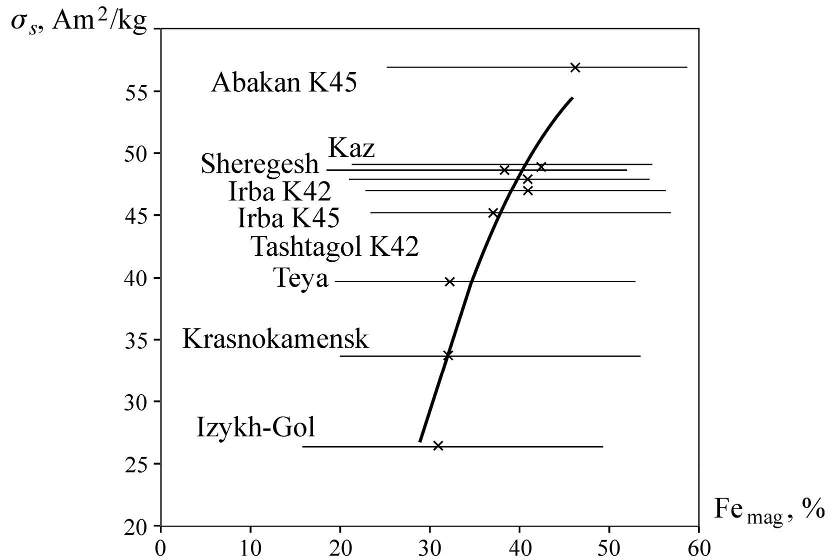

Fig. 1. Dependence of specific saturation magnetization on magnetite iron content in test specimens.

It is established the clearly defined correlation of the specific saturation magnetization values σ_s for test specimens and the magnetite iron content Fe_{mag} in them in Fig. 1: the maximum σ_s and Fe_{mag} values are found for Abaza material and the minimum ones for Izykh-Gol, that is the magnetization is practically linear proportional to magnetite content in the intermediate product.

From the magnetic measurement data saturation fields H_s are approximately 400–480 kA/m for magnetite ores and 720–800 kA/m for lightly oxidized ones, so lightly oxidized minerals are prone to be lost in enrichment tailings. Coercive force H_c is, as a rule, higher in fine classes. This is in compliance with an expected value for lightly oxidized ores. The maximum of 10.6 kA/m in value is established for Izykh-Gol ore specimens.

Table 4. Specific magnetic susceptibility of the primary test specimens in different magnetic fields

Specimen	Maximum χ		$\chi \cdot 10^{-4}$, m^3/kg in field H			
	H, kA/m	$\times 10^{-4}$, m^3/kg	H, kA/m			
			80	95	111	175
Teya	11.83	4.32	1.88	1.48	0.83	0.25
Izykh-Gol	21.04	2.26	1.28	1.07	0.70	0.35
Irba, K42	10.42	5.71	2.24	1.75	1.13	0.48
Irba, K45	11.11	5.52	2.16	1.66	1.23	0.39
Abakan, K45	12.37	6.84	2.58	2.00	1.42	0.52
Tashtagol, K42	9.68	5.29	2.10	1.67	0.97	0.34
Sheregesh	9.76	5.94	2.25	1.80	1.28	0.44
Kaz	11.03	5.93	2.19	1.75	1.07	0.43
Krasnokamensk	14.09	3.32	1.62	1.31	0.92	0.45

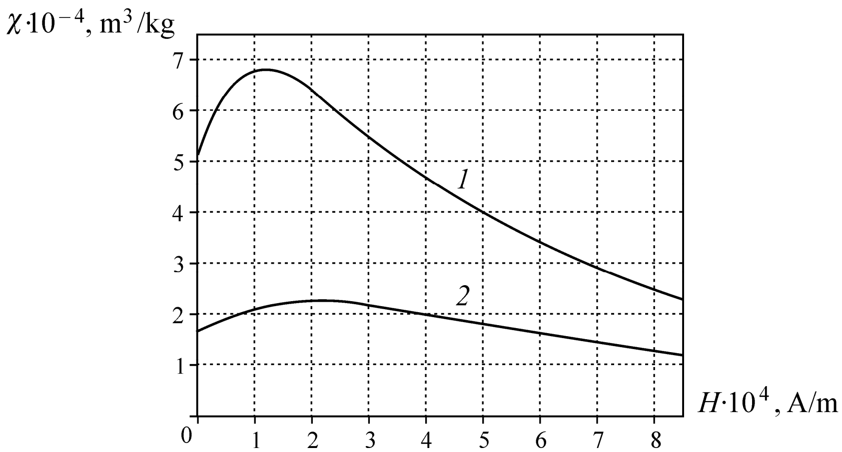

Fig. 2. Relationship of the specific magnetic susceptibility versus a field magnitude: *1*—Abakan, *2*—Izykh-Gol.

According to standard terminology the primary lightly oxidized ore concentrates can be classified as hard magnetic material; intermediate magnetite ore products are referred to soft magnetic materials in terms of H_c values, the marginal value being $H_c = 4.0$ kA/m [5].

Thus, coercive force parameter H_c for the primary concentrates supplied to Abagur plant does not make any problems in their magnetization and demagnetization in the course of the technological process. In terms of specimen hysteresis hoops the specific magnetization σ is evaluated in different fields; the specific magnetic susceptibility χ is calculated for known σ and H for -0.07 mm size class. The field relationship of the specific susceptibility χ of two "typical" magnetite and lightly oxidized specimens is presented in Fig. 2. The specific susceptibility maximums and their fields, as well as, values χ in the field range 80.0–176.0 kA/m for all nine specimens are reported in Table 4. It is obvious that the specific susceptibility of lightly oxidized ores is greatest in field $H \sim 20.8$ kA/m (Izykh-Gol), while the specific susceptibility of magnetite ores is the maximum in field $H \sim 12.0$ kA/m (Abakan) and falls sharply in stronger fields. This field relationship for the specific susceptibility of ferromagnetic minerals was described much earlier [1].

In [7] the researchers obtained similar variations in the specific susceptibility in response to a magnetic field and mastered the procedure to evaluate the specific force of the magnetic attraction of strongly magnetic particles to the separator poles. The present measurement results qualitatively comply with the data reported in [1, 7].

Specific magnetic susceptibility maximums for the primary magnetite ore concentrates is within 6.84×10^{-4} (Abakan)—5.29 m^3/kg (Tashtagol), and much less within 4.32×10^{-4} (Teya)—2.26 m^3/kg (Izykh-Gol) for intermediate lightly oxidized products. The actual difference between magnetite and lightly oxidized ores indicates the necessity in the magnetic treatment of lightly oxidized ores blended with purely magnetite ores in order to reduce the loss of magnetite containing in lightly oxidized ores in tailings.

Comparing the specific susceptibility values with magnetite iron content in specimens reveals their proportionality. As fields grow, the specific susceptibility values tend to reduce a few times, while the character of the field relationship χ for all the study specimens remains the same as it is seen in Fig. 2. The type of the field specific susceptibility relationship and its values “disclose” the optimal magnetic separation conditions specific for a material under treatment.

However, the specific magnetic force f_m except χ is also proportional to the specific magnetic force of the magnetic system $H\text{grad}H$ [5], namely, the magnetic treatment of lightly oxidized ores of low χ magnitudes implies high $H\text{grad}H$. Taking into account that the second parameter is more adjustable than the first one, it is imperative to know the specific susceptibility values and fields of their maximums.

CONCLUSIONS

1. The magnetic characteristics, governing the magnetic separation performance are studied on nine primary ore concentrates supplied as a feedstock to Abagur enrichment-agglomeration plant and the following research results are obtained.

2. The difference in magnetic characteristic values for intermediate products is great for Abakan, Irba, Kaz ores and less for Izykh-Gol and Krasnokamensk ores. The specific saturation magnetization σ_s for the primary concentrates is proportional to a magnetite iron content in an ore specimen The specific magnetic susceptibility in field H = 80 kA/m, being close to the working field of Abagur enrichment process, appears maximal for Abakan and Sheregesh ores and minimal for Izykh-Gol and Krasnokamensk ores.

3. In terms of coercive force H_c the primary concentrates can be classified into soft magnetic (magnetite ores) and hard magnetic (lightly oxidized ores) types, however, the hard magnetic ores make no technical problems in magnetization and demagnetization operations

4. The low values of magnetic parameters of intermediate lightly oxidized ore products (Teya, Izykh-Gol, Krasnokamensk ores) prove the reasonability for their wet treatment in a charge mixture with intermediate products of magnetite ores from Tashtagol, Sheregesh, Irba, Abakan, and Kaz ores to minimize magnetite loss in tailings.

5. When enriching the study ores, the demagnetization operation does not contribute to a greater loss of magnetite in tailings at the enrichment-agglomeration plant.

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