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Wet Magnetic Separation of Siberian Iron-Ore Concentrates

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Abstract—Wet separation of the primary Siberian iron-ore concentrates processed at Abagursk enrichment facility (OAO Evrazruda) is studied in the laboratory. Nine samples of concentrates (–0.07 mm class) from magnetite ore and weakly oxidized ore are subjected to wet magnetic analysis in a field of 80 kA/m. The basic magnetic characteristics of the initial concentrates and the products obtained on separation are measured. The yield of magnetic product is greatest for magnetite ores: more than 68% (Abakan), as compared to 43–45% for weakly oxidized ore. Thus, the yield of magnetic product falls with decrease in magnetite content in the initial material. The following practical recommendations are offered: (1) it is expedient to enrich weakly oxidized ore after mixing with magnetite ore, so as to reduce the loss of iron with the tailings; (2) the magnetic systems of PBM 90/250 separators must be reconstructed, with the introduction of stronger magnets.

Keywords: wet magnetic separation, concentrate, ore

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The iron-ore concentrate from Abagursk enrichment plant sent to OAO EVRAZ ZSMK is a complex product obtained from primary Siberian ore concentrates. In processing those primary concentrates, however, the part of the iron associated with ferrosilicates, sulfur, and oxidized minerals is lost with the enrichment tailings.

In view of the different conditions in which they are formed, the primary concentrates differ in composition—primarily in the content, proportions, and grain size of the ferromagnetic materials. That leads to considerable fluctuation in their magnetic characteristics. Consequently, primary concentrates from different deposits will behave differently in wet magnetic separation.

To obtain an optimal final product—the concentrate for metallurgical use—and select the correct production conditions, we need to know the wet-enrichment characteristics of all the components.

In the present work, we determine the wet-separation characteristics of the primary concentrates processed at Abagursk enrichment plant and assess the relations between the magnetic properties of the material and their behavior in wet magnetic separation.

At Abagursk enrichment plant (operated by OAO Evrazruda), samples of homogenized primary concentrates (size class –1 + 0 mm) from nine Siberian iron-ore deposits: the Teya, Izykh-Gol, and Krasnokamensk fields with weakly oxidized ore; and the Irba (K42 and K45), Kaz, Sheregesh, Tashtagol (K42), and Abakan (K45) fields with magnetite ore.

At the Institute of Physics, Siberian Branch, Russian Academy of Sciences, the initial samples are classified and screened and undergo wet magnetic separation; their magnetic properties are also measured.

A 25T analyzer is used for wet magnetic analysis of the samples in a magnetic field of 80 kA/m, which is close to the working separation field; 100% of the samples are in the –0.071 mm class.

The magnetic properties of the primary concentrates and the products of their separation (–0.071 mm class) are measured on an automated vibrational magnetometer in saturation fields $H \approx 800$ kA/m and also in a field $H = 80$ kA/m. The measurement error is no worse than 10^{-8} A m^2 for the magnetic moment; 40 A/m for the magnetic field; 0.1 mg for the mass of the initial samples; and about 5 mg for the mass of the investigated samples. The measurement procedure was described in [1].

The basic magnetic characteristics are measured: the saturation magnetization σ_s; the magnetization σ in a field $H = 80$ kA/m; the residual magnetization σ_r; and the coercive force H_c. From the measurements of σ and H for five hysteresis loops, the magnetic susceptibility χ in a field $H = 80$ kA/m is calculated.

Chemical analysis of the initial samples and investigated samples (separation products) is undertaken at the Central Technological Laboratory, OAO Evrazruda.

Table 1. Results of wet magnetic separation of the primary concentrates

Ore deposit	Yield of concentrate, %	Content, %				Extraction, %	
		Fe_{tot}	Fe_{mag}	FeO	Fe_2O_3	Fe_{tot}	Fe_{mag}
Teya	51.5/48.5	61.25/1.97	60.37/1.87	25.32/3.22	59.46/9.26	87.62/12.12	96.85/2.87
Initial	100.0	36.0	32.1	14.83	35.09	–	–
Izykh-Gol	43.5/56.5	67.33/20.60	66.24/3.83	20.18/2.98	73.86/26.13	71.86/28.25	93.25/7.00
Initial	100.0	41.2	30.9	10.48	47.23	–	–
Irba, K42	60.5/39.5	66.39/11.30	65.54/1.91	27.43/4.58	64.46/11.08	89.45/9.94	97.18/1.85
Initial	100.0	44.9	40.8	18.53	43.64	–	–
Irba, K45	60.9/39.1	66.34/11.35	65.53/2.08	26.38/4.39	65.59/11.36	89.78/9.86	97.57/1.98
Initial	100.0	45.0	40.9	17.82	44.60	–	–
Krasnoka-mensk	45.25/54.75	65.94/14.71	65.11/1.59	23.45/7.84	68.26/12.34	76.70/20.70	92.35/2.74
Initial	100.0	38.9	31.9	15.15	38.85	–	–
Kaz	64.75/35.25	64.67/15.05	63.26/1.89	34.11/11.84	54.62/8.38	88.90/11.26	96.6/1.58
Initial	100.0	47.1	42.4	26.62	37.87	–	–
Sheregesh	60.0/40.0	63.04/8.34	62.14/1.51	27.75/3.86	59.35/7.65	91.80/8.09	97.60/1.58
Initial	100.0	41.2	38.2	18.33	38.57	–	–
Tashtagol, K42	55.5/44.5	66.06/10.59	65.33/1.60	27.32/4.81	64.14/9.80	88.56/11.38	97.2/1.9
Initial	100.0	41.4	37.3	17.27	40.07	–	–
Abakan, K45	68.5/31.5	66.80/17.60	65.75/2.67	29.79/12.08	65.45/11.76	89.89/10.89	97.91/1.82
Initial	100.0	50.9	46.0	24.81	45.29	–	–

Results for magnetic/nonmagnetic fraction.

Table 1 presents the characteristics of wet magnetic separation of the primary concentrates and the results of chemical analysis of the separation products.

Overall, the results of laboratory separation of the primary concentrates—including the concentrate yield, its iron content, the iron extraction, and the iron losses with the tailings—are better for the magnetite ore than for the weakly oxidized ore. In Fig. 1, we show the yield γ_m of the magnetic separation product as a function of the iron content in the initial samples. We find that γ_m is correlated with the content of total iron Fe_{tot} and magnetite iron (Fe_{mag}).

In all the magnetic products, the iron content is high: approximately 61–67% Fe_{tot} and 60–66% Fe_{mag}; the figures are lowest for Teya weakly oxidized ore. The extraction of metal from the primary concentrates is very high: around 90% for total iron (except for weakly oxidized ore); and 92–98% for magnetite iron.

The relation between the iron content in the wet separation concentrate and its content in the initial material is not linear, since the composition and structure of the ore are different.

The loss of iron with the tailings is mainly as follows: poorly magnetite iron from weakly oxidized ore (martite and limonite); and iron sulfide from magnetite ore, whose magnetic properties are practically an order of magnitude less than for magnetite. The loss of magnetite iron is greatest for Izykh-Gol ore—around 4%. The corresponding figures for Abakan and Irba ore are 2.7% and more than 2%. The losses for the other concentrates are between 1.9 and 1.5%.

In the laboratory enrichment experiments with a field $H = 80$ kA/m, the lowest content of magnetite iron in the tailings is 1.51%; this is higher than the figures for the enrichment plant (1.0–1.1%). However, at the plant, the main equipment used for wet magnetic separation is the PBM 90/250 unit with a modernized magnetic system based on high-strength neodymium–iron–boron permanent magnets; its working field is 176 kA/m.

With increase in field strength, some of the poorly magnetic materials are also extracted in the concentrate. That reduces the losses of magnetite iron in the tailings, as confirmed by experiments on the enrichment of oxidized Abakaz ore, where the Fe_{mag} losses in the strong field $H = 480$ kA/m are around 0.4–0.7%, which is half as much as when $H = 80$ kA/m [2].

The relation between the magnetic properties and the characteristics of laboratory wet separation for primary concentrates of ore from different deposits confirms that the enrichment characteristics corresponding to the attractive magnetic force F_m are directly proportional to the magnetic susceptibility χ of the ore [3].

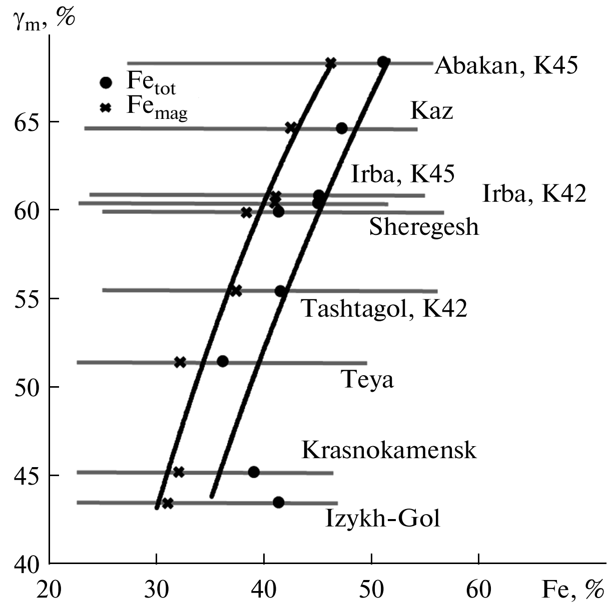

Fig. 1. Dependence of the yield of the magnetic product on the iron content in the initial samples, for different deposits.

Table 2 presents the magnetic properties of the primary concentrates. If we compare the saturation magnetization σ_s, magnetization σ, and magnetic susceptibility χ in a field $H = 80$ kA/m with the separation

Table 2. Magnetic properties of the primary concentrates/products of wet separation

Ore deposit	σ_s, A m^2/kg	σ_r, A m^2/kg	$\sigma_{H = 80\ kA/m}$, A m^2/kg	H_c, kA/m	$\chi_{H = 80\ kA/m} \times 10^{-4}$, m^3/kg
Teya	39.76/73.70	5.57/7.53	26.60/55.50	4.96/4.78	1.88
Izykh-Gol	26.57/57.65	2.87/8.63	14.93/38.00	10.56/9.66	1.28
Irba, K42	48.00/76.70	2.87/6.75	32.10/59.50	4.09/3.76	2.24
Irba, K45	47.07/73.20	3.18/7.14	31.40/56.30	4.68/4.31	2.16
Abakan, K45	56.93/81.98	3.92/8.09	38.50/61.70	4.53/4.58	2.58
Tashtagol, K42	45.28/78.62	2.04/5.84	30.42/61.70	3.15/3.09	2.10
Sheregesh	48.73/78.25	2.56/6.40	33.25/61.40	3.47/3.40	2.25
Kaz	48.91/75.48	3.19/7.01	33.30/58.80	4.26/3.94	2.19
Krasnokamensk	33.81/71.40	2.42/7.66	20.45/51.70	6.02/5.50	1.62

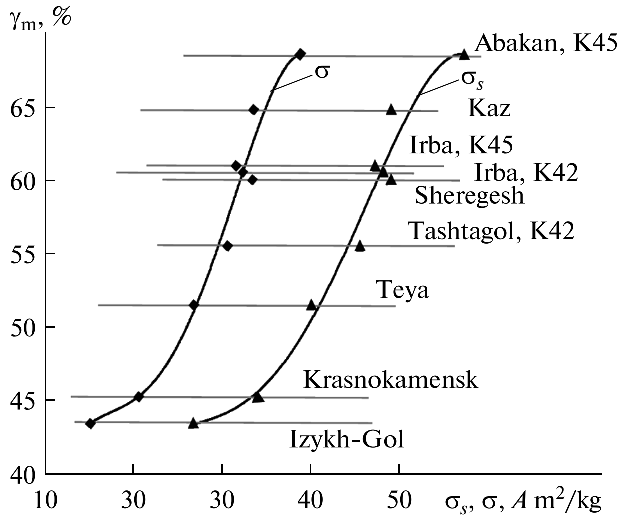

Fig. 2. Dependence of the concentrate yield on the magnetic properties for samples from different deposits.

characteristics—the yield γ_m of the magnetic separation product, the content of magnetite iron Fe_{mag}—we find that the greatest and smallest values are obtained for the same samples: Abakan and Izykh-Gol ore. As already noted, the yield of the magnetic product is greatest for primary magnetite concentrates and falls with decrease in magnetite content in the initial material.

In Fig. 2, we show the yield γ_m of the magnetic product as a function of the saturation magnetization σ_s of the primary concentrate. We also plot γ_m as a function of the magnetization σ in the separation field $H =$ 80 kA/m. We see a clear correlation.

The quality of the magnetic products obtained by laboratory wet separation is established not only by chemical analysis but also in terms of their magnetic properties. Table 2 presents the magnetic properties of the magnetic fractions obtained from the primary concentrates.

The saturation magnetization σ_s is much greater for the magnetic products (82 A m^2/kg for Abakan samples) than for the initial concentrate. The other magnetic characteristics $\sigma_{H = 80\ \mathrm{kA/m}}$ and σ_r are also significantly higher. On account of the increased magnetite content in the magnetic product, σ_s is high even for the weakly oxidized ore; it is smallest for Izykh-Gol ore (58 A m^2/kg). The increase in the magnetic characteristics is greater for the weakly oxidized ore than for the magnetite ore: the difference is more than twofold for the Izykh-Gol and Krasnokamensk samples. This increase may be estimated on the basis of Table 2.

The coercive force H_c of the magnetic product is practically unchanged for the magnetite ore but declines for the weakly oxidized ore, on account of the smaller content of poorly magnetic materials with high H_c.

Analysis of Tables 1 and 2 indicates that the degree of laboratory separation correlates with the magnetic characteristics of the products, confirming the basic principle of magnetic enrichment.

CONCLUSIONS

The yield of magnetic products is greatest for magnetite ore (more than 68% for Abakan ore) and significantly (by a third) less for weakly oxidized ore (44% for Izykh-Gol ore). The magnetic characteristics of the laboratory separation products are relatively close—σ_s = 73–82 A m^2/kg for magnetite ore and σ_s = 58–73 A m^2/kg for weakly oxidized ore—and are considerably higher than those of the initial material. The poorer laboratory separation and inferior magnetic characteristics of the weakly oxidized ores indicates that it is expedient to mix them with magnetite ore before wet enrichment, so as to reduce the loss of iron in the tailings. Magnetite particles with high magnetization become centers of flocculation for the grains of weakly oxidized ore, so that they remain in the magnetic fraction. Since the iron losses with the tailings depend on the magnetic field used for separation, we should evidently reconstruct the magnetic system in PBM 90/250 separators: specifically, the barium-ferrite magnets should be replaced with high-strength neodymium–iron–boron magnets. The results of laboratory separation may serve as a guide in developing industrial separation conditions.

REFERENCES

1. Balaev, A.D., Boyarshinov, Yu.V., Karpenko, M.M., and Khrustalev, B.P., *Prib. Tekh. Eksperim.*, 1985, vol. 3, pp. 167–168.
2. Kilin, V.I., Yakubailik, E.K., Kostenenko, L.P., and Ganzhenko, I.M., *Fiz. Tekh. Probl. Razrab. Polezn. Iskop.*, 2012, no. 2, pp. 160–166.
3. Karmazin, V.V. and Karmazin, V.I., *Magnitnye, elektricheskie i spetsial'nye metody obogashcheniya poleznykh iskopaemykh. T. 1. Vysshee gornoe obrazovanie* (Magnetic, Electrical, and Special Methods of Mineral Enrichment, Vol. 1: Mining Aspects), Moscow: Izd. MGTU, 2005.

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