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INVESTIGATION INTO MAGNETIC PROPERTIES AND PROCESSES OF SEPARATION OF ABAKAN MAGNETITES

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An analysis is performed for the magnetization, coercive force, and chemical composition of dressing products. The use of pulsed magnetic fields made it possible to increase the content of iron in concentrate and decrease simultaneously the iron losses.

Magnetic separation, concentrate, tails, permanent magnets

The “Abakan Ore Management” Joint-Stock Company delivers primary magnetite concentrate to the West-Siberian Metallurgical Integrated Works, where the concentration plant is absent; therefore, a poor concentrate is used, and the production efficiency decreases at the initial stage. Abakan grinding-and-concentrating plant produces primary magnetite concentrate $0-8$ mm in size with an average iron and sulfur content of 48 % and up to 2.5 %, respectively. By the two-stage dry separation scheme, the tails of two size classes $0-10$ and $5-20$ mm form. Currently, more than 18 mln t of tails with iron mass share of 13.7 % is accumulated in tailing dump.

The technological samples of original ore taken in Abakan plant were investigated; the ore contained 24.1 and 15.2 % of total (Fe_t) and magnetic (Fe_m) iron, 46.6 and 39.5 % of concentrate, as well as 10.9 and 2.2 % of tails, respectively, of $0-8$, $0-5$, and $0-3$ mm size classes. We determined the mineral composition of the samples and the degree of opening of the main ore minerals. Magnetite with grain dimensions from 2.5×2.5 up to 91×125 μm and nonmetalliferous minerals form close concretions containing numerous inclusions. This governs the losses of useful components and decreases the quality of concentrate. Each sample was sized into classes, the magnetic parameters (magnetization *J*, coercive force H_c) were measured, and chemical analysis was performed (Table 1).

The magnetic properties were studied on ballistic installation with the magnetic field intensity up to 160 kA/m. The values of the magnetization J presented in Table 1 were obtained at $H \approx 144$ kA/m. It is obvious that in ore and tails, the content of iron (particularly Fe_m) increases with a decrease in size of the particles; in concentrate, the inverse relationship is observed. The particles with greater magnetite grains are extracted during separation; their magnetic susceptibility χ is high. With reduction in the particle size (less than $60-70$ μm), χ decreases. The magnetic field of separator does not make it possible to extract mineral to the concentrate, and magnetite enters the tails, which ensures the high iron content in fine fractions.

The data of chemical analysis coincide with the results of measuring the magnetization *J*, since the value of *J* is governed by the amount of Fe_m. The influence of other low-magnetic minerals of iron (hematite, hydroxides, and iron sulfides) is insignificant. The coercive force H_c of ore, concentrate, and tails varies from 2.4 up to 4.4 kA/m in coarse $(2.5-3$ mm) and fine $(-0.07$ mm) classes, respectively. The lower is H_c, the more effective are the magnetization and dressing in the fields with low intensity.

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TABLE 1

Size, mm	Iron content, %						Magnetic parameters					
	Ore		Concentrate		Tails		Ore		Concentrate		Tails	
	Fe_t	Fe_m	Fe_t	Fe_m	Fe_t	Fe_m	J	H_c	J	H_c	J	H_c
0 – 8	24.7	15.4	47.2	41.1	11.4	2.8	—	—	—	—	—	—
5 – 8	24.0	14.7	49.5	42.5	11.7	1.7	—	—	—	—	—	—
0 – 5	25.0	15.5	44.3	36.8	11.2	2.6	—	—	—	—	—	—
2.5 – 3	23.8	15.3	48.6	41.5	11.1	3.3	18.0	2.4	30	2.8	4.0	2.4
1 – 2.5	22.9	14.3	48.0	40.7	10.2	1.8	14.0	—	28	—	2.5	—
0.5 – 1	23.3	12.3	45.8	36.3	11.0	2.6	13.0	3.2	25	3.6	3.5	4.0
0.2 – 0.5	24.4	14.9	38.6	29.3	13.2	4.4	13.0	—	23	—	5.0	—
0.07 – 0.2	30.5	23.5	42.9	33.2	14.8	4.0	18.6	4.0	28	3.2	5.5	3.2
– 0.07	34.6	27.6	45.1	36.4	21.1	10.7	22.4	4.4	23	3.6	5.4	4.0

The ore magnetizing is characterized by the dependences of J and the residual magnetization J_r on the magnetic field intensity H (Fig. 1). It is evident from the curves $J = f(H)$ that in the fields of $H = 16 - 64$ kA/m, J increases almost linearly, and then saturation begins. The dependence $J_r = f(H)$ is different: in the fields up to $H \approx 100$ kA/m, a flat increase in J_r is noted, and in the working field of separator, J_r reaches its maximum J_{rs}. The obtained magnetic characteristics are consistent with the results of [1].

In Table 2, the screen analysis of tails 0–10 mm in size is presented; it shows that Fe_m remained in tails is connected with size classes less than 71 μm, where the magnetic iron content is 49.5 %. Thus, the main reason of iron losses in separation is the impossibility of extracting fine grains of magnetite to the concentrate by the existing technology.

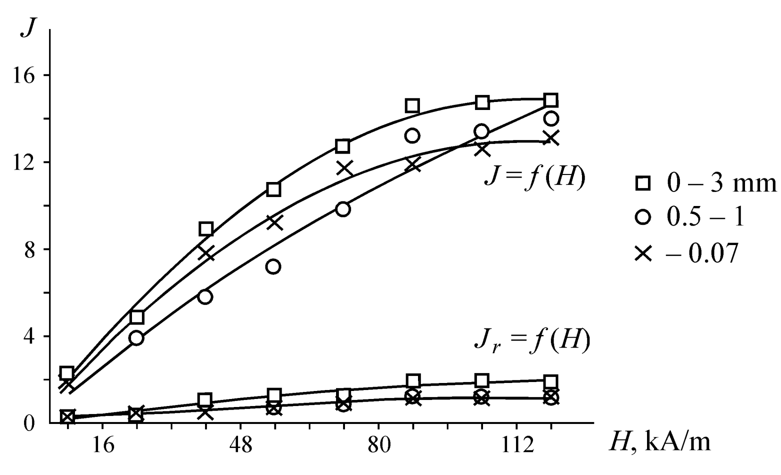

Fig. 1

TABLE 2

Size, mm	Yield γ	Content		Extraction	
		Fe_t	Fe_m	Fe_t	Fe_m
	%				
5 – 8	21.7	10.1	1.21	16.6	6.1
2.5 – 5	29.31	10.4	1.75	23.1	11.9
1.25 – 2.5	13.2	11.4	2.40	11.4	7.3
0.63 – 1.25	14.54	12.0	2.89	13.2	9.7
0.16 – 0.63	7.16	11.7	1.72	6.3	2.9
0.071 – 0.16	6.94	18.1	7.85	9.5	12.6
– 0.071	7.15	36.9	29.96	19.9	49.5
Total	100.0	13.22	4.32	100.0	100.0

In the Institute of Physics, Siberian Branch, Russian Academy of Sciences, the investigations are carried out for the improvement of concentrate quality and decrease in iron losses in dressing tails by method of dry separation in pulsed electromagnetic fields. Based on permanent magnets, the models of separators are designed for studying the Abakan samples. The experimental results are the following: from the high-sulfur intermediate magnetite product ground up to -0.074 mm with 42 % of iron and 1.9 % of sulfur, we can extract 57 % of concentrate containing more than 65 % of iron and less than 0.2 % of sulfur; from tails — approximately 20 % of concentrate, where the content of iron and sulfur is 66 and 0.1 %, respectively. On iron extraction, the similar result (65.7 %) was obtained in cleaning the primary concentrate on wet magnetic analyzer [2, 3]. These indices are obtained by the material -70 μm in size.

On the model proposed in [4], the separation of samples was realized in the changing magnetic field created by meeting fields of ferrite-barium prisms rotating on two disks. The experiments were carried out in primary concentrate and tails of various size classes (Table 3).

The cleaning of concentrate $4-8$, $2-4$ mm in size increases the content of iron by 6 %, and $1-2$ mm in size — by 13 % with up to 60 % yield of more qualitative concentrate. Close results are obtained in dressing of concentrate $0-5$ and $0-2$ mm in size. By the data of granulometry, the content of $0-5$ mm size class is 43 % in concentrate and 78 % in tails. The experiments show that from tails $0-5$ and $0-2$ mm in size, we can extract, respectively, 5 and 8 % of magnetite concentrate containing more than 50 % of iron.

In the experiments on dressing of concentrate and tails, an increase in the content of iron in product is observed when the material size decreases. A comparison of the chemical analysis data, magnetic parameters, magnetization curves, and separation indices shows that as the size of particles grows, the iron quantity and J reduce in them. The exception is coarse monomineral magnetite grains, where the magnetic moment is directly proportional to the volume of magnetite. According to [5], the magnetic force

$$F_M = \mu_0 \chi H \operatorname{grad} H .$$

TABLE 3

Product	Size, mm	Fe_t	Fe_m	γ	ΔFe_t
		%			
Primary concentrate					
Concentrate	4 – 8	54.0	46.6	59.9	5.9
Tails		38.7	22.9	40.1	—
Total		48.1	39.2	100.0	—
Concentrate	2 – 4	54.9	47.8	61.8	6.8
Tails		36.6	19.7	38.2	—
Total		48.1	39.7	100.0	—
Concentrate	1 – 2	56.1	51.6	51.0	13.6
Tails		28.2	14.9	49.0	—
Total		42.5	34.8	100.0	—
Concentrate	0 – 5	54.5	46.1	70.3	5.2
Tails		37.6	27.1	29.7	—
Total		49.3	40.6	100.0	—
Concentrate	0 – 2	54.5	48.2	70.5	9.6
Tails		22.6	13.7	29.5	—
Total		44.9	37.5	100.0	—
Tails					
Concentrate	0 – 5	50.1	46.0	5.1	37.1
Tails		11.0	3.0	94.9	—
Total		13.0	3.9	100.0	—
Concentrate	0 – 2	52.3	48.1	8.0	38.0
Tails		11.0	3.0	92.0	—
Total		14.3	6.2	100.0	—

The susceptibility χ is constant for ore of homogeneous composition, the magnetic field gradient grad$H$ is as well unaffected and governed by the design of separator. Thus, for extraction of ore particles with the least magnetic moment, it is required to increase H and grad$H$. To verify this, the experiments on determining the dependence between the yield γ of magnetic fraction of tails and the magnetic field intensity H were carried out on wet analyzer. The tail samples $0-0.07$ mm (19 and 14.3 %) and $0.5-1$ mm (12.1 and 9.9 %) in size with high and low content of iron were separated in the fields with $H = 80$ and 320 kA/m. In the intense field, the growth of γ was approximately 2 % (from 23.7 up to 25.3 %) and 4 % (from 11 up to 15.2 %) for fine size classes of high and low tails, respectively. In coarser material, γ increased from 7.1 up to 17.7 % for high and from 3.8 up to 11.3 % for low tails. Obviously, the less are the ferrimagnetic particles and magnetic interaction in tails, the more intense fields are required for extraction of the magnetic product. However, with an increase in H and γ, the quality of product decreases (from 40.4 up to 20.3 % for tails with coarse size classes).

TABLE 4

Product	γ	Fe_t	Extraction of Fe
	%		
Separator with standard magnetic system			
Concentrate	46.3	49.45	74.2
Tails	53.7	14.78	25.8
Total	100.0	30.83	100.0
Separator with modernized magnetic system			
Concentrate	46.7	49.47	75.9
Tails	53.3	13.79	24.1
Total	100.0	30.46	100.0

The investigations showed the main trends of increasing the quality of primary concentrate and decreasing the losses of iron in tails:

— modernization of separators of the second dressing stage;

— rise of rotational velocity of separator drums;

— improvement of ore preparation before separation: decrease in size of material, control of material feed to drum.

The upgrading of separators of the "Rudgormash" Plant (Voronezh) is carried out jointly with the "EMKO" Company (Moscow) — one of the producers of high-intense magnetic neodymium–iron–boron ceramics, magnetic systems, and equipment based on them. Replacement of ferrite-barium blocks with new ceramics made it possible to raise H on the drum surface from 90 up to 160 kA/m, thereby the field gradient increased by a factor of 1.5, and F_M grew. The advantage of the magnetic systems based on rare-earth metals is also their small mass and dimensions.

Table 4 presents the indices of ore dressing in two separators. A comparison of the indices established that in modernized separators, under conditions of obtaining the concentrate with the same quality, the content of iron in tails decreased by 1 %.

With growth of H the aggregate with less amount of magnetite is extracted to the magnetic product. To increase the concentrate quality, it is required to raise the drum rotation velocity so that only the particles with high magnetite content are on the drum surface. In the plant, this velocity was increased from 48 up to 82 min^{-1}. The experiments were carried out in separator equipped with a direct current engine with possibility of controlling the number of drum rotations from 0 up to 110 min^{-1}. Prior to the primary operation of separation, the process of ore preparation was improved: the coarseness was decreased from 0 – 16 up to 0 – 8 mm, the special facilities uniformly feeding the drum were installed.

In 2002, the wasteless technology cycle is introduced in operation in Abakan plant for processing the tails of separation, as well as for obtaining the iron-ore concentrates and crushed stone of the required size. All the measures taken in the plant made it possible to increase the content of iron in the primary concentrate from 43.5 up to 48 %. Later on, it is planned to improve the first stage separators for coarse size material and devices for tail cleaning.

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