ISSN 0967-0912, Steel in Translation, 2016, Vol. 46, No. 6, pp. 390–394. © Allerton Press, Inc., 2016.
Original Russian Text © E.K. Yakubailik, I.M. Ganzhenko, P.Yu. Butov, V.I. Kilin, 2016, published in Izvestiya Vysshikh Uchebnykh Zavedenii, Chernaya Metallurgiya, 2016, No. 6, pp. 397–401.

Losses of Magnetite Iron in Wet Separation

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Received December 25, 2015

Abstract—Samples of all the tailings from enrichment processes at the Abagur plant operated by OAO Evrazruda are studied. The tailings are subjected to magnetic and chemical analysis, and the magnetic characteristics of the products are measured. The mean magnetite iron content in the tailings was about 0.9% in 2013. Experiments confirm that the main magnetite losses are associated with small classes and their poor magnetic properties. The losses of magnetite are reduced as the separation field is increased. At the plant, 45% of the barium–ferrite magnetic systems in the PBM 90/250 separators have been replaced by a system based on neodymium–iron–boron composites, with increase in the field from 111 to 175 kA/m. Modernization of the magnetic systems in all the separators at the Abagur plant is recommended. In thickening, the installation of separators for regeneration of the suspensions, with a field of 190 kA/m, is recommended. After reconstruction, the losses of magnetite iron at the plant may be reduced to 0.45–0.55%.

Keywords: magnetite iron, tailings, iron losses, wet separation, high-power magnets, magnetic parameters

DOI: 10.3103/S0967091216060115

In enrichment, it is important to reduce the loss of iron with magnetite tailings in wet magnetic separation.

Primary dry concentrate from different Siberian iron-ore deposits is supplied to the Abagur enrichment plant operated by OAO Evrazruda, for two-stage enrichment to obtain secondary concentrate containing 70% of the <71 μm class (as shown in the figure).

Thus, the secondary concentrate from the Abagur plant must be produced from material with a wide range of magnetic parameters. That complicates the enrichment process.

The losses of iron in dry enrichment (the first stage) are practically zero. Attention focuses on the losses of iron in wet enrichment (the second stage), since mainly textured aggregates are isolated in dry enrichment, as against structural aggregates with very diverse magnetic properties in wet separation [1].

In the present work, we analyze the magnetite losses in wet magnetic separation and search for means of reducing them, on the basis of data gathered in recent years by specialists at the Abagur branch of OAO Evrazruda and at the Kirenskii Institute of Physics, Siberian Branch, Russian Academy of Sciences.

Historically, the magnetite iron in wastes was first determined in 1971, when a standard method was developed [2]. In the total iron content, according to reference data, the content of the magnetite iron is 3–5% [3].

In the 1980s, when mass production of the Mekhanobr PBM separator with barium-ferrite poles began [4], the losses of magnetite iron were reduced to 1.7–2.8% [5]. At present, this figure is even lower, thanks to the modernization of separators and optimization of the technology. At the Abagur plant, equipped with PBM 90/250 separators, the mean content of magnetite iron in the tailings was 0.90% in 2013. Thus, we need to consider the limit on the reduction of these losses.

The losses of magnetite with the tailings in magnetic enrichment are mainly due to the character of ferrimagnetism. With decrease in magnetite particle size below 60–70 μm, the magnetic susceptibility χ and residual magnetization σ_r are markedly reduced, while the coercive force H_c is sharply increased.

A conflict is encountered here: to ensure sufficient magnetite extraction and increase its content in the concentrate, the initial sample is finely crushed (to 70 μm), which impairs separation. The local field of the separator is unable to extract such small grains in the concentrate, and they leave with the tailings, with increase in the losses of magnetite iron.

These findings were reported for magnetite ore in [6]; similar experiments were described in [7]. Considerable increase in the content of magnetite iron in fine classes of the tailings waste at the Abagur plant was confirmed in [8]. Note also that analysis of the saturation field H_S according to magnetic measurements shows considerable spread for ore from different Siberian fields. That also impairs enrichment [9].

In practice, the losses of iron with the tailings are generally reduced by increasing the magnetic field strength and its gradient. In the last two decades, powerful neodymium–iron–boron magnets have been used for that purpose [10, 11].

As the limiting case, we consider high-gradient magnetic separation. The physical principles of separation in Russian and imported high-gradient systems and operational experience may be found in [12].

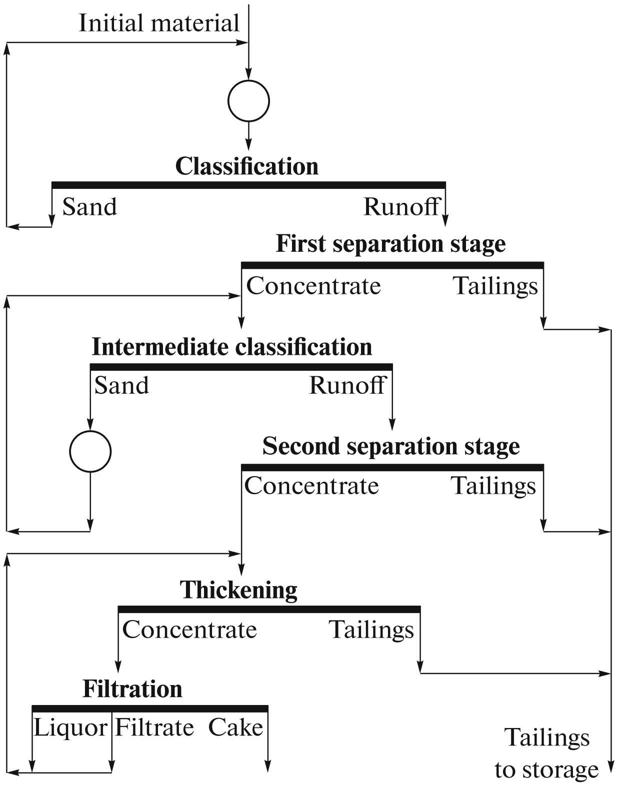
In the present work, we consider the high-gradient separation of four samples from the Abagur ore field: oxidized hematite ore (samples 60 and 62); and magnetic-separations of mixed ore from a magnetic analyzer with H = 80 kA/m (samples 61 and 1). The strength of the primary field in the gap of an electromagnet filled with steel balls (diameter 5 mm) is H = 960 kA/m. The content of magnetite iron in the tailings from high-gradient magnetic separation is reduced to 0.1% in all cases [13].

The concentrates from high-gradient magnetic separation cannot be used in metallurgical processing on account of their low iron content, but experiments show the dynamics of iron losses in high magnetic fields. Obviously, we require not only a powerful magnetic field (as in high-gradient magnetic separation) but also change in the separator design so as to increase the washing of material as a means of compensating the corresponding increase in magnetic field.

In the course of this research, 17 separators with poles made of neodymium–iron–boron composite were installed at the Abagur plant, creating a field of 175 kA/m at the drum surface in the PBM 90/250 separators. The distance between the poles is 80 mm. The other PBM 90/250 separators have barium–ferrite magnets in which the distance between the poles is 120 mm and the field strength at the drum surface is 111 kA/m. Thus, the increase in magnetic field at the new separators is compensated by increase in the pole-switching frequency and hence in the mixing frequency of the material being enriched. At the time of the tests, around 45% of the magnetic systems in the separators had been updated in the first stage, with around 45% replacement in the thickening stage, as well as 35% of the magnetic systems in the second stage. In all, when the samples were taken, about 45 PBM 90/250 separators were operating.

The results of industrial trials associated with modernizing the magnetic systems of the separators at OAO Evrazruda plants were presented in [14].

For the research on separation, mean samples of the tailing waste for all operations at the plant (summarized in the figure) were taken over two months in 2013. Table 1 presents the results of analysis for these samples.



Qualitative flowsheet of enrichment

Enrichment process.

As is evident from Table 1, the losses of magnetite iron in the large tailing classes (–1 + 0.2 mm and –0.2 + 0.071 mm) are practically the same for all the operations (0.87–1.15%). However, in the –0.071 + 0 mm class, it increases to 3.25% in thickening, as against 0.57 and 0.50% in the first and second stages of enrichment.

These findings in production conditions confirm that smaller magnetite classes have poorer magnetic properties. Whereas this is slight in the small classes during the first and second stages of enrichment, it is pronounced in thickening.

Since thickening is accompanied by filtration, with closed circulation of the filtrate (as seen in the figure), gravitational enrichment is observed in the filter bath and the filtrate, consisting of the smallest washed or seeping particles, including magnetite. These particles are not effectively mixed with second-stage concentrate before thickening (as evident in the figure) and are lost with the tailings in traditional separators.

This proposition is verified by magnetic analysis of the –0.071 + 0 mm class of tailings in all enrichment operations (Table 2).

Table 1. Granulometric and chemical composition of enrichment-plant tailings

Operation	Yield, %	Size class, mm	Yield of class, %	Iron content, %	
				Fe_{tot}	Fe_{mag}
First separation stage	22–26	–1 + 0.2	6.5	7.2	0.87
		–0.2 + 0.1	15.4	9.2	1.07
		–0.1 + 0.071	3.9	–	–
		–0.071 + 0	74.2	9.6	0.57
		Total	100.0	9.4	0.67
Second separation stage	11–13	–1 + 0.2	3.7	6.9	0.90
		–0.2 + 0.1	15.0	9.1	1.15
		–0.1 + 0.071	6.2	–	–
		–0.071 + 0	75.2	10.9	0.50
		Total	100.0	10.5	0.54
Thickening	2.5–3.5	–1 + 0.2	0.3	8.1	1.05
		–0.2 + 0.1	1.8	9.0	1.10
		–0.1 + 0.071	0.6	–	–
		–0.071 + 0	97.3	13.4	3.25
		Total	100.0	13.3	3.20
Total tailings	39.0	–	100.0	9.7	1.00

Here Fe_{tot} denotes the total iron and Fe_{mag} denotes magnetite iron.

Table 2. Magnetic analysis of the –0.071 + 0 mm class of tailings

Tailings	Content, % in					
	initial product		magnetic product		nonmagnetic product	
	Fe_{tot}	Fe_{mag}	Fe_{tot}	Fe_{mag}	Fe_{tot}	Fe_{mag}
From first stage	9.6	0.57	53.3	49.8	9.3	0.29
From second stage	10.9	0.50	41.5	37.6	10.7	0.23
From thickening	13.4	3.25	51.6	48.5	10.2	0.31

Next, we determine the magnetic properties of the separation products. The magnetic parameters of the products of magnetic analysis of the tailings are measured on an automated vibrational magnetometer in a field of 800 kA/m, with a measurement error of 10 A/m for the magnetic moment and 40 A/m for the field; the mass of the samples is measured with an error of no more than 0.1 mg. The measuring procedure on the vibrational magnetometer was outlined in [15]. Table 3 presents the magnetic parameters.

On the basis of Table 3, we calculate the magnetic susceptibility χ of the separation products from tailings in the –0.071 + 0 mm class.

As is evident from Table 4, the magnetic susceptibility χ (with field strength $H = 175$ kA/m) of magnetite in the –0.071 + 0 mm class is practically the same in all the enrichment processes. This means that the closed filtrate cycle is responsible for increased losses. To eliminate these losses, it is best to use PBR-P-90/250A separators for the regeneration of suspensions (produced by Voronezh Enrichment-Equipment Plant) with neodymium–iron–boron magnetic systems (field strength at the drum surface 190 kA/m) in the thickening stage. These separators have a deep bath and quiescent laminar internal flow; the capture angle of the magnetic system is 270°, as against 130–150° for standard equipment. The use of such equipment in thickening reduces the losses of magnetite iron in the tailings by 0.15–0.20% (according to the data in Tables 1 and 2).

In 2013, the losses of magnetite iron in the tailings were 0.90% after the installation of the new neodymium–iron–boron magnetic systems at 17 separators

Table 3. Magnetic characteristics of the initial tailings and products of magnetic analysis

Tailings	σ_s, A m^2/kg	σ_r, A m^2/kg	H_c, kA/m	σ_H, A m^2/kg, for a field of H		
				80 kA/m	111 kA/m	175 kA/m
From first stage	1.67/57.3	0.146/6.33	9.70/5.18	0.70/40.4	1.02/45.5	1.30/50.4
From second stage	0.82/43.0	0.10/4.7	12.00/5.34	0.44/29.1	0.54/33.2	0.65/37.3
From thickening	1.51/61.3	0.129/7.48	8.80/5.90	0.87/43.6	1.04/48.9	1.23/53.1

Initial sample/magnetic product of analysis.

Table 4. Magnetic susceptibility of magnetic products from tailings

Tailings	Iron		Maximum $\chi \times 10^{-4}$, m^3/kg		$\chi \times 10^{-4}$, m^3/kg, when		
	Fe$_{tot}$, %	Fe$_{mag}$, %	H, kA/m	χ	H = 80 kA/m	H = 111 kA/m	H = 175 kA/m
From first stage	53.3	49.9	9.9	0.79	0.22	0.13	0.05
From second stage	41.5	37.6	10.8	0.47	0.15	0.10	0.04
From thickening	51.6	48.5	10.8	0.83	0.21	0.13	0.05

(distributed more or less uniformly among operations), which amounts to around 45% of all the separators in operation. Before their introduction, the best figure for the magnetite losses was 1.10%. Hence, complete replacement of the barium–ferrite magnetic systems by neodymium–iron–boron systems could reduce the losses of magnetite iron in the tailings to 0.20–0.25%. Overall, such replacement of the magnetic systems and the introduction of the PBR-P-90/250A separators for the regeneration of suspensions (produced by Voronezh Enrichment-Equipment Plant) in the thickening stage permits reduction in the losses of magnetite iron in the wastes to 0.45–0.55%.

CONCLUSIONS

We have studied the wet magnetic separation of primary dry concentrates from different Siberian iron-ore deposits with magnetite-iron content 0.9–1.0% at the Abagur plant operated by OAO Evrazruda.

At the plant, 45% of the barium–ferrite magnetic systems in the PBM 9/250 separators have been replaced by a system based on neodymium–iron–boron composites, with increase in the field from 111 to 175 kA/m.

The main magnetite losses are found to be associated with the small classes (<70 μm, which have poor magnetic properties. That supplements previous research findings.

The measures adopted at the plant reduce the losses of magnetite iron in tailings by at least 0.15–0.20%. After complete reconstruction, the losses of magnetite iron at the plant may be reduced to 0.45–0.55%.

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Translated by Bernard Gilbert