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Dry magnetic separation of iron ore of the Bakchar deposit

A.M. Ezhov^{a*}, Y.B. Shvaljov^a

^a Department of Chemical Engineering, National Research Tomsk Polytechnic University, Lenin avenue, 30, Tomsk, 634050, Russia

Abstract

Currently, the development of iron ore of the Bakchar deposit (Tomsk region) is considered promising because of the extremely large reserves of iron ore. Ores of this deposit are related to the high-grade type and expected to have a magnetic concentration for iron extraction. The main task of magnetic separation is to increase the total iron content in concentrates to a value which allows its further metallurgical processing. Ferruginous ore particles have a rounded shape that facilitates a separation process. The paper considers the influence of technological parameters on the magnetic concentrate yield and recovery rate of iron-containing fractions.

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1. Introduction

At present, heavy industry and chemical industry require high-quality raw materials to meet their production targets, but directly extracted mineral ores often have too low content of a valuable component. Besides, the prepared feedstock must contain not only the necessary amount of a valuable component, but also meet many other requirements. Thus, for example, cast iron melting in a blast furnace proceeds equally the faster, the more a specific surface area of ore minerals; the greater the permeability of the layer; the less the content of lower oxides of iron; the less the amount of moisture and impurities; the less the variability in properties in the sort^{1,2}. The basic kind of metallurgical raw materials is a concentrate consisting of natural minerals in which the metal content is high enough to become possible and economically feasible to extract it³.

* Corresponding author. Artyom M. Ezhov Tel.: +7-952-805-4584.

E-mail address: ame1@tpu.ru

Iron ore considered in this paper, according to the sources^{4,5}, contains up to 43.9% total iron (Fe), presented in the form of a mixture of iron oxides and partly as goethite (FeOOH), hydrogoethite (FeOOH·nH₂O) and siderite (FeCO₃), whose magnetic properties appear only after the heat treatment that is associated with their transition to the oxide form. The iron ores of the Bakchar deposit have a low content of sulfur and arsenic impurities and a high content of phosphorus oxide (V) – up to 1.2% and vanadium oxide (V) – up to 0.15%⁶. All this makes it possible to attribute them to high-grade and promising iron ores, but in the works^{3,7} it has been stated that for heat treatment in blast furnaces ordinary concentrates should contain from 60 to 70% of iron and not more than 10% of contaminants. Heightened slag formation and low quality of melted metal are observed with a less content of the iron and impurities excess. In the ore of the Bakchar deposit a suitable content for the iron extraction is presented mainly in the form of FeO and Fe₂O₃ oxides (their contents are 1.77 ... 31.64% and 14.61 ... 56.22%, respectively)⁵.

Magnetic separation is the only effective way of separating the valuable components of iron ore from the diamagnetic inclusions so far as the extractable iron compounds have a high magnetic susceptibility (as a rule, 20–90·10⁻⁷ m³/kg⁸). In mining industry the technology of preliminary minerals concentration with self-propelled crushing-concentrating plants should be applied⁹. Nevertheless, some authors¹⁰⁻¹² propose the flotation concentration of iron ore. However, this method is prolonged and more technically difficult as it requires careful drying of iron concentrates and localized reservoir storage. The topicality of the research work consists in the large prospects of Bakchar deposit's development and the production of a high-grade iron ore for the need of heavy industry. Large amounts of the iron ore deposits (according to the preliminary estimates of over 30 billion tons) are the other not the least of the factors.

The aim of this work was to study the influence of the current strength in the electromagnet winding on the output of iron concentrate and extraction ratio of iron when ore concentrating.

2. Experimental

The process of magnetic separation of iron ore was carried out by a laboratory separator EVS-10/5. Schematic diagram of the device is shown in Fig. 1.

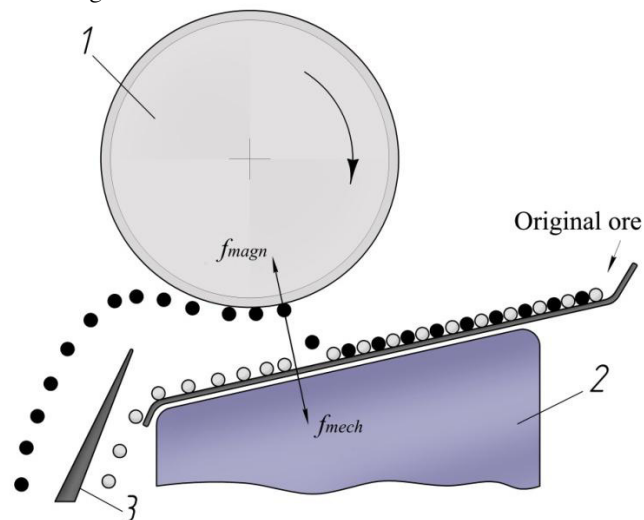


Fig. 1. Scheme of the magnetic separator EVS-10/5:

1 – drum of electromagnet; 2 – guide tray; 3 – separatory partition;

f_{magn} – magnetic force; Σf_{mech} – sum of mechanical forces (inertia, gravity).

Technological parameters of separation are listed in Table 1.

Table 1. Process parameters of magnetic separation

Parameter	Value
Current strength in electromagnet winding, A	1...8
Clearance under the drum, mm	4
Feed rate of the sample, m/sec	0.1
Size of the ore particles, mm	-0.63 +0.5

The sequence of the separation process corresponded to the method¹³ and was as follows: the sample of iron ore (60 g) was fed into the working area of the device and in the magnetic field was divided into the magnetic and non-magnetic components. After the separation cycle at a given current strength in the winding the magnetic concentrate was weighed on laboratory scales and returned to the original sample. Then the same sample was subjected to the separation at the linearly increasing current strength in the winding again (and, consequently, at increasing magnetic field intensity) when the other parameters were constant.

For chemical analysis on total iron content a part of the ore (2 g) was selected from each magnetic fraction.

After the concentration cycle magnetic afterpurification of ore was applied. For this, the initial sample of ore was subjected to separation with the current strength in the winding 4A, and then the derived concentrate was separated again at the same current strength.

The total iron content in the obtained concentrates was determined by a dichromate method of chemical analysis (GOST 22772.4–96). For this purpose the sample of iron ore concentrate (0.5 g) was dissolved in a mixture of hydrochloric acid and stannous chloride SnCl_2 . After dissolution the ferric ions Fe^{3+} were reduced to Fe^{2+} by means of a dilute solution of stannous chloride. Then, a formed system $[\text{FeCl}_2 + \text{SnCl}_4]$ was added to sulfuric acid solution. After the addition of an organic indicator (sodium diphenylamine sulfonate) the iron-containing solution was titrated with 0.1N solution of potassium dichromate till the achievement of equivalence point. Calculation of total iron was made based on the quantity of the expended dichromate. Chemical analysis was carried out for two parallel ore samples to avoid statistical and systematic errors. The statistical and graphical processing of the experimental data was produced on a computer using analysis software *MS Excel 2007* and *Adobe Photoshop CS6*.

3. Results and discussion

Photographic analysis of the magnetic concentrate, which was carried out by using a digital camera *Alcatel One Touch 6040X* and an integrated graphics-processing program *Adobe Photoshop CS6* has shown that iron oxides and hydroxides in the ore are represented predominantly in the form of oolites with a smooth surface (Fig. 2).



Fig. 2. Photo of iron concentrate particles.

Dependence of the magnetic concentrate yield on the current strength in the winding of the separator was determined based on magnetic separation (Fig. 3).

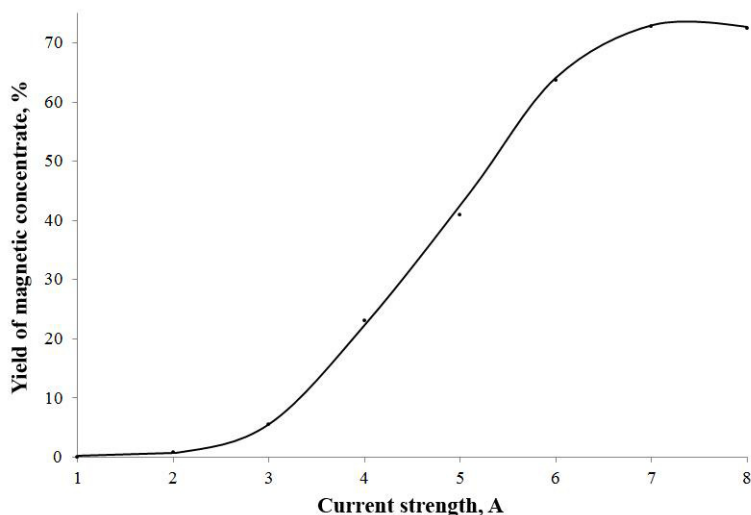


Fig. 3. Dependence of magnetic concentrate yield on current strength.

As follows from Fig. 3 separation of the magnetic concentrate begins after the amperage equal to 2A, because before that the value of the magnetic force is not enough to separate magnetic and diamagnetic particles. After 3A the concentrate yield rises sharply, but after 6A this tendency is slowing down and, after reaching a maximum at 7A, the yield of the ferrous fraction becomes invariable. This feature of the curve allows relating it to the so-called «classical» type described in methodology instructions¹³⁻¹⁵.

Concentrate yield at 7A reaches 72.8%, but this does not mean that an equivalent amount of magnetic compounds has passed from the original ore. Such an output value indicates only the transfer of diamagnetic particles in the concentrate by the magnetic field (mainly, quartz). The deviation of a substantial part of the magnetic particles in a dense stream via transverse magnetic force gives, as a result, a deviation of all stream¹⁶, which adversely affects the purity of the final magnetic fraction and compels to carry out the stage of post-treatment of the concentrate.

As noted above, values of the mass yield of the concentrate are not fundamental when determining the efficiency of concentration. It is much more important to know the total iron content in the concentrates and its dependence on the intensity of the magnetic field when separating (Fig. 4).

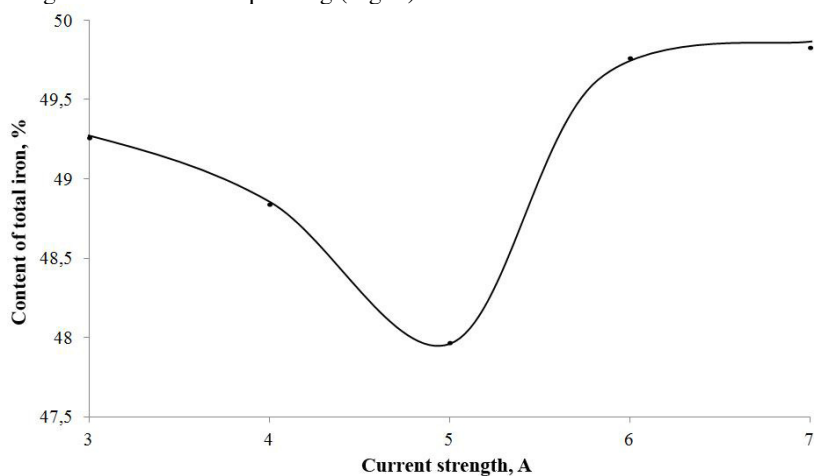


Fig. 4. Dependence of total iron content on current strength.

As noted above, a Bakchar iron ore relates to the high-grade ores containing in natural form up to 43.9% of iron. But chemical analysis indicated that before the magnetic separation that ore had already contained 46.2% of iron. Probably, this is explained by centralization of the ferruginous particles in a selected fraction ($-0.63 +0.5$ mm). A complex shape of the curve (Fig. 4) is explained by the peculiarities of the response of the ferruginous particles to a magnetic field of the separator. At relatively low 3A the most iron-containing particles are separated primarily as they have a maximum magnetic susceptibility. Further, with the increase of the current in the winding, particles of the gangue begin to move to the concentrate more and more, reducing the quality of the concentrate. Thus, at 5A the iron content in the concentrate is only 1.5% more than its content in the original ore. Iron content in the concentrate increases considerably with the further increase of the current strength because iron ore particles with a low magnetic susceptibility (ore aggregates) begin to separate in the technological process. The form of obtained dependence is confirmed according to the preliminary chemical analysis (according to GOST 22772.4–96) of the concentrates obtained under the same conditions but from a different sample of the ore to avoid a systematic error of the experimental series.

In general, the maximum change in the total iron content was 3.6% at 7A in the winding of the separator. Nevertheless, the greatest iron content (49.8%) is still below the minimum acceptable value for the industrial melting process, and it indicates the need for afterpurification of ore. Also, due to the complex feature of the curve (Fig. 4), it is necessary to establish the most acceptable value of the current in the winding of the magnet at which the greatest extraction of iron fraction is achieved at minimal energy demands. According to the results of a series of the experiments, this value of the amperage is corresponded to 4A or 6A (the iron content in the concentrates 48.8% and 49.8%, respectively).

An implementation of two-step concentration (afterpurification) allowed increasing the iron content in the concentrate up to 48.2%. It forces to upgrade the process of dry magnetic separation or carry it out in the liquid phase (so-called, wet separation).

Fig. 5 shows the iron ore after the process of magnetic separation. The concentrate (b) has a pronounced dark color due to the iron oxides in its composition while the tailings (shown by clastic rocks) are lighter and partially transparent (a).

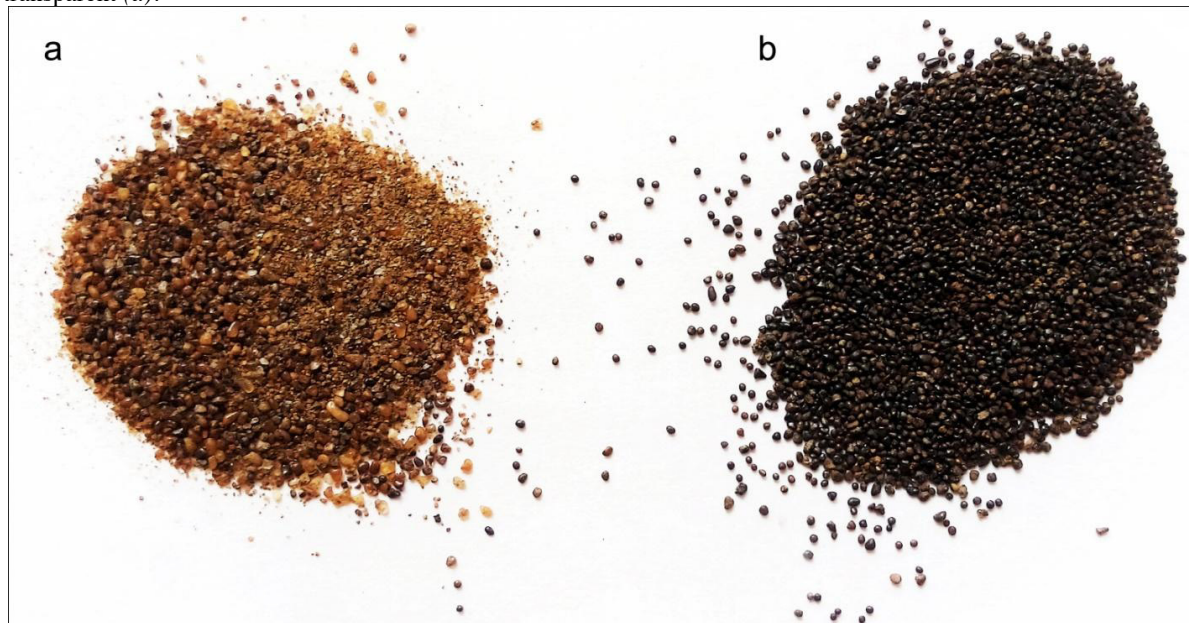


Fig. 5. Iron ore after magnetic separation:
(a) tailings; (b) iron-ore concentrate.

4. Conclusion

By means of the optical analysis it has been determined that ferruginous ore particles represent oolites – the spheroidal formations with a smooth surface. An influence of the current strength in the winding of the magnetic separator on the yield of the iron concentrate has been studied. It has been found that at the magnetic field intensity increase mass yield of the concentrate (up to 72.8%) greatly increases as well, but the main indicator for the metallurgical processing is the content of total iron. Chemical analysis has shown a significant decrease of the iron concentration in the test sample obtained at 5A, which is caused by excessive capture of diamagnetic particles (quartz and concomitant oxides). The maximum iron content in the concentrate (49.8%) is achieved at 7A in separator's winding, but it is advisable to limit the amperage at 6A to avoid excessive energy demands. The iron concentration in this case practically does not change (49.7%), but extraction ratios at 6A and 7A differ sufficiently – 68.7% and 78.6%, respectively. Thereby, the loss of the iron ore in tailings is larger at 6A, but amounts of the iron ore deposits allows avoiding a problem of losses (at least, at the beginning of deposits development).

The two-stage afterpurification of ore was carried out for achieving metallurgical features of the iron ore concentrate. It increased the iron content up to 48.2%. Thus, the maximum difference of iron content between the natural ore fraction and the concentrate was 3.6%, which is expected during the dry magnetic separation without a sorting process after initial concentration. Also, in consideration of the graphic chart complexity between the concentrate yield and the current in the winding, the most acceptable parameters of the process should be installed. Thus, the iron content in the concentrate reaches 48.8% at 4A, and at 6A – 49.9%, which allows selecting one of them as working (especially against the background of iron extraction ratio falling at 5A).

The wet magnetic separation can be applied both as an independent process and directly after dry concentration for more efficient magnetic separation. In domestic factories, the wet magnetic separation is carried out on drum separators with semicountercurrent baths, with the exception of the first stage, when direct-flow or countercurrent baths are used of the particle size of $-2 +0$ mm¹⁷.

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