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Ponomarenko [1], O.M., Brik [1], A.B., Dudchenko [1], N.O., and Evtekhov [2], V.D.

[1] Semenenko Institute of Geochemistry, Mineralogy, and Ore Formation, the NAS of Ukraine,
34, Palladina Ave., Kyiv, 03680, Ukraine,
tel. +380 44 424 0105, fax: +380 44 424 1270, abrik@voliacable.com,
nataliiadudchenko@hotmail.com
[2] Kryvyi Rih National University, MES of Ukraine, 11, XXII Partzyizdu St., Kryvyi Rih, 50027, Ukraine,
tel.: +380 56 409 0606, fax: +380 56 74 5257

FACILITY FOR SEPARATION OF FINE-DISPERSED RAW IRON ORE BY COMBINED EFFECT OF CONSTANT AND VARIABLE MAGNETIC FIELDS

An analogue of semi-industrial facility for the separation of finely dispersed raw iron ore has been created. Using the created facility, magnetic separation of raw iron ore samples from the tailing dump of Valyavko Pivnichna mine concentrator has been carried out. The samples have been separated after transformation of hematite to magnetite using carbon monoxide. It has been shown by X-ray diffraction method that the initial transformed ore was mainly represented by magnetite and quartz, and the concentrate – by magnetite. Reflexes on the diffraction patterns of tailings obtained by magnetic separation have shown that the tailings mainly consist of quartz. The iron content in the iron ore concentrate was 69.5 w/w%.

Keywords: magnetite, hematite, structure transformation, magnetic separation, and finely-dispersed iron raw material.

Ukraine is known to possess large raw iron ore reserves. However, nowadays, the reserves of high-grade iron ores and easily enriched iron ores have been almost exhausted in Ukraine. Therefore, the production of iron ore concentrates from weakly oxidized (weakly-magnetic) ferruginous quartzites, as well as from ore mining and processing waste becomes increasingly important. The Kryvyi Rih iron ore basin has huge reserves of low-grade hematite quartzites (several ten billion tons) and accumulated more than two billion ton waste of mining and processing plants (dumps and tailing dumps). The waste contains more than 30 percent of iron in the form of hematite and/or goethite. These wastes occupy large areas and pollute the environment with finely dispersed iron and silicon oxides and hydroxides.

The extraction of low-grade hematite raw materials for the production of iron ore concentrates is significantly less costly as compared with the extraction of high-grade iron ores. The waste of ore mining and processing plants can be considered as manmade deposits of raw iron ore, which do not require mine extraction, crushing and other processes. The development of efficient energy and material saving technologies for the production of iron ore concentrates from weakly oxidized iron ores and waste of mining and concentrating plants is a very important task for the preservation and further development of metallurgy in Ukraine [1].

Different types of magnetic separators used for separating the ore from the nonmetallic component, constant magnetic fields, variable magnetic fields, traveling magnetic fields, electromagnetic and vibro-magnetic fields have been described in the monograph [2]. The gen-

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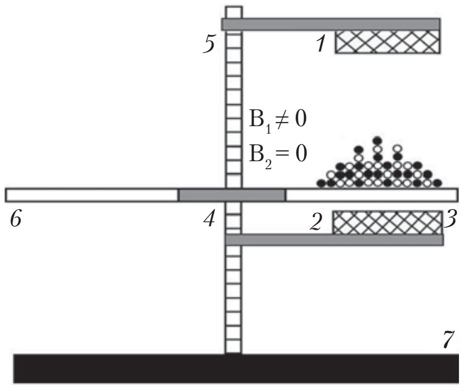

Fig. 1. Flowchart of the first stage of raw iron ore separation: *1* — electromagnet with turned off variable magnetic field; *2* — magnet generating constant magnetic field; *3* — platform for raw iron ore; *4* — system for vertical displacement of constant magnet; *5* — system for electromagnet rotation; *6* — platform for massing up concentrated iron ore; *7* — platform for facility nodes fastening

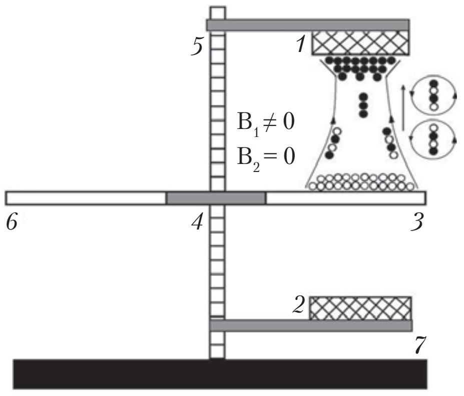

Fig. 2. Flowchart of the second stage of raw iron ore separation: *1* — electromagnet generating a variable magnetic field; *2* — magnet distanced from the ore; *3* — platform for raw iron ore; *4* — system for vertical displacement of constant magnet; *5* — system for electromagnet rotation; *6* — platform for massing up concentrated iron ore; *7* — platform for facility nodes fastening

eral disadvantage of these magnetic separators is the fact that their efficiency gets significantly lower when processing fine iron ore because of the formation of floccules under the influence of magnetic field during the separation. This leads to the necessity of iron ore desliming during which a significant amount of ore minerals

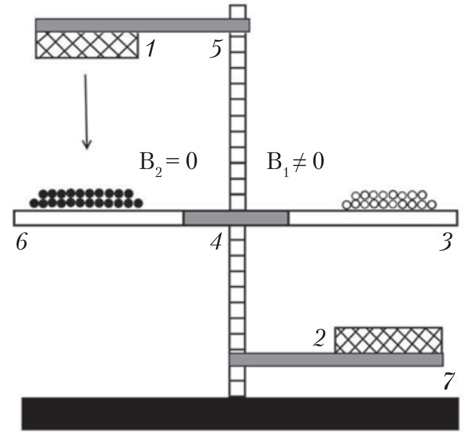

Fig. 3. Flowchart of the third stage of raw iron ore separation: *1* — idle electromagnet; *2* — magnet distanced from the ore; *3* — platform for massing up the tailings; *4* — system for vertical displacement of constant magnet; *5* — system for electromagnet rotation; *6* — platform for massing up concentrated iron ore; *7* — platform for facility nodes fastening

is lost. Since, in many cases, fine particles make up a significant part of raw iron ore, the desliming results in the formation of a large amount of waste and in environmental pollution with fine iron oxides and hydroxides.

The purpose of research is to create a facility for the separation of fine iron ore using a combined effect of constant and variable magnetic fields and to study the possibility of magnetic separation of raw iron ore samples of manmade deposits from tailings of the Valyavko *Pivnichna* mine concentrating plant after transformation of hematite into magnetite under the action of CO, using the facility designed.

MATERIALS AND METHODS

According to the X-ray diffraction analysis, the initial sample of raw iron ore to be separated contained mainly magnetite and quartz, with a particle size less than 0.05 mm. The total iron content in the raw material was about 40 wt. %. The sample was obtained by thermal treatment of manmade raw iron ore under the action of reducing gases (predominantly, CO) at a temperature of 600 °C for 60 minutes and at a reducing gas flow rate of 2.8 cm^3/sec.

The phase composition of the samples was studied by X-ray diffraction (DRON-3M). The sample saturation magnetization was determined using a magnetometer with a Hall sensor. The iron content of the samples was determined by X-ray fluorescence analysis using an ARL Optim'X WD (Switzerland) X-ray fluorescence spectrometer with wave dispersion.

RESULTS AND DISCUSSION

The facility has been designed based on the following ideas: initially, a constant magnetic field acts on a finely dispersed raw iron ore creating floccules represented by persistent formations of finely dispersed ore and nonmetallic particles. After the flocculation of raw iron ore it is subject to the action of an variable magnetic field that raises the magnetic particles upwards, with the particles moving in the air towards the maximum of variable magnetic field. While being in the air, the floccules rotate, since the polarity of variable magnetic field, along which the floccules are oriented, varies with the frequency of variable magnetic field. The floccule rapid rotation leads to their destruction due to the action of centrifugal forces and, accordingly, to the separation of ore (magnetite) and nonmetallic (quartz) particles. The floccules having been destroyed, the magnetic (ore) particles continue to move towards the maximum of variable magnetic field while the non-magnetic (nonmetallic) particles stop moving in this direction.

In order to verify the efficiency of processes related to the separation of ore (magnetic) and nonmetallic (nonmagnetic) fine particles described above, a facility has been created. It consists of the main stages schematically shown in Figs. 1—3.

The procedure for obtaining iron ore concentrate has three stages. The flowchart of the first one is given in Fig. 1. At this stage, the variable magnetic field (B_1) in raw iron ore is equal to zero ($B_1 = 0$). The constant magnetic field B_2 in raw iron ore is created using a constant magnet (*2*). This constant magnetic field creates floccules in the raw iron ore material.

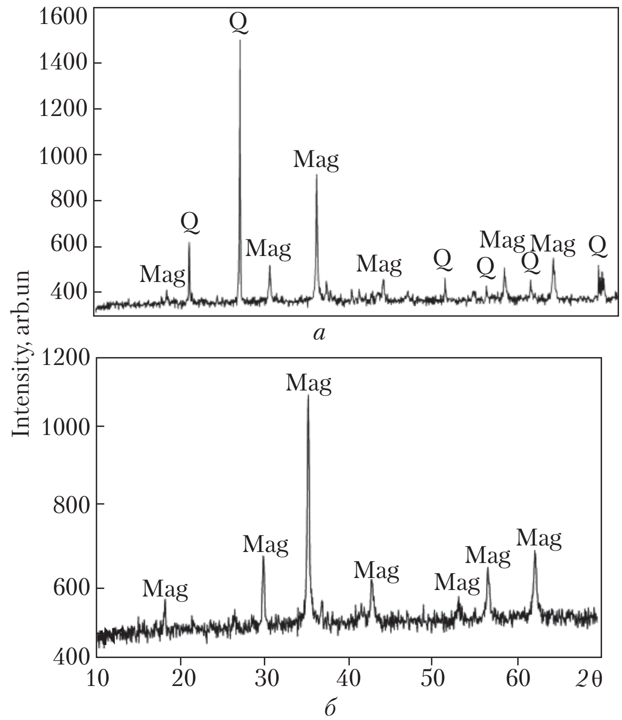

Fig. 4. Diffraction patterns of initial raw iron ore (*a*) and concentrated iron ore (*b*) obtained by magnetic separation method

At the second stage (Fig. 2), the constant magnet is distanced from the ore in such a way as the constant magnetic field in it nears zero ($B_2 \approx 0$). Then, a voltage with a frequency of 50 Hz is fed to the electromagnet. The alternating electric current running through the electromagnet coils (*1*) generates an variable magnetic field ($B_1 \neq 0$) that interacts with raw ore; B_1 is adjusted at a such level as mainly the floccules created by constant magnetic field move upwards, to the maximum of variable magnetic field. A flux of iron ore floccules in air from the platform (*3*) to the electromagnet (*1*) is shown in Fig. 2.

While shifting towards the maximum of variable magnetic field the floccules rotate as a result of changing magnetic field polarity (Fig. 2). They change their orientation with a frequency of variable magnetic field. Because of rotation, the centrifugal forces act on the floccule particles and pull them to pieces. As a result of their destruction, separate metallic (magnetic) and nonmetallic (non-magnetic) particles appear in the air. After this, almost only magnetic particles arrive at the maximum of variable magnetic field (at the electromagnet surface).

At the third stage (Fig. 3), the electromagnet (*1*) at whose surface the magnetic particles of concentrated iron ore arrive is horizontally rotated by 180° using a special system (*5*). As a result, the electromagnet is located above the platform (*6*) acting as concentrator. As soon as the electromagnet (*1*) is above the platform (*6*), the electric current turns off. As a result, the electromagnet magnetic field disappears ($B_1 = 0$), with the concentrated ore particles falling onto the platform. All three stages are repeated several times.

The procedure having been completed, the concentrated iron ore masses up on the platform *6*, while the tailings remain on the platform *3*.

The obtained concentrated iron ore and the tailings have been analyzed using the X-ray diffraction method (Fig. 4). The results show that the initial raw iron ore consists of magnetite and quartzite, whereas the concentrated iron ore obtained using the magnetic separation method consists mainly of magnetite.

Iron concentration in concentrated ore as measured using X-ray fluorescent analysis is equal approximately to 69.5 w/w %, whereas that in the tailing reaches 9 w/w %.

The saturation magnetic moment of concentrated iron ore reaches ~90 $A{\cdot}m^2/kg$, which is close to that of pure magnetite (92 $A{\cdot}m^2/kg$).

CONCLUSIONS

1. A facility for magnetic separation of finely dispersed raw iron ore has been created based on the action of constant and variable magnetic fields. A magnetic separation of manmade raw iron ore with a structure transformed by magnetizing roasting under the action of CO has been carried out.

2. The iron ore concentrate has been shown to consist mostly of magnetite. Iron concentration in concentrated ore is equal approximately to 69.5 w/w %, whereas that in the tailing reaches 9 w/w %.

3. The saturation magnetic moment of concentrated iron ore reaches ~90 $A{\cdot}m^2/kg$, which is close to that of pure magnetite (92 $A{\cdot}m^2/kg$).

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О.М. Пономаренко [1], О.Б. Брик [1],
Н.О. Дудченко [1], В.Д. Євтєхов [2]

[1] Інститут геохімії, мінералогії та рудоутворення
ім. М.П. Семененка НАН України,
пр. Академіка Палладіна, 34, Київ, 03680, Україна,
тел. +380 44 424 0105, факс +380 44 424 1270,
abrik@voliacable.com,
nataliiadudchenko@hotmail.com
[2] ДВНЗ «Криворізький національний університет»
МОН України,
вул. XXII партз'їзду, 11, Кривий Ріг,
Дніпропетровська обл., 50027, Україна,
тел. +380 56 409 0606, факс +380 56 74 5257

ПРИСТРІЙ ДЛЯ СЕПАРАЦІЇ ВИСОКОДИСПЕРСНОЇ ЗАЛІЗОРУДНОЇ СИРОВИНИ ЗА ДОПОМОГОЮ КОМБІНОВАНОГО ВПЛИВУ ПОСТІЙНИХ ТА ЗМІННИХ МАГНІТНИХ ПОЛІВ

Створено аналог напівпромислової установки для сепарації високодисперсної залізорудної сировини, за допомогою якої проведено магнітну сепарацію зразків техногенної залізорудної сировини з хвостосховища збагачувальної фабрики шахти «Північна» ім. В.А. Валявка. Сепарацію проведено після перетворень гематиту на магнетит за допомогою монооксиду вуглецю. За допомогою методу дифракції рентгенівських променів показано, що вихідна перетворена руда була представлена, переважно, магнетитом і кварцом, а концентрат – магнетитом. Рефлекси на дифрактограмі хвостів, отриманих в результаті процесів сепарації, показують, що вони складені, головним чином, кварцем. Вміст заліза в складі залізорудного концентрату становив 69,5 мас. %.

Ключові слова: магнетит, гематит, перетворення структури, магнітна сепарація, високодисперсна залізорудна сировина.

А.Н. Пономаренко [1], А.Б. Брик [1],
Н.А. Дудченко [1], В.Д. Евтехов [2]

[1] Институт геохимии, минералогии
и рудообразования им. Н.П. Семененко НАН Украины,
пр. Академика Палладина, 34, Киев, 03680, Украина,
тел. +380 44 424 0105, факс +380 44 424 1270,
abrik@voliacable.com,
nataliiadudchenko@hotmail.com
[2] ГВУЗ «Криворожский национальный университет»
МОН Украины,
ул. XXII партсъезда, 11, Кривой Рог,
Днепропетровская обл., 50027, Украина,
тел. +380 56 409 0606, факс +380 56 74 5257

УСТРОЙСТВО ДЛЯ СЕПАРАЦИИ ВЫСОКОДИСПЕРСНОГО ЖЕЛЕЗОРУДНОГО СЫРЬЯ ПРИ ПОМОЩИ КОМБИНИРОВАННОГО ВЛИЯНИЯ ПОСТОЯННЫХ И ПЕРЕМЕННЫХ МАГНИТНЫХ ПОЛЕЙ

Создан аналог полупромышленной установки для сепарации высокодисперсного сырья, с помощью которой проведена магнитная сепарация образцов техногенного железорудного сырья из хвостохранилища обогатительной фабрики шахты «Северная» им. В.А. Валявко. Сепарацию проводили после превращения гематита в магнетит с помощью монооксида углерода. С помощью метода дифракции рентгеновских лучей показано, что исходная превращенная руда была представлена, преимущественно, магнетитом и кварцем, а концентрат — магнетитом. Рефлексы на дифрактограмме хвостов, полученных в результате процессов сепарации, показывают, что они состоят, преимущественно, из кварца. Содержание железа в составе железорудного концентрата составляло 69,5 мас. %.

Ключевые слова: магнетит, гематит, преобразование структуры, магнитная сепарация, высокодисперсное железорудное сырье.