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PRODUCTION OF IRON ORE CONCENTRATES FROM OXIDISED IRON ORE TAILINGS BY TRANSFORMATION OF THEIR MAGNETIC PROPERTIES AND SUBSEQUENT MAGNETIC SEPARATION

Technological parameters of concentrated ores obtained using the developed approaches and the conventional methods of beneficiation have been determined. The parameters of concentrated ores obtained by the proposed method have been showed to be higher than that of those obtained by the conventional methods as iron concentration in the concentrated ores is 70.6 and 65.42%, respectively, with iron loss in the tailings being 2.9 and 22.02%, respectively.

Keywords: magnetite, hematite, structural transformation, and magnetic separation.

The analysis of situation in various mining corporations of Kryvyi Rih has showed that the conventional techniques for beneficiating oxidized ferruginous quartzite, for the most part, are ineffective. This constrains the widespread use of oxidized iron quartzite as raw mineral for the production of concentrated ores. The lack of efficiency of techniques for processing rebellious iron ore leads to the buildup of a large number of dumps and tailings (billion tons), contamination of large areas with fine iron hydroxides and oxides and impairs quality and competitiveness of manufactured concentrated ores.

The foreign practice of preparing poor oxidized, mixed (nano-, micro- and macro-size) and rich iron ores for beneficiation, primarily, the grinding (wet and dry) method is used with the mills operating in closed loop cycle with vibrating screens. As a result of beneficiation of initially poor oxidized and mixed ores one can get hematite concentrated ores with a mass content of iron 65–66% and that of silica 5.6%. In some cases, a fairly high extraction of iron into concentrated ores (76–86%) can be achieved [1].

In [2], the author notes that Ukraine has considerable deposits of oxidized iron ores. Only those of Kryvbass are estimated at 5 billion tons. The ores have a high iron and a low sulfur content. For a long time, many leading research institutions and researchers have been engaged in creating techniques for beneficiation of oxidized ores. Their accomplishments have been used in the feasibility study for Kryvyi Rih oxidized ores mining and beneficiation works (KOOMBW). The KOOMBW process chart for the treatment of oxidized iron ores foresees the production of magnetic concentrate with a mass iron content of 61% [3]. However, this quality of iron ore concentrate does not meet the requirements of modern steel industry. All these factors lead to the expediency of developing new, more advanced and efficient technologies and techniques for processing oxidized iron ores. The beneficiation of oxidized

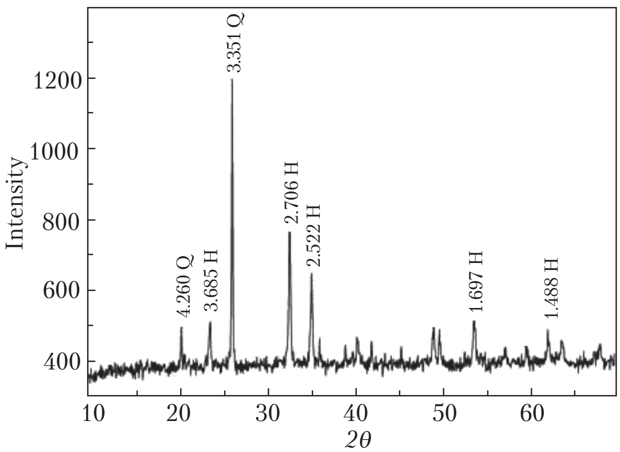

Fig. 1. Diffraction pattern of the sample after structural transformation (Q — quartz, H — magnetite)

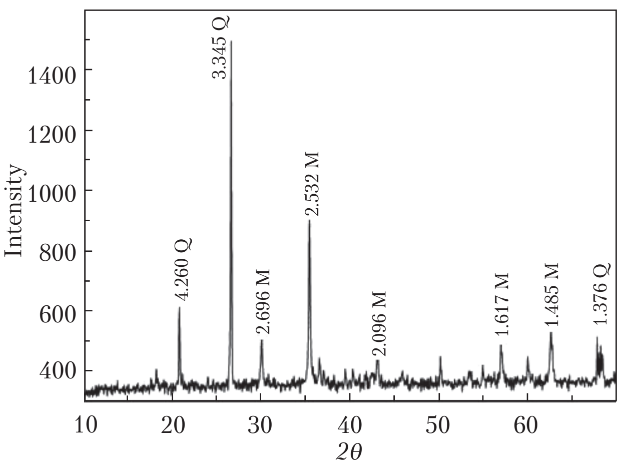

Fig. 2. Diffraction pattern of the sample after structural transformation (Q — quartz, M — magnetite)

iron ores using rotary separators has been studied at the KOOMBW. It has confirmed that rotary separators can extract 80–82% iron minerals to concentrated ore, which is 8–10% higher than the design capacity of KOOMBW. Further flotation of raw concentrate can increase iron mass content in concentrated ore up to 66%, which significantly exceeds the design capacity [4].

Having analyzed the recent experience in beneficiating oxidized iron ores based on previous studies and KOOMBW research and test results, proposals were developed to revise design on the basis of the technology for magnetic flotation beneficiation of oxidized ferruginous quartzite using cationic reverse flotation [5]. This implies the transition from the magnetic beneficiation to the 3-phasic magnetic flotation beneficiation with additional grinding of magnetic product at the second stage of beneficiation and further reverse cationic flotation. The proposed scheme provides for magnetic beneficiation of primary ore, which enables to get an up to 60% iron content in concentrated ore, and flotation to reach an iron content of 66.5% in the concentrate. Proceeding from the above said, one can conclude that the use of selective flocculation with desliming is an alternative and promising option in the development of iron ore slime beneficiation, which enables to reduce the loss of nanoscale iron minerals in the tailings and to increase its extraction to the concentrate. However, this process is subject to strict requirements for the selective flocculation operations being very sensitive.

The use of pre-beneficiation [6] resulted in stabilized quality of initial raw material to be processed for deep beneficiation using the magnetic and magneto-flotation schemes. The mass content of iron in the initial raw material increases by 3.7% due to a

Table 1

Fractions Studied and Their Size

No.	Fraction	Size, mm
1	T1	Initial sample with particles of size varying within wide range
2	T1–01	< 0.05
3	T1–03	$0.063 < d < 0.071$
4	T1–06	$0.1 < d < 0.25$

Table 2

Iron and Silica Content in the Samples and Saturation Magnetization Ms after Structural Transformation

No.	Sample code	Fe, wt %	Si, wt %	M_s, A·m²/kg
1	T1	42.7	11.9	52
2	T1–01	40.5	13.9	59
3	T1–03	52.7	7.56	62
4	T1–06	25.9	20.99	24

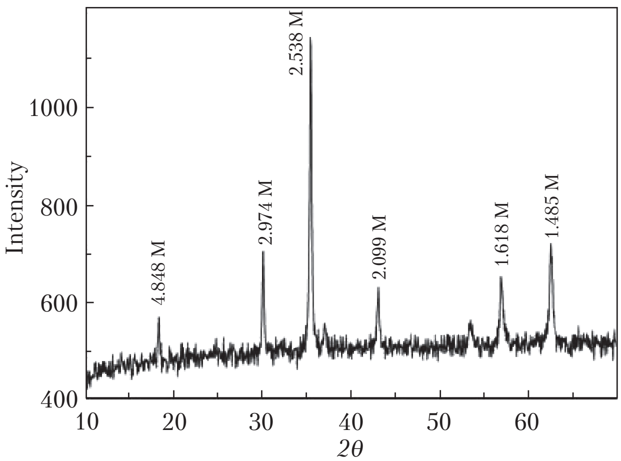

Fig. 3. Diffraction pattern of strongly magnetic concentrate obtained from T1 sample (M — magnetite)

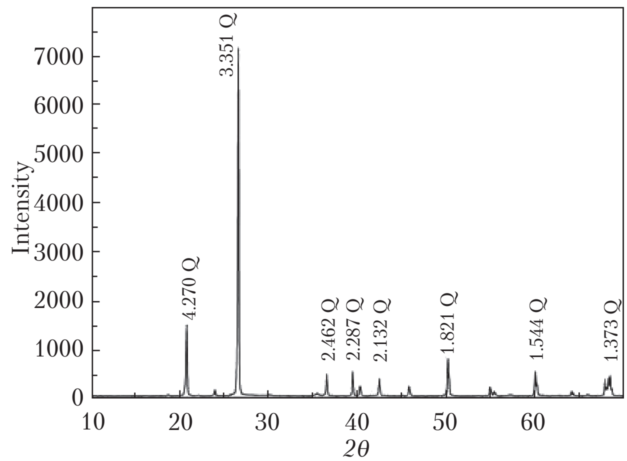

Fig. 4. Diffraction pattern of weakly magnetic tailing obtained from T1 sample (Q — quartz)

cutoff of 12.9% final tailings with iron mass content of 13.8%. Due to improved scheme of magneto-flotation beneficiation the (total) iron mass content in the flotation concentrate reaches 66.0% (pre-beneficiation) and 65.3% in the raw mix. The extraction of total iron into the flotation concentrate comes to 81.0 and 67.3%, respectively [7, 8].

In [9], engineering solutions have been proposed for ensuring highly effective beneficiation of oxidized ferruginous quartzite from Kryvbas deposits. These solutions underlie the schematic diagram for processing raw iron ore with preliminary desliming of dispersed particles. The studies have showed that desliming of milled ore before beneficiation materially improves (by up to 5–8%) the quality of magnetic product and reduces the loss of total iron in the nonmagnetic product. As a result of desliming of milled ore, magnetic susceptibility of ore grains grows, while that of nonmetallic grains decreases. The use of recommended technique enables reducing contamination of beneficiated products and raising effectiveness of beneficiation from 44.8 to 47.9%.

Since the conventional approaches to addressing the problems of concentrates iron ore production from rebellious raw ores mostly have exhausted their potential, in order to raise the effectiveness of mining and concentrating works and to enhance the competitive ability of final products it is necessary to design new technologies based on innovative framework.

Approaches used in this research for designing new technologies and equipment for producing concentrated ore are based on transformation of weakly magnetic minerals such as hematite Fe_2O_3 and goethite FeO(OH) into the strongly magnetic Fe_3O_4 using various techniques and further separation of metallic and nonmetallic minerals.

The research is aimed at studying the changes in magnetic properties and phase composition of the samples from beneficiation waste of iron ores from Valiavka *Pivnichna* Mine tailing dump in gaseous environment and at producing the concentrated ore from the obtained samples using the magnetic separation method.

MATERIALS AND METHODS OF RESEARCH

The tests were made using samples from Valiavka *Pivnichna* Mine tailing dump. The mineral composition was as follows: magnetite (1.5%); hematite, martite, micaceous hematite (52.5%); ion hydroxides (9.4%); silicates (1.3%); carbonates (0.5%); apatite (0.1%); quartz (33.8%); others (0.9%).

The initial sample was divided into fraction by size and the fractions to be studies were selected (Table 1).

To study the structural and magnetic transformations the samples were annealed in reducing gases (mainly, CO), at 600 °C, during 60 min, with the reducing gases flowing at a rate of 2.8 cm^3/s.

Saturation magnetization of the samples before and after the transformation were measured using a device for express magnetization measurements for ores and magnetic materials [10]. The phase mineral composition and structural transformations of the sample were studied by the X-ray diffraction method (DRON-3M). The element composition was studies by X-ray fluorescent analysis (X-ray fluorescent spectrometer with wave dispersion ARL Optim'X WD).

RESULTS AND DISCUSSION

The phase composition of initial fractions has been studied using the X-ray diffraction method and established to consist of mostly quartz and hematite (typical XRD pattern of sample is given on Fig. 1). Saturation magnetization of the samples before transformations was ~1 $A{\cdot}m^2/kg$. Iron and silica content in the samples is given in Table 2. Magnetization of the transformed samples grew significantly (Table 2).

Maximum saturation magnetization was reported for the T1–03 sample having maximum content of iron and minimum content of silica.

According to data obtained by the XRD method, the reflections typical for hematite disappeared in the samples after transformation in gaseous environment, while those typical for magnetite appeared (Fig. 2).

The transformed samples underwent magnetic separation. As a result, from each sample, two samples were obtained: *the strongly magnetic concentrated ore* and *the weakly magnetic tailing*. The phase composition of concentrates and tailings was studied by XRD method. The concentrate has been established to consist mainly of magnetite (Fig. 3), whereas the tailing largely contains quartz (Fig. 4).

The element composition of the samples studied after structural transformation and magnetic separation is given in Table 3.

The XRD and XR spectroscopy data have showed that after magnetic separation the concentrated ore contains mainly magnetite, with quartz remaining in the tailing. Saturation magne-

Table 3

Iron and Silica Content in the Samples after Magnetic Separation

Sample code	Type of sample	Fe, wt %	Si, wt %
T1	Concentrated ore	70.0	–
	Tailing	11.3	38.3
T1–01	Concentrated ore	70.6	–
	Tailing	2.9	44.4
T1–03	Concentrated ore	71.1	–
	Tailing	13.9	36.9
T1–06	Concentrated ore	69.0	–
	Tailing	11.3	37.7

Table 4

Technological Parameters Obtained for Different Beneficiation Techniques

Beneficiation technique	Technological parameters				
	α, wt. %	Concentrated ores		Tailings	
		β, wt. %	$\gamma_к$, %	θ, wt. %	$\gamma_х$, %
Intensive magnetic separator	46.5	57.93	63.4	26.7	36.6
Concentrating table	46.5	65.42	56.4	22.02	43.6
Phase transformation in gaseous environment and magnetic separation	40.5	70.6	55.5	2.9	44.5

Note: α is iron concentration in ore, β is iron concentration in concentrated ore, $\gamma_к$ is yield of concentrated iron ore, θ is iron concentration in tail, $\gamma_х$ is tail yield.

tization for all concentrated ore samples obtained amounts to ~90 A·m^2/kg.

Having obtained the preliminary data, the technological parameters of the sample studied were compared with the conventional techniques for iron ore beneficiation (the intensive magnetic separator and the concentrating table) [11]. The technological parameters are showed in Table 4.

The iron density in the concentrated ore obtained by phase transformation with further magnetic separation has been showed to be higher than that in the samples received by the conventional techniques (70.6 and 65.42%, respectively), with iron loss in the tailings making up 2.9% only, which is much lesser as compared with the conventional methods (22.02%).

CONCLUSIONS

1. A technique for obtaining concentrated iron ores based on transformation of magnetic properties of beneficiation wastes with further magnetic separation has been designed.

2. The XRD method study has showed that hematite transforms into magnetite. Saturation magnetization of all transformed samples increases drastically (~50 times) as compared with the initial samples. This makes them effective if furtherly subjected to magnetic separation in order to obtain concentrated iron ores.

3. The transformed samples have been magnetically separated and showed to have an iron content of ~70% in the concentrated ore, with saturation magnetization of concentrated ore reaching ~90 A·m^2/kg that is close to that of pure magnetite (92 A·m^2/kg).

4. The technological parameters of the concentrated ores and the tailings obtained by phase transformation with further magnetic separation and those obtained by the conventional beneficiation methods have been calculated. Iron concentration in the concentrated ore obtained by the transformation method has been established to be higher than that of the samples beneficiated in conventional ways.

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СТВОРЕННЯ КОНЦЕНТРАТІВ З ВІДХОДІВ ЗБАГАЧЕННЯ ОКИСЛЕНИХ ЗАЛІЗНИХ РУД З ВИКОРИСТАННЯМ ПЕРЕТВОРЕННЯ ЇХ МАГНІТНИХ ХАРАКТЕРИСТИК ТА ПОДАЛЬШОЇ МАГНІТНОЇ СЕПАРАЦІЇ

Визначено технологічні показники концентратів, що були отримані за розробленими підходами збагачення, а також за традиційними методами. Показано, що характеристики концентратів, отриманих за допомогою розроблених підходів, більш високі, ніж отриманих за допомогою традиційних методів, при цьому концентрація заліза в концентраті складала 70,6 та 65,42 % відповідно, а втрати заліза у хвостах 2,9 та 22,02 % відповідно.

Ключові слова: магнетит, гематит, перетворення структури, магнітна сепарація.

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СОЗДАНИЕ КОНЦЕНТРАТОВ ИЗ ОТХОДОВ ОБОГАЩЕНИЯ ОКИСЛЕННЫХ ЖЕЛЕЗНЫХ РУД С ИСПОЛЬЗОВАНИЕМ ПРЕВРАЩЕНИЯ ИХ МАГНИТНЫХ ХАРАКТЕРИСТИК С ПОСЛЕДУЮЩЕЙ МАГНИТНОЙ СЕПАРАЦИЕЙ

Определены технологические показатели концентратов, полученных с помощью разработанных методов обогащения, а также по традиционным методам. Показано, что характеристики концентратов, полученных с помощью разработанных подходов, выше, чем полученных с помощью традиционных подходов, при этом концентрация железа в концентрате составляла 70,6 и 65,42 % соответственно, а потери железа в хвостах 2,9 и 22,02 % соответственно.

Ключевые слова: магнетит, гематит, преобразование структуры, магнитная сепарация.

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