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Research of Magnetizing Roasting of Iron Ore Before Beneficiation and Dephosphorizing

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Abstract

There are quite a lot of iron ore deposits in the world with increased (0.75%) phosphorus content, which is an obstacle to their involving in production. Research of removal of detrimental impurities from such iron ores has a great prospect. On the experimental base of OJSC VNIIMT, it was studied dephosphorizing technology at which after preliminary magnetizing roasting and subsequent dephosphorization of iron ore with aqueous solution of sulfuric acid the least residual phosphorus content in concentrate was observed. Research of influence of temperature and duration of magnetizing roasting on iron content and residual phosphorus content in dephosphorized concentrate was studied. The influence of specific consumption of solid reductant (brown coal) on the quality of magnetite concentrate was also studied. Based on the results of the experiment, the optimal technological parameters of magnetizing roasting of iron ore before beneficiation and subsequent dephosphorization were selected.

Keywords: magnetizing roasting, beneficiation, dephosphorizing, research, rotary furnace, optimal process parameters, iron content, residual phosphorus content

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1. Introduction

The Algerian People's Democratic Republic is one of Africa's largest countries by mineral reserves. By iron ore reserves, this country is in the second place in Africa. In the southern province Tinduf the largest in Algeria Devonian sediment deposits of oolitic iron ore are discovered – Gara Djebilet, the total reserve of which is more than 2 billion tons, with content 52.1% Fe_{gen}, 12.1% FeO, 0.75% P and 6.29 weight loss on ignition. Ore mining is carried out in an open pit way, which provides for cheaper field development. But at the same time there is a problem of difficulties in ore beneficiation and complexity of their complex use due to high phosphorus content (up to 0.75–1.0%) [1–6]. The

Algerian company Feraal Spa intends to develop this prospective deposit. In this regard, it is relevant to carry out laboratory research to determine and test effective process of Algerian iron ore processing with obtaining maximum possible beneficiation of raw materials on iron content by high-temperature magnetizing roasting and maximum possible reduction of phosphorus content in the final product after the stage of sulfuric acid leaching.

2. Objectives

To achieve the objective of this research, the following tasks shall be completed.

1. To develop technique and equipment for carrying out laboratory experiment under various conditions of high-temperature magnetizing roasting of Algerian iron ore.

2. Based on the results of the experiment, to choose optimal process parameters of iron ore magnetizing roasting before beneficiation and subsequent dephosphorizing.

3. Laboratory Research and Analysis of Results

Research of technology of high-temperature magnetizing roasting of iron ore was carried out on the experimental basis of OJSC VNIIMT using laboratory roasting plant. The general view of the plant is shown in Figure 1.

To determine optimal parameters of magnetizing roasting of Algerian iron ore raw materials such temperature of calcination was selected in experimental way in which at the subsequent process stages, after magnetic separation and dephosphorizing, the residual content of phosphorus in the concentrate was the smallest, and iron content – the largest. Thus, the high-temperature magnetizing roasting of iron ore was carried out according to the following temperature mode:

1. heating of the material to the set temperature at the same speed in each experiment;

2. exposure within the specified time at the given temperature;

3. concentrate cooling to room temperature for subsequent process without oxygen access to prevent secondary oxidation.

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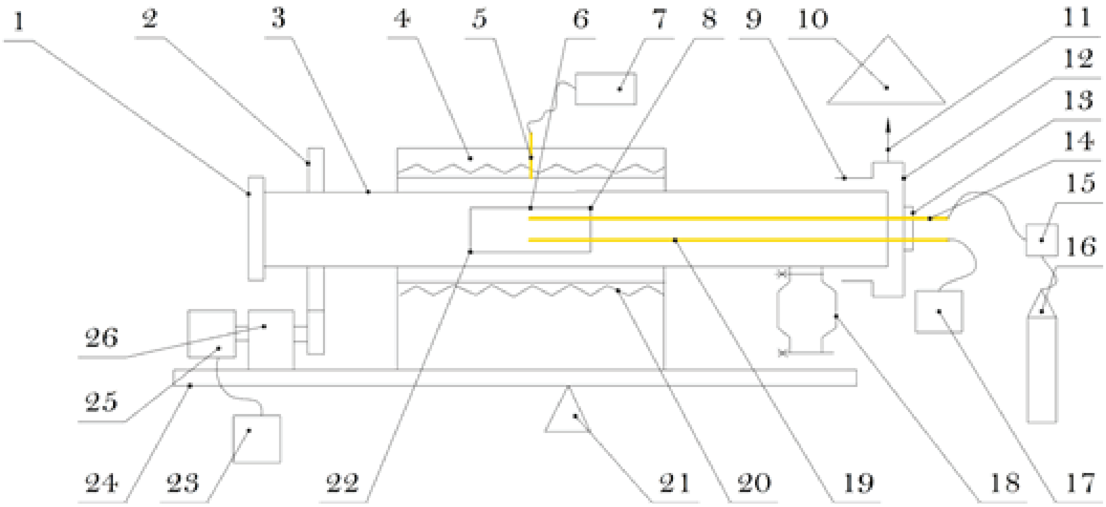

Figure 1: Diagram of laboratory rotary kiln: 1 – cover; 2 – gear; 3 – pipe; 4 – silit furnace; 5 – thermocouple; 6 – glass reactor; 7 – temperature control unit; 8 – glass reactor open end; 9 – rubber seal; 10 – extractor; 11 – gas outlet nozzle; 12 – loading and unloading head; 13 – cover; 14 – gas supply pipe; 15 – gas flow meter; 16 – inert gas tank; 17 – potentiometer; 18 – refrigerator;19 – thermocouple; 20 – silicone carbonate heaters; 21 – support; 22 – reaction glass closed end; 23 – pipe rotation control unit; 24 – rotary plate; 25 – motor; 26 – reducer.

In the first series of experiments, the search for optimal temperature of iron ore roasting was carried out, in which the residual content of phosphorus in the concentrate after leaching would be of the smallest value. Magnetizing roasting of ore was carried out at different temperatures in the range from 750°C to 1000° C. After high-temperature processing in the laboratory furnace, iron ore was milled to a size of –0.071 mm and dephosphorized with diluted aqueous solution of sulfuric acid. The time of magnetizing roasting equal to 120 minutes was taken with plenty to spare to avoid probable error in the final result. Dephosphorization was carried out in same conditions for each experiment. At a temperature of 1000°C (experiment 5) traces of sintering of ore particles were observed. This roasting mode is difficult to implement on an industrial scale.

Results of laboratory studies are given in Table 1.

As can be seen from Table 1 at roasting temperature of 900°C (experiment 3) the best result is observed in dephosphorized concentrate, in which content of iron is equal to 65.3%, and the content of residual phosphorus is 0.16%. In experiments 1, 2, 4 at roasting temperatures of 750, 850 and 950 °C, respectively, the residual content of phosphorus is higher than at 900°C (experiment 3), at roasting temperature of 950°C (experiment 4) signs of sintering of material particles are already showing. In accordance with the results of magnetizing roasting experiments, 900°C is the optimal temperature.

TABLE 1: Influence of temperature of magnetizing roasting on phosphorus and iron content in dephosphorized concentrate.

No.	Roasting	Magnetite concentrate			Dephosphorization	Dephosphorized concentrate	
		Fineness, mm	Content, %			Content, %	
			Fe	P		Fe	P
1	t_{roas} = 750°C, τ_{roas} = 120″	−0.071	63.1	0.50	S:L = 1:2, C H_2SO_4= 20 r/100 g T, τ_{deph} = 120″, t_{sol}= 65°C	63.1	0.24
2	t_{roas} = 850°C, τ_{roas} = 120″	−0.071	63.6	0.56	S:L = 1:2, C H_2SO_4= 20 r/100 g T, τ_{deph} = 120″, t_{sol} = 65°C	64.7	0.19
3	t_{roas} = 900°C, τ_{roas} = 120″	−0.071	63.6	0.55	S:L = 1:2, C H_2SO_4= 20 r/100 g T, τ_{deph} = 120″, t_{sol}= 65°C	65.3	0.16
4	t_{roas} = 950°C, τ_{roas} = 80″	−0.071	61.7	0.54	S:L = 1:2, C H_2SO_4= 20 r/100 g T, τ_{deph} = 120″, t_{sol}= 65°C	63.8	0.17
5	t_{roas} = 1000°C, τ_{roas} = 60″	–	–	–	–	–	–

Legend: t_{roas} – ore roasting temperature; τ_{roas} – ore exposure time; t_{sol} – pulp temperature (solution + ore); τ_{deph} – dephosphorizing time; S – solid phase (ore); L – aqueous solution of sulfuric acid; C H_2SO_4 – concentration of sulfuric acid in water solution.

In the next series of experiments, the optimal duration of magnetizing roasting of ore before beneficiation and dephosphorization stages was determined. Roasting was carried out at an optimal temperature of 900°C, obtained by experimental way. Fineness of the magnetite concentrate and process parameters of sulfuric dephosphorization remain the same as in previous experiments. The results are presented in Table 2.

As can be seen from Table 2, at roasting temperature of 900°C and roasting duration 20–120 minutes the iron content in dephosphorized concentrate is 64.4–65.8%. Residual phosphorus content in dephosphorized concentrate when roasting time of 40–120 minutes ranges from 0.16 to 0.20%. It has been established that duration of iron ore roasting of 20 minutes is not sufficient, as the residual content of phosphorus equal to 0.25% is higher than in experiments with longer ore exposure. Thus, when analyzing data from Table 2, the time of 40 minutes is taken as the optimal roasting duration.

Table 2: Influence of duration of magnetizing roasting on phosphorus and iron content in dephosphorized concentrate.

No.	Roasting	Magnetite concentrate			Dephosphorization	Dephosphorized concentrate	
		Fineness, mm	Content, %			Content, %	
			Fe			Fe	P
6	t_{roas} = 900°C, τ_{roas} = 20′′	−0.071	61.4	0.60	S:L = 1:2, C H_2SO_4 = 20 г/100 г T, τ_{deph} = 120′′, t_{sol} = 65°C	64.8	0.25
7	t_{roas} = 900°C, τ_{roas} = 40′′	−0.071	61.7	0.54	S:L = 1:2, C H_2SO_4= 20 г/100 г T, τ_{deph} = 120′′, t_{sol} = 65°C	64.4	0.19
8	t_{roas} = 900°C, τ_{roas} = 80′′	−0.071	61.9	0.60	S:L = 1:2, C H_2SO_4= 20 г/100 г T, τ_{deph} = 120′′, t_{sol} = 65°C	65.8	0.20
9	t_{roas} = 900°C, τ_{roas} = 120′′	−0.071	–	–	S:L = 1:2, C H_2SO_4= 20 г/100 г T, τ_{deph} = 120′′, t_{sol} = 65°C	65.3	0.16

Legend: t_{roas} – ore roasting temperature; τ_{roas} – ore exposure time; t_{sol} – pulp temperature (solution + ore); τ_{deph} – dephosphorizing time; S– solid phase (ore); L – aqueous solution of sulfuric acid; C H_2SO_4 – concentration of sulfuric acid in water solution.

Also a series of experiments was conducted in laboratory rotary furnace on magnetizing ore roasting with different specific consumption of solid reductor (coal), in the interval from 1.0 to 3.0%. The reducing roasting of iron ore using solid reductor is presented in Table 3.

Roasting of iron ore of 2–0 mm fineness was carried out at optimal process parameters: temperature 900°C and exposure 40 minutes. As a solid reductor brown coal precalcined to remove the bulk of volatile components was used.

It can be seen from Table 3 that with increase of specific consumption of coal from 1.0 to 3.0% there is a significant increase of monoxide iron FeO in roasted concentrate in relation to the raw initial iron ore (from 30.9 to 55.6%, respectively). The share of total iron Fe_{tot} in roasted concentrate at specific coal consumption from 1.0 to 3.0% slightly changes and varies in the range from 57.7 to 58.2%. In this connection, the specific consumption of coal 1.0% (in relation to the ore sample weight) is taken as optimal, as it is sufficient for the full iron oxides reduction in the ore before magnetite.

Table 3: Influence of specific flow of solid reductor on the quality of magnetite concentrate.

No.	Roasting			Roasted ore	
	Temperature, °C	Time, min	Specific consumption of coal, %	Content, %	
				Fe_{tot}	FeO
10	–	–	–	52.1	12.1
11	t_{roas} = 900	τ_{roas} = 40′′	1.0	57.7	30.9
12	t_{roas} = 900	τ_{roas} = 40′′	1.5	58.1	38.2
13	t_{roas} = 900	τ_{roas} = 40′′	2.0	57.9	43.9
14	t_{roas} = 900	τ_{roas} = 40′′	3.0	58.2	55.6

Legend: t_{roas} – ore roasting temperature; τ_{roas} – ore exposure time.

4. Summary

On the experimental base of OJSC VNIIMT were conducted experiments on high-temperature iron ore roasting with the use of laboratory roasting plant 'rotary furnace'. For iron ore of the deposit Gara Djebilet the preliminary roasting shall be magnetized not only to provide heat treatment required for the subsequent dephosphorizing, but also to convert oxidized forms of iron minerals in magnetite. As a result of the conducted researches the optimal process parameters of high-temperature magnetizing roasting were determined, at which after the process of dephosphorizing the iron content in concentrate increased from the initial 52.1% to 64.0–65.3%, and the residual content of phosphorus in the concentrate decreased from the initial 0.75% to 0.16–0.20%.

Main process parameters of magnetizing ore roasting:

1. In the series of experiments with different roasting temperature (750–1000°C) it is shown that the optimal roasting temperature is 900 ± (5–10)°C. IN this case iron content in dephoshorized concentrate was 65.3%, and the residual content of phosphorus was 0.16%.

2. In a series of experiments with different duration of iron ore roasting it is shown that the optimal roasting duration is 40 minutes. When such duration of high-temperature treatment after the dephosphorization process concentrate with iron content of 64.4% and residual content of phosphorus 0.19% is obtained.

3. Experiment on magnetizing roasting of iron ore using solid reductor (brown coal) was carried out. These experiments found that the specific consumption of coal 1.0% is sufficient for reduction of oxidized ore minerals to magnetite. As a result, the roasted concentrate with total iron content in the ore 57.7% and content of monoxide iron 30.9% was obtained.

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