Strengthening iron enrichment and dephosphorization of high-phosphorus oolitic hematite using high-temperature pretreatment

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Abstract: The efficient development and utilization of high-phosphorus oolitic hematite is of great strategic significance for the sustainable supply of iron-ore resources in China. In this paper, the mechanism of high-temperature pretreatment for enhancing the effect of iron enrichment and dephosphorization in the magnetization roasting–leaching process was studied by X-ray diffraction (XRD), vibration sample magnetometer (VSM), scanning electron microscopy and energy dispersive spectrometry (SEM–EDS). Compared with the process without high-temperature pretreatment, the iron grade of the magnetic separation concentrate after high-temperature pretreatment had increased by 0.98%, iron recovery rate had increased by 1.33%, and the phosphorus content in the leached residue had decreased by 0.12%. High-temperature pretreatment resulted in the dehydration and decomposition of hydroxyapatite, the dehydration of limonite and the thermal decomposition of siderite, which can produce pores and cracks and weaken the compactness of the ore, improve the magnetization characteristics of roasted ore, and strengthen the iron enrichment and dephosphorization during the magnetization roasting and leaching process.

Keywords: high-phosphorus oolitic hematite; high-temperature pretreatment; iron enrichment and dephosphorization; magnetization roasting–leaching process; phase transformation

1. Introduction

The iron and steel industry, an important economic pillar in China, plays an essential role in supporting the sustainable development of the national economy and ensuring the safe operation of people's livelihoods. In recent years, the rapid development of China's iron and steel industry has greatly increased the demand for iron ore. At the end of 2017, China had identified 84.888 billion tons of iron-ore reserves. However, the iron-ore resources in China that can be characterized as being low grade and having a fine grain size and a complex mineral composition means that a large volume of iron-ore resources has yet to be effectively exploited and utilized. Among them, the oolitic hematite reserves exceed 10 billion tons, accounting for 12% of the total iron-ore reserves and 30% of the total hematite reserves in China. The iron deposited in western Hubei province, Xuanlong in Hebei province, Ningxiang in Hunan province, and Tunqiu in Guangxi province is all oolitic hematite [1–2]. Some oolitic hematite ores in China have a high-phosphorus content in the general range of 0.4wt% to 1.2wt%, which are referred to as high-phosphorus oolitic hematite ores. The high-phosphorus oolitic hematite in China with reserves of 3.72 billion tons is mainly composed of hematite, oolitic chlorite, calcite, dolomite, collophanite and other minerals. Phosphorus in ores is mainly in the form of collophanite, which coexists with other minerals. Since the size of collophanite particles can be less than 2 μm, due to its complex characteristics, useful minerals are difficult to separate from collophanite and other gangues and have become one of the world’s most refractory iron ore [3–9]. In the blast-furnace smelting process, all phosphorus in ore is transformed into hot metal. Phosphorus has a very harmful effect on most kinds of steel. Therefore, in the mineral separation and smelting process, efficient iron enrichment and dephosphorization are key factors in achieving a comprehensive development and utilization of the ore. To realize iron enrichment of high-phosphorus oolitic hematite, many
scholars have compared and analyzed the results of separation experiments using gravity separation, high-intensity magnetic separation, anion reverse flotation, and direct reduction–magnetic separation, and found the magnetization roasting–low intensity magnetic separation process to be an effective way to deal with weakly magnetic iron ore [10–13]. Some successful applications, such as the magnetization roasting–weak magnetic separation process for iron tailings, carbonate-bearing iron ores, and other refractory iron ores have achieved efficient recovery and utilization [14–18]. Meanwhile, research on the dephosphorization of high-phosphorus oolitic hematite has tended to use additives such as direct reduction–magnetic separation dephosphorization and chemical leaching [19–20]. The former has demonstrated a good phosphorus removal effect, but its economics are unreasonable. The latter can also achieve a certain phosphorus removal effect. Although a large amount of acid is consumed in the treatment process, current acid recycling methods can significantly reduce acid waste and environmental pollution. Industrial practices have shown that the phosphorus content of iron concentrate should be less than 0.20wt% in metallurgical application, but few processes can meet this demand. In this paper, the process and mechanism of high-temperature pretreatment in the magnetization roasting–leaching process were investigated, and a new way for the efficient development and utilization of the ore was proposed.

2. Experimental

2.1. Materials

2.1.1. Chemical composition

The test ore samples were obtained from the Tunqiu Iron Mine of Liuzhou Iron & Steel, the chemical composition of which is listed in Table 1.

<table>
<thead>
<tr>
<th>TFe</th>
<th>FeO</th>
<th>P</th>
<th>SiO₂</th>
<th>Al₂O₃</th>
<th>CaO</th>
<th>MgO</th>
<th>S</th>
<th>LOI</th>
</tr>
</thead>
<tbody>
<tr>
<td>46.63</td>
<td>2.43</td>
<td>1.00</td>
<td>19.17</td>
<td>5.71</td>
<td>2.45</td>
<td>0.38</td>
<td>0.21</td>
<td>4.25</td>
</tr>
</tbody>
</table>

Note: TFe—total iron; LOI—loss on ignition.

Table 1 shows that the main useful element in the ore is iron with a mass fraction of 46.63%, the main impurities are Al₂O₃ with a mass fraction of 5.71% and SiO₂ with a mass fraction of 19.17%, and the harmful element is phosphorus with a mass fraction of 1%.

2.1.2. Phase analysis of iron in ore

To ascertain the composition of the iron phase in oolitic hematite, the phase of the iron element in oolitic hematite was analyzed. Iron phase was usually analyzed by magnetic separation, acetic acid treatment, tin chloride and hydrogen chloride treatment, aqua regia treatment and other titration operations. The results are shown in Table 2.

<table>
<thead>
<tr>
<th>Phase analysis of iron</th>
<th>Content / wt%</th>
<th>Distribution rate / %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iron in hematite</td>
<td>39.20</td>
<td>84.07</td>
</tr>
<tr>
<td>Iron in limonite</td>
<td>4.56</td>
<td>9.78</td>
</tr>
<tr>
<td>Iron in magnetic</td>
<td>0.09</td>
<td>0.19</td>
</tr>
<tr>
<td>Iron in sulfide</td>
<td>0.17</td>
<td>0.36</td>
</tr>
<tr>
<td>Iron in siderite</td>
<td>0.72</td>
<td>1.54</td>
</tr>
<tr>
<td>Iron in ferrosilicate</td>
<td>1.89</td>
<td>4.05</td>
</tr>
<tr>
<td>Total</td>
<td>46.63</td>
<td>99.99</td>
</tr>
</tbody>
</table>

In Table 2, it can be seen that the main phase of the iron element in ore is hematite with a mass fraction of 39.20% and a distribution rate of 84.07%, followed by limonite with a mass fraction of 4.56% and a distribution rate of 9.78%. The iron content in the other ores was much lower.

2.1.3. Mineral composition

To analyze the mineral composition and relative content of the ores, an automatic particle mineralogical analyzer (PMA) was used, the results of which are shown in Table 3.

Table 3 shows that the main metal minerals in the ore are oolitic hematite with a content of 60.02wt%, and small amounts of limonite, siderite, and micro-magnetite. The non-metallic minerals are mainly quartz, clay minerals and phosphate minerals (mainly apatite) with the quartz having a mass fraction of 12.41%, the clay minerals having a mass fraction of 5.07%, the phosphate minerals having a mass fraction of 8.35%, and the remainder comprising trace amounts of chloride, mica and feldspar. The phosphate min-

Table 2. Phase analysis results of iron element in ores

Table 3. Mineral composition and content of ore determined by PMA
erals are mainly apatite, which consists primarily of hydroxyapatite and fluoroapatite with some chlorinated apatite.

2.1.4. Disseminated structure of the ore

The disseminated structure of the ore was analyzed using an optical microscope and PMA, the results of which are shown in Figs. 1 and 2, respectively.

In Figs. 1 and 2, it can be seen that hematite is the main mineral, occurring primarily in the oolite and aggregates. The oolitic bodies in the ores are mostly round or elliptical, and the oolitic nuclei comprise quartz, clay minerals, hydroxyapatite, and limonite particles. Colloidal hematite was coagulated layer by layer along the core with gangue minerals (clay minerals, apatite and other veins), which have formed concentric layered structures with each other. Some hematite deposits had a single thin concentric layer forming a ring structure. The oolite particle sizes were mostly between 0.05–0.5 mm. The hematite comprises acicular crystals several hundred nanometers in width and several micrometers in length. The annular hematite observed in the oolitic grains was actually an aggregate of microgranular hematite, which had a different density and porosity. The pores contained gangue minerals such as clay minerals and
mica, as shown in Fig. 1. This embedded structure poses a great challenge to the effective separation of iron minerals.

2.2. Methods

After crushing and grinding, the samples, for which 80% of the mass was less than 0.074 mm in size, were pretreated at high temperature in a muffle furnace. The pretreatment temperature was higher than 1000°C and the pretreatment time was 30 s, after which the high-temperature pretreatment products were transferred to a tubular furnace. First, the air in the reaction chamber using a protective gas (nitrogen) was cleared. Next, after reaching the predetermined temperature, the reducing gas was introduced. The input gas was a mixture of CO and N\(_2\) with a total flow rate of 500 mL/min, for which we set the proportion of carbon monoxide according to the test requirements. The CO concentration can be calculated using the equation 

\[ C_{CO} = \frac{Q_{CO}}{Q_{CO} + Q_{N_2}} \]

where \( Q_{CO} \) and \( Q_{N_2} \) are the respective CO and \( N_2 \) flow rates. After the predetermined time, the flow of reducing gas was stopped and the flow of protective gas continued to cool the roasted ore sample to room temperature. Then, the grinding fineness and other tests were carried out.

Fig. 3 shows a schematic diagram of the test process. After grinding the roasted ore sample, the magnetic separation test was conducted using a magnetic separator (XCSG-ϕ50 mm) with a working magnetic field of 80 kA/m, and the magnetic separation concentrate and tailing were obtained. The iron grades of the concentrate and tailings were determined by chemical analysis, and the recovery rate was calculated using Eq. (1) below. After drying the magnetically separated concentrate, it was placed in a leaching tank for testing. The leaching test was performed with certain leaching times, liquid-to-solid ratios, and sulfuric acid concentrations. After the test, the leached residue was dried and then tested, and the phosphorus removal rate was calculated using Eq. (2) shown below:

\[ \eta = \frac{\beta}{\alpha} \times \left(1 - \frac{\theta}{\theta} \right) \times 100\% \]  

(1)

\[ \rho = \frac{M_1 \beta_1 - M_2 \beta_2}{M_1 \beta_1} \times 100\% \]  

(2)

where \( \alpha, \beta, \) and \( \theta \) are the iron grades of the feed samples, magnetic concentrates, and tailings, respectively, and \( \eta \) is the iron recovery rate. \( \rho, M_1, \beta_1, M_2, \) and \( \beta_2 \) are the phosphorus removal rate, the quality of the leached feed samples, the phosphorus grades of the leached feed samples, the quality of the leached concentrate (leached residue), and the phosphorus grades of the leached concentrate, respectively.

The chemical compositions, mineral compositions, ore structures, mineral dissemination characteristics, and main mineral granularities of the roasted products were studied by chemical analysis using an XRD analyzer (PANalytical X’pert PW3040), PMA, VSM, and SEM–EDS. The iron phase of the samples was analyzed using both physical and chemical methods, as shown in Fig. 4. In this way, the enhancement mechanism of iron enrichment and dephosphorization during the magnetization roasting–leaching process of the high-phosphorus oolitic hematite was explored, and the optimum conditions, phase transformation, and magnetic transformation rules of the roasting process were obtained.
3. Results and discussion

The magnetization roasting test mainly affects the iron separation index, but acid leaching has a great influence on the separation of phosphorus. Previous research data obtained in this laboratory show that the optimum acid-leaching conditions at normal temperature and pressure have been determined to be acid-leaching time of 30 min, liquid-to-solid ratio of 20 mL/g, sulfuric acid concentration of 0.5 mol/L, and stirring speed of 200 r/min. The optimum high-temperature pretreatment time is 30 s.

3.1. Effect of high-temperature pretreatment on direct leaching

To investigate the influence of the high-temperature pretreatment temperature on dephosphorization, the direct acid leaching was performed using the optimum conditions identified for laboratory leaching, the results are shown in Fig. 5.

![Fig. 5. Effect of temperature on leaching dephosphorization during high-temperature pretreatment.](image)

Fig. 5 shows that the removal efficiency of phosphorus was remarkable under different high-temperature conditions. A better dephosphorization index at 1050°C was obtained. After high-temperature pretreatment, the phosphorus content decreased from 0.32wt% to 0.17wt%, and the phosphorus removal rate was 85.07%. The mechanism of high-temperature pretreatment that facilitates leaching and dephosphorization was described in detail below.

3.2. Magnetization roasting–magnetic separation test

The main factors affecting the quality of magnetic roasting products are the amount of reducing gas, the roasting time, and the roasting temperature. Therefore, in this experiment, the influence of CO content, roasting time, and roasting temperature on the magnetic roasting and magnetic separation of high-phosphorus oolitic hematite were mainly investigated. The results are shown in Figs. 6–9.

![Fig. 6. Effect of CO content on iron grade and iron recovery rate of magnetite concentrate (roasting temperature: 650°C; roasting time: 25 min; grinding fineness: 75wt% particles less than 38 μm in size).](image)

Fig. 6 shows that with increasing of CO content, both the iron grade and recovery rate increased gradually until reaching a maximum, which is due to the gradual transformation of hematite into magnetite. However, when the CO content is excessive, some newly formed and primary magnetite is reduced to weakly magnetic ferrous oxide, which worsens the magnetic separation index [21]. The results of our comprehensive analysis show that better separa-
tion indexes are obtained when the CO content is 25vol%.

Fig. 7 shows the effect of roasting time on the iron grade and recovery rate. It can be seen that with the extension of roasting time, the iron grade and recovery rate continued to increase due to the gradual transformation of hematite into magnetite until reaching a peak roasting time of 25 min, after which it sharply decreased. With a suitable CO content, however, an overlong roasting time might lead to a reduction in the newly formed and primary magnetite to weakly magnetic ferrous oxide, which would cause incomplete magnetic separation and reduce the quality of the iron concentrate [22]. The best separation indexes was obtained when the roasting time was 25 min.

![Fig. 7. Effect of roasting time on iron grade and iron recovery rate of magnetite concentrate (roasting temperature: 650°C; CO content: 25vol%; grinding fineness: 75wt% particles less than 38 μm in size).](image)

Fig. 8 illustrates the effect of roasting temperature on the iron grade and recovery rate. It can be seen that with increasing of the roasting temperature, the iron grade and recovery rate continued to increase due to the gradual transformation of hematite into magnetite. The peak iron grade and recovery rate were reached at 650°C, and then decreased gradually as some of the newly formed and primary magnetite were reduced to weakly magnetic oxidized ferrous iron ore (FeO, Fe₂SiO₄), which worsened the magnetic separation index [23].

It is clear that the iron grade of magnetic separation concentrate was not significantly improved by the above conditions, mainly due to the insufficient dissociation between the iron ore and gangue minerals. Therefore, to fully dissociate iron minerals from other gangues, an optimization test was needed to determine the optimal grinding fineness. Fig. 9 explores the influence of grinding fineness on iron grade and recovery rate, it can be seen that with an increase in the mass fraction of particles less than 38 μm in size, the iron grade and recovery rate also continued to increase. The best separation indexes were obtained when the grinding fineness was 85wt% particles less than 38 μm in size. Under these optimum conditions, iron concentrate with an iron grade of 59.74% and iron recovery rate of 86.31% were obtained by magnetic separation. However, as the ore particle size became finer, it becomes difficult to capture the fine particles by magnetic separation, which would reduce the recovery rate of iron ore [24].

![Fig. 8. Effect of roasting temperature on iron grade and iron recovery rate of magnetite concentrate (roasting time: 25 min; CO content: 25vol%; grinding fineness: 75wt% particles less than 38 μm in size).](image)

![Fig. 9. Effect of mass fraction of particles less than 38 μm in size on iron grade and iron recovery rate of magnetite concentrate (roasting time: 25 min; CO content: 25vol%; roasting temperature: 650°C).](image)

3.3. Effect of high-temperature pretreatment on magnetization roasting and leaching

The influence of high-temperature pretreatment on the subsequent magnetization roasting and acid-leaching process was investigated with 85wt% particles less than 0.043 mm in size, CO content of 25vol%, roasting temperature of 650°C and roasting time 25 min, magnetic separation
strength of 80 kA/m, acid-leaching time of 30 min, liquid-to-solid ratio of 20 mL/g, and sulfuric acid concentration of 0.5 mol/L. The results are shown in Fig. 10. Under these optimum conditions, the chemical composition analysis of iron concentrate after magnetization roasting and leaching was analyzed, the results are shown in Table 4.

![Graph](image1)

**Fig. 10. Effect of high-temperature pretreatment on magnetization roasting and leaching.**

<table>
<thead>
<tr>
<th>Table 4. Chemical composition of concentrate</th>
<th>wt%</th>
</tr>
</thead>
<tbody>
<tr>
<td>TFe</td>
<td>P</td>
</tr>
<tr>
<td>60.72</td>
<td>0.14</td>
</tr>
</tbody>
</table>

From Fig. 10, it can be seen that high-temperature pretreatment had an obvious effect on promoting subsequent magnetization roasting and acid leaching. The iron grade of magnetic separation concentrate increased by 0.98%, the iron recovery rate increased by 1.33%, and the phosphorus content of the leaching residue decreased from 0.26% to 0.14%. As shown in Table 4, the total iron content was 60.72wt%, the contents of the harmful phosphorus and sulfur elements were 0.14wt% and 0.02wt%, respectively, and the SiO₂ and Al₂O₃ contents were 11.02wt% and 4.72wt%, respectively. This confirms that high-temperature pretreatment had an obvious effect on subsequent magnetization roasting and acid-leaching dephosphorization.

3.4. Mechanism analysis

To explore the effect of high-temperature pretreatment on the phase transformation the magnetic and microstructural changes during magnetization roasting and leaching, the VSM, XRD, and SEM–EDS were analyzed. The results are shown in Figs. 11–13. As shown in Fig. 11, U represents unit mass magnetic moment, A·m²/kg; S represents specific magnetic coefficient, 10⁻³ m³/kg; E represents external magnetic field strength, kA/m.

Fig. 11 shows that the unit mass magnetic moment and specific magnetization coefficient of ore before magnetization roasting had low values and could be categorized as a weakly magnetic material. After magnetization roasting, however, the unit mass magnetic moment of the ore increased rapidly with increasing of the intensity of the external magnetic field, and when this intensity reached 600 kA/m, the increasing trend tended to stabilize to magnetic saturation. At this time, the unit mass magnetic moment was 30 A·m²·kg⁻¹, which qualifies it is a ferromagnetic material. After magnetization roasting, the specific magnetization coefficient of the minerals first increased and then decreased with increasing of the external magnetic field intensity, after which it tended to stabilize, reaching a maximum value of 0.206 m³/kg at an external magnetic field intensity of 62.96 kA/m. The specific magnetization coefficient decreased gradually to 0.05 m³/kg as the external magnetic field intensity continued to increase. The results of the magnetic analysis show that the magnetic properties of the minerals obviously changed from weak to strongly magnetic minerals that were effectively enriched by weak magnetic separation. Thus, transformation from complex and difficult separation to easy separation was realized. When high-temperature pretreatment was performed, the unit mass magnetic moment of ore samples after magnetization roasting could be improved even more, which indicates that high-temperature pretreatment can promote the greater transformation of weakly magnetic minerals to strongly magnetic minerals.

![Graph](image2)

**Fig. 11. Magnetic analyses of iron ore by different treatments.**

As can be seen in Fig. 12, prior to high-temperature pretreatment, phosphorus was mainly in the form of hydroxyapatite. After high-temperature pretreatment, the hydroxyapatite dehydrated to form apatite. Before magnetization roasting, iron ore was mainly in the form of hematite and after roasting it was transformed into a new mineral dominated by magnetite. The gangue minerals showed no obvious change after roasting.
According to the XRD analysis in Fig. 12, some hydroxyapatite was present in the high-phosphorus oolitic hematite. The results show that pure hydroxyapatite was characterized by high-temperature instability, and dehydration and decomposition reactions occurred easily between 1100 and 1200°C, resulting in the formation of apatite and tetracalcium phosphate, as shown in Eqs. (1), (2), and (3). In the actual minerals, the presence of reinforcements such as Al₂O₃ would reduce the reaction temperature. Meanwhile, the ore contained 8.55wt% limonite, and the free water in the limonite could be removed when the temperature exceeded 110°C. When the temperature exceeded 650°C, the water in the limonite crystals could be completely removed by dehydration, after which the limonite transformed into hematite, as shown in Eq. (4). In addition, the ore contained 1.69wt% siderite, which began to decompose into CO₂ at 350°C, and CO began to form at 430°C. The siderite could be converted into magnetite to the greatest extent at 620°C, which then oxidized to iron oxide in air atmosphere. The reaction processes are as shown in Eqs. (5) and (6).

![XRD analysis of iron ore at different stages](image)

**Fig. 12.** XRD analysis of iron ore at different stages in the process: (a) raw sample; (b) sample after high-temperature pretreatment; (c) roasted sample; (d) magnetic separation concentrate.

According to the XRD analysis in Fig. 12, some hydroxyapatite was present in the high-phosphorus oolitic hematite. The results show that pure hydroxyapatite was characterized by high-temperature instability, and dehydration and decomposition reactions occurred easily between 1100 and 1200°C, resulting in the formation of apatite and tetracalcium phosphate, as shown in Eqs. (1), (2), and (3). In the actual minerals, the presence of reinforcements such as Al₂O₃ would reduce the reaction temperature. Meanwhile, the ore contained 8.55wt% limonite, and the free water in the limonite could be removed when the temperature exceeded 110°C. When the temperature exceeded 650°C, the water in the limonite crystals could be completely removed by dehydration, after which the limonite transformed into hematite, as shown in Eq. (4). In addition, the ore contained 1.69wt% siderite, which began to decompose into CO₂ at 350°C, and CO began to form at 430°C. The siderite could be converted into magnetite to the greatest extent at 620°C, which then oxidized to iron oxide in air atmosphere. The reaction processes are as shown in Eqs. (5) and (6).

![SEM image and EDS analysis results](image)

**Fig. 13.** SEM image (a) and EDS analysis results (b–d) of the samples before high-temperature pretreatment.
\[
\begin{align*}
\text{Ca}_{10}(PO_4)_6(OH)_2(s) & \rightarrow \text{Ca}_{10}(PO_4)_6(OH)_{2-2x}O_x(s) + xH_2O(g) & \quad (3) \\
\text{Ca}_{10}(PO_4)_6(OH)_2(s) & \rightarrow 2\text{Ca}_3(PO_4)_{2(s)} + \text{Ca}_4P_2O_9(s) + H_2O(g) & \quad (4) \\
x\text{Fe}_2O_3 \cdot yH_2O(s) & \rightarrow x\text{Fe}_2O_3(s) + yH_2O(g) & \quad (5)
\end{align*}
\]

where □ indicates a vacancy at the hydroxyl lattice position. The dehydration reaction causes hydroxyapatite to lose its hydroxyl group and form Ca\(_{10}(PO_4)_6(OH)_{2-2x}O_x\) (OHA—oxy-hydroxyapatite). The subsequent decomposition reaction transformed this product into Ca\(_x\)(PO\(_4\))\(_2\) and Ca\(_3P_2O_9\).

Figs. 13 and 14 show the SEM–EDS results of our microstructure analysis of the samples before and after high-

**Fig. 14.** SEM image (a) and EDS analysis results (b–d) of the samples after high-temperature pretreatment.

**Fig. 15.** Schematic diagram of influence mechanism of high-temperature pretreatment.
temperature pretreatment. Using high-temperature pretreatment, the dehydration reaction of limonite and the dehydration and decomposition reactions of hydroxyapatite could all weaken their degree of internal compactness, making them prone to cracks and other loose structures. Meanwhile, the thermal decomposition process of siderite was accompanied by the formation of pores and cracks, all of which had a great impact on mineral dissociation in the subsequent grinding process and strengthened the results of the magnetization roasting and subsequent leaching process.

Fig. 15 shows a schematic diagram of the influence mechanism of the high-temperature pretreatment. It can be seen that high-temperature pretreatment can promote the entry of carbon monoxide into the ore through cracks and thereby enhance the selective transformation of weakly magnetic minerals into strongly magnetic minerals. In addition, it also strengthens the combination of sulfuric acid molecules and phosphorus in the ores to achieve effective dephosphorization.

4. Conclusions

In this study, it was determined that high-temperature pretreatment resulted in the dehydration and decomposition of hydroxyapatite, the dehydration of limonite, and the thermal decomposition of siderite, which produces pores and cracks and thus weakens the compactness of the ore, improves the magnetization characteristics of roasted ore, and strengthens the iron enrichment and dephosphorization during the magnetization roasting and leaching process. After high-temperature pretreatment, under these optimum conditions of CO content of 25vol% (total flow rate was 500 mL/min), roasting temperature of 650°C, and roasting time of 25 min, iron concentrate with iron grade of 60.72%, iron recovery rate of 87.64%, and phosphorus content of 0.14wt% were obtained by magnetic separation and leaching.

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