Preparation of the Iron Oxide Red from the Converter Dust by the Magnetic Separation and Roasting Process

Z J Guo, S Q Li, C Q Yang

School of Metallurgical and Ecological Engineering, University of Science and Technology Beijing, Beijing 100083, China

Abstract. Preparation of iron oxide red ($\alpha$-$\text{Fe}_2\text{O}_3$) from the converter dust by the superconductivity high gradient magnetic separation (S-HGMS) and roasting process was investigated in the paper. The basic properties of the dust were studied by the X Ray Fluorescence, the chemical analysis and the X Ray Diffraction methods. The results showed that the raw dust mainly contained elements of Fe, O, Si, Ca, the iron content of the raw dust was 61.80%, and there were ferrous phases of $\text{Fe}_3\text{O}_4$, $\alpha$-$\text{Fe}_2\text{O}_3$, $\text{Fe}_2(\text{SiO}_4)$ and $\text{CaFe}(\text{Si}_2\text{O}_6)$ in the raw dust. Under the optimum conditions of magnetic field intensity of 1.8T, the dispersion agent of 30mg/L and velocity of 500mL/min, the powders absorbed by the magnetic medium mainly contained $\text{Fe}_3\text{O}_4$ and $\alpha$-$\text{Fe}_2\text{O}_3$, and the iron content of powders absorbed was up to 65.90%. The $\text{Fe}^{2+}$ content of the powders absorbed under the optimum magnetic conditions dropped to 0.25% from 19.10% after roasting of fifty minutes, and the iron content of powders absorbed under the optimum magnetic conditions fell to 64% due to oxidation, and the $\text{Fe}_3\text{O}_4$ was removed. Finally the $\alpha$-$\text{Fe}_2\text{O}_3$ content was up to 91.07% in the iron oxide red.

1. Introduction

In recent years, the converter dust mushroom with the rapid development of the iron and steel industry in China. Due to the high iron content, the dust is usually used as coolant in the converter by making the heated pressed block [1]-[2], and the dust also can be used as sintering burdening [3]. But the K, Na, Zn, S in the dust are bad for the ironmaking and steelmaking process or the steel quality. The high-iron-content dust can also be made into the high purity $\alpha$-$\text{Fe}_2\text{O}_3$. The $\alpha$-$\text{Fe}_2\text{O}_3$ has excellent light fastness, high temperature, alkali resistance and corrosion resistance. It can be made into the high temperature resistant coatings [4], the anticorrosion coating [5], strong acid resistance floor coating [6], ceramic colorant [7] and nano iron oxide material [8]. The dust contains magnetite and weakly magnetic hematite, and more weakly magnetic minerals. The hematite only is absorbed by high magnetic field. The experiment magnetic equipment in the study has the maximum magnetic intensity of 5T.

2. Experimental

2.1. The raw material

The chemical compositions and ferrous phases of the converter dust were studied by the XRF-1800 X Ray Fluorescence, the chemical analysis and the D8 ADVANCE Cu X Ray Diffraction. The results were showed as the table 1 and the figure 1. According to the figure 1, Fe is in form of $\text{Fe}_3\text{O}_4$, $\alpha$-$\text{Fe}_2\text{O}_3$, $\text{Fe}_2(\text{SiO}_4)$, and $\text{CaFe}(\text{Si}_2\text{O}_6)$. $\text{Fe}^{2+}$ is in the $\text{Fe}_3\text{O}_4$, $\text{Fe}_2(\text{SiO}_4)$, $\text{CaFe}(\text{Si}_2\text{O}_6)$. The magnetic susceptibilities are showed as the table 2.
Table 1. Main chemical compositions of the dust/\%.

| Element | TFe | Fe\(^{2+}\) | CaO | SiO\(_2\) |
|---------|-----|------------|-----|---------|
| Content | 61.80 | 19.10 | 4.42 | 1.41 |

![X-ray diffraction patterns of ferrous phases of the dust.](image)

Figure 1. X-ray diffraction patterns of ferrous phases of the dust.

Table 2. The susceptibilities of minerals/4\(\pi\times10^6\)SI.

| Phase         | Fe\(_3\)O\(_4\) | \(\alpha\)-Fe\(_2\)O\(_3\) | Fe\(_2\)(SiO\(_4\)) | CaFe(Si\(_2\)O\(_6\)) |
|---------------|-----------------|-----------------------------|---------------------|-----------------------|
| Susceptibility| 100000–570000   | 50–4000                     | 2–160               | 40–467                |

2.2. The process route

The magnetic intensity is the decisive fact, and the particle dispersion and velocity of flow are the secondary facts. The optimum conditions which Fe\(_3\)O\(_4\) and \(\alpha\)-Fe\(_2\)O\(_3\) were absorbed mostly, and Fe\(_2\)(SiO\(_4\)) and CaFe(Si\(_2\)O\(_6\)) were not absorbed as far as possible by the magnetic medium was found in the experiment. The experiment was based on the other certain empirical facts, such as the size and concentration of particles, and the magnetic medium filling ratio. The powders absorbed were roasted in the temperature of 250\(\degree\)C, because Fe\(_3\)O\(_4\) turned into \(\alpha\)-Fe\(_2\)O\(_3\) [9] under 250\(\degree\)C. The process route was showed as the figure 2.

![Process route diagram](image)
2.3. Results and discussion

2.3.1. The influence of the magnetic field intensity on the magnetic separation

This section was under the conditions of velocity of 500mL/min, at -200 mesh and with 8g steel wool and without the dispersion agent. The result was showed as the figure 3.

![Figure 3](image-url)

**Figure 3.** The influence of the magnetic field intensity on the magnetic separation.

The iron content of Fe₃O₄ is 72.41%, the iron content of α-Fe₂O₃ is 70%, the iron content of Fe₂(SiO₄) is 54.90%, the iron content of CaFe(Si₂O₆) is 22.58%. According to the figure 3, in a certain range, the iron content of powders absorbed increased with the rise of the intensity, so the total content of Fe₃O₄ and α-Fe₂O₃ increased in this range. When the intensity reached 1.8T, the iron content reached the maximum of 64.50%, then the iron content declined with the rise of the intensity. The magnetic force of the particle was showed as the formula 2-1.

$$F_m = KVH \frac{dH}{dx}$$  \hspace{1cm} (2-1)

According to the formula 2-1, the magnetic susceptibility K, the particle volume V and the magnetic gradient dH/dx are certain, thus F_m is proportional to the magnetic intensity H. Fe₃O₄ is totally absorbed under the low H, and when the intensity is under 1.8T, the more higher the H is, the more α-Fe₂O₃ are adsorbed, when the intensity is out of 1.8T, the more higher the H is, the more particles which the H is less than α-Fe₂O₃ are adsorbed by steel wool, so the total content of Fe₂(SiO₄) and CaFe(Si₂O₆) increases.

2.3.2. The influence of the dispersion agent on the magnetic separation

This section was under the conditions of 1.8T and velocity of 500mL/min, at -200 mesh and with 8g steel wool. The result was showed as the figure 4.

![Figure 4](image-url)

**Figure 4.** The influence of the dispersion agent on the magnetic separation.
According to the figure 4, in a certain range, the iron content of powders absorbed increased with the increasing of the dispersion agent. And when the dispersion agent concentration reached 30mg/L, the iron content reached the maximum of 65.90%, then the iron content declined with the rise of the dispersion agent.

Na$_6$(PO$_3$)$_6$ ionizes out the PO$_3^{-1}$, the PO$_3^{-1}$ is absorbed by the particles surface, which is called the surface ion. Ions with the opposite charge in the medium are called the antiparticle. Some antiparticles are absorbed by the static electricity, which forms the close layer with negative charge. The antiparticles around the particles form the diffused layer. So the particles can repel each other by the electric double layer. But if the agent exceeds 30mg/L, more antiparticles will be absorbed by the close layer, the potential declines until the electric double layer disappears.

2.3.3. The influence of velocity of flow on the magnetic separation

This section was under the conditions of 1.8T and dispersion agent of 30mg/L, at -200 mesh and with 8g steel wool. The result was showed as the figure 5.

According to the figure 5, the iron content declined with the rise of velocity of flow. When velocity of flow reached 500mL/min, the iron content reached the maximum of 65.9%. The phases were mainly Fe$_3$O$_4$ and α-Fe$_2$O$_3$. The fluid drag force of the particle is as the formula 2-2.

\[ F_n = 12 \pi uvb \]

According to the formula 2-2, the kinematic viscosity u, the particle relative speed v and the particles radius b is certain. The $F_n$ is proportional to v, so the iron content declines with the increasing of velocity of flow.

2.3.4. The effect of roasting time on Fe$^{2+}$ content of powders absorbed under the optimum magnetic conditions

The powders absorbed under the optimum magnetic conditions were roasted in the air under 250℃ with the different time. Fe$_3$O$_4$ turned into α-Fe$_2$O$_3$. The result was showed as the figure 6.
According to the figure 6, the Fe$^{2+}$ content declined with the increasing of the roasting time. The Fe$^{2+}$ content reached 0.25% after the roasting of fifty minutes. Then the Fe$^{3+}$ content was almost unchanged after more roasting time, so Fe$_2$O$_3$ was removed. The iron content of powders absorbed under the optimum magnetic conditions fell to 64% due to oxidation. The particle morphology of iron oxide red was showed as the figure 7.

![Figure 7](image_url)

**Figure 7.** The particle morphology of iron oxide red.

3. Conclusions
The converter dust mainly contains magnetite, hematite, iron olivine, hedenbergite phase. Under the optimum conditions of magnetic field intensity of 1.8T, the dispersion agent of 30mg/L and velocity of 500mL/min, the powders absorbed by the magnetic medium mainly contained Fe$_3$O$_4$ and α-Fe$_2$O$_3$, and the iron content of powders absorbed was up to 65.90%. The Fe$^{3+}$ content of the powders absorbed under the optimum magnetic conditions dropped to 0.25% from 19.10% after roasting of fifty minutes, and the Fe$_2$O$_3$ was removed. Finally the α-Fe$_2$O$_3$ content was up to 91.07% in the iron oxide red.

4. References
[1] Hong J G and Zheng H W 2015 Technical research and application of dry cold pressing block of the converter LT dust. Proceedings of the 2015 Annual Conference on refractories (the Thirteenth National Symposium on unshaped refractories and the Academic Symposium on refractories of the 2015) Thesis collection (3).
[2] Wan X F, Cao D, Gao X Z 2014 Research and application of the metallurgical dust sludge in converter. China Metallurgy, 24(11) 35-41.
[3] Meng X F 2015 Comprehensive application of dust in sintering process. Heilongjiang Metallurgy, 36(5) 59-61.
[4] Li Y N 2013 Development and evaluation of fluoro silicone resin coatings. (Jinan, University of Jinan).
[5] Chen Z and Yang Y P 2016 Study on the permeable closed waterborne epoxy anticorrosive primer. Jiangsu Construction, (Suppl) 79-82.
[6] He S P, Gao Q, Xu X T 2011 Method for preparing iron oxide red and its application in coatings. Chemical production and technology, 18(1) 29-32.
[7] Qin W 2011 Application of iron oxide red pigment in ceramic industry. Foshan Ceramics, (7) 9-12.
[8] He M L, Li W, Su X 2015 Research progress of nano magnetic materials in water treatment. New chemical materials, 43(11) 28-29.
[9] Liu X M, Jiang J Z, Mao X F 2010 The analysis of several types and characteristics of the magnetic hematite. Chinese Science, 40(5) 592-601.