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Iron Extraction From Oolitic Iron Ore by a Deep Reduction Process

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Abstract: A laboratory experiment was carried out to extract iron from oolitic iron ore by a deep reduction and magnetic separation technique. The raw coal with fixed carbon of 66.54% was used as the reductant. The iron was successfully extracted from the oolitic iron ore which otherwise is nearly impossible to be separated due to its extremely fine-grain and mosaic nature. The results showed that an iron recovery rate of 90.78% and an iron content of 92.53% of iron concentrate could be obtained by such a technique. The optimized roast temperature is 1200 ℃ and time is 60 min. The subsequent magnetic separation was performed by using a magnetic field intensity of 111 kA · m^{-1} and a grinding fineness less than 45 μm of 96.19% for the sintered product.

Key words: oolitic hematite; deep reduction; magnetic separation

More than 500 Mt of iron ore was imported every year in China, which represents more than half of the iron ore for its total iron and steel production[1-2]. Besides, there are several billion tons of oolitic iron ore resources in China which are nearly impossible to be used by the iron and steel factories owing to its extreme difficulties of separation and concentration of iron oxide minerals by traditional magnetic or floating separation methods[3-4]. Several researchers have reported techniques of magnetizing processes by roasting-reduction in the temperature range of 700-900 ℃[5-7], but most of them do not have a satisfied recovering rate and cost balance. In this paper, an experiment was performed, aiming at developing a technique of "deep-reduction and magnetic separation" technique[8-9]. By this technique, metal iron powder with more than 90% of iron concentration can be obtained as the final product, rather than magnetite minerals or hematite minerals. The metal iron powder obtained by this technique can be directly used in the steel production process or other high-value-added industries. This will balance the costs and energy consumption of the process.

1 Experimental

1.1 Materials

The oolitic iron ore was collected from Xuanhua, Hebei Province of China, which belongs to Xuanlong-type iron ore deposit in a geological term. The chemical composition and iron-bearing phase of the iron ore are shown in Table 1 and Fig. 1.

Table 1 shows that apart from the iron oxides, the other major compositions are SiO_2, Al_2O_3 and alkali metal oxides, which coincide well with the previous studies on minerals compositions of the ore[10-11]. From Fig. 1, it can be seen that the major ore minerals include hematite, siderite and the major gangue minerals is quartz.

The coal is collected from Datong, Shanxi Province of China. Its composition is fixed carbon 66.54%, fugitive constituent 27.82%, ash 3.64% and moisture 27.82%, and it belongs to the anthracite type.

Table 1 Chemical composition of raw ore sample (mass percent, %)

TFe	CaO	MgO	SiO_2	FeO	Fe_2O_3	Al_2O_3	K_2O+Na_2O	S	P	Loss	Total
47.66	0.92	1.27	15.08	17.04	49.03	2.58	3.18	0.22	0.24	10.42	100

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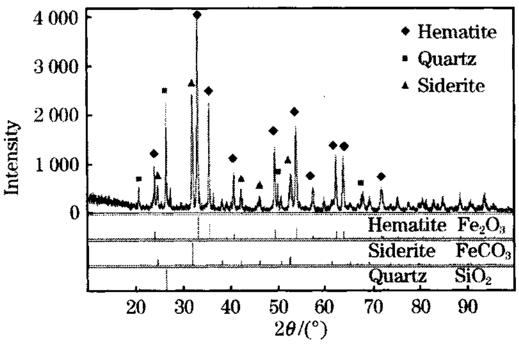

Fig. 1 Iron-bearing phase analysis of the sample

1.2 Experimental methods

The iron ore and coal were crushed and sieved to a size range of 0 — 2 mm. The sieved iron ore grains and coal grains were mixed together and charged into graphite crucibles (ϕ10 cm × 20 cm) with pre-designed ratios. The charged crucibles was covered with graphite lids and sealed with clay, and then they were placed in an electric furnace with its working temperature up to 1 700 ℃. After the crucibles were placed into the furnace, the furnace was heated up from room temperature to the pre-set temperature in a rate of 5—6 ℃ · min^{-1}. The crucibles were kept in the furnace at the pre-set temperature for different times as designed, then taken out from the furnace at the high temperature and cooled in the air down to room temperature. After the reacted products were taken out from the crucibles, they were crushed and wet milled to different finenesses in order to pursue magnetic separation. Wet magnetic separation was carried out to the milled products with different magnetic field intensities.

2 Results and Discussion

2.1 Single factor experiment

2.1.1 Effect of coal content in mixture on iron grade and recovery rate

5 samples of iron ore and coal mixture with coal content of 10%, 20%, 30%, 40%, and 50% were sintered, then milled and magnetically separated. The iron powder samples were subsequently obtained. The sintering temperature was set at 1 200 ℃ and the sintering time was set at 60 min. The milling fineness less than 45 μm was set at 96.19% and magnetic field intensity was set at 111 kA · m^{-1}. The results of iron grade and recovery rate are shown in Fig. 2.

It can be seen from Fig. 2 that the best results are obtained when the mixture contains 30% of coal,

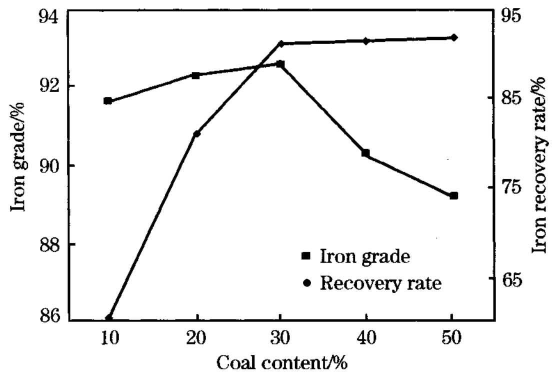

Fig. 2 Effect of coal content on iron grade and iron recovery rate

where the separated iron powder has an iron grade of 92.53%, and iron recovery rate reaches 90.78%. However, when the coal content continues to increase, the iron grade decreases sharply even though the recovery rate continues to increase slightly. It is expected that the ash components in the coal will increase along with the increase of the coal content. These inorganic components which are rich in Al_2O_3 and SiO_2 are very active owing to their very fine nature and dispersive distribution in the coal. The high temperature reaction is likely to form some ferrous silicates, ferrous aluminates and ferrous alumino-silicates such as 2FeO · SiO_2, 2FeO · Al_2O_3, and 2FeO · $2Al_2O_3$ · $5SiO_2$[9]. They might be included in the iron grains during their growth. Besides, small amount of melts would appear in this system at the temperature of 1 200 ℃, which may be filled into the spaces in and between coke grains transferring from the coal grains. The decrease of the melts in the inorganic part will depress the growth and self-purification of the iron grains, which subsequently may result in the decrease of iron grade of the final products.

2.1.2 Effect of sintering temperature

In order to evaluate the effect of sintering temperature on the iron grade and recovery rate, 7 samples with coal content of 30% were prepared. They were sintered at temperatures of 950, 1000, 1050, 1100, 1150, 1200 and 1250 ℃, respectively. The sintered products were subsequently wet milled to a fineness less than 45 μm of 96.19%, and magnetically separated at a magnetic field intensity of 111 kA · m^{-1}.

The effect of temperature on the recovery rate and iron grade of the products is shown in Fig. 3. As shown in Fig. 3, the iron grade increases continuously, but the highest value of the recovery rate appears at