Preparation and Consolidation Mechanism of Nickel Laterite Carbon Composite Hot Briquette

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Abstract. Blast furnace smelting process has advantages in producing ferronickel products because of its low comprehensive energy consumption and high production efficiency. However, laterite nickel ore has poor performance of pellets and lump ore due to its own characteristics. At present, the main lumping method is low basicity sinter, which is difficult to optimize the charge structure. This paper mainly studies the preparation process of laterite nickel carbon composite hot briquette (LN-CCHB) and the influence of process parameters on the basic compressive strength properties, so as to explore a new charge for smelting laterite nickel in blast furnace process. Results showed that the influence of pressure and temperature of hot briquette on the compressive strength of NL-CCHB is obvious. The compressive strength of NL-CCHB increases with the increase of briquetting pressure increases first and then decreases with the increase of hot briquetting temperature. The FC/O ratio (the ratio of the fixed carbon mol (C) in coal to the reducible oxygen mol (O) in iron oxides) has little effect on the compressive strength of NL-CCHB. In the experimental range, the mixture of laterite nickel ore and pulverized coal can obtain NL-CCHB with compressive strength of more than 1300N after hot briquetting. After heat treatment, NL-CCHB with compressive strength of more than 1800N can be obtained. The optimum hot briquetting process parameters are: FC/O ratio 1.25, hot briquetting temperature 450℃, hot briquetting pressure 80MPa. The optimum heat treatment process parameters are: FC/O ratio 1.50, heat treatment temperature 550℃.

1. Introduction
Nickel is the main alloy element in the production of stainless steel. At the same time, it is also the basic raw material in ternary batteries and various nickel alloys. It is widely used in industry. Nickel resources mainly exist in nickel sulfide ore and laterite nickel ore, of which about 30% are nickel sulfide ore and 70% are laterite nickel ore. With the reduction of nickel sulfide resources, the amount of nickel produced by laterite nickel ore is increasing. There are more and more researches on laterite nickel ore at home and abroad, and the treatment processes are mainly pyrometallurgy and hydrometallurgy[1-4]. The main products of pyrometallurgy are nickel matte and ferronickel. Ferronickel process route mainly includes the following two: first, rotary kiln and electric furnace process to produce high ferronickel; the other is the blast furnace process, which produces medium nickel and low nickel iron products. The blast furnace process has advantages in the production of medium and low ferronickel products due to low comprehensive energy consumption and high
production efficiency. At present, the raw material containing nickel in the blast furnace process is mainly low basicity sinter. This is due to the high content of crystal water, low content of iron and high content of silicon and aluminium in laterite nickel ore. The quality of natural lump ore and pellet is low, which does not meet the requirements of blast furnace raw materials\cite{5-7}. Studies have shown that the preparation of pellets from laterite nickel ore mixed with magnetite can significantly improve the quality of pellets. However, this method will also reduce the nickel grade of the comprehensive charge, which is not conducive to the improvement of nickel content in the final product\cite{4}.

As a new type of blast furnace burden carbon composite iron ore hot briquettes (CCB) have been proposed to achieve low-carbon and low-temperature iron production. CCB has the advantages of good reducibility, high temperature strength and strong adaptability of raw materials. The introduction of LN-CCHB into furnace charge plays an important role in improving the simple structure of charge and optimizing the basicity of sinter\cite{8-10}. Based on this, this study studied the influence of hot briquetting temperature, hot briquetting pressure and FC/O ratio on the strength of LN-CCHB, as well as the influence of heat treatment temperature and FC/O ratio on the strength of LN-CCHB.

2. Experimental

2.1. Raw materials
The chemical compositions of laterite nickel ore and bituminous coal used in the experiment are shown in Table 1 and Table 2 respectively.

| Table 1. Main chemical composition of laterite nickel ore (Weight percent). |
|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| TFe             | CaO             | MgO             | SiO₂            | Al₂O₃           | Mn              | Cr₂O₃           | Ni              | LOI             |
| 41.69           | 0.28            | 1.26            | 9.23            | 6.96            | 0.58            | 2.37            | 1.10            | 15.45           |

| Table 2. Proximate analyses of coal and chemical compositions of ash (Weight percent). |
|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| FC              | Vdaf            | Mad             | Ash (7.99)      | CaO             | MgO             | SiO₂            | Al₂O₃           |
| 61.10           | 29.65           | 1.26            | 9.16            | 0.86            | 46.23           | 32.08           |

2.2. Experimental Methods
Due to the high content of crystal water in laterite nickel ore used in the experiment, it was baked at 600 °C for 30 minutes before mixing with pulverized coal to remove most of the crystal water. Mixed with certain bituminous coal. The mixture was pressed by hot pressing die to prepare LN-CCHB. After cooling, the compressive strength of LN-CCHB under different process parameters was measured. The LN-CCHB after hot briquetting needs heat treatment to further remove volatiles and enhance compressive strength. The heat treatment was carried out in muffle furnace. After cooling, the compressive strength of LN-CCHB under different process parameters was measured.

3. Results and discussion

3.1. Effect of FC/O ratio on compressive strength of LN-CCHB
The FC/O ratio refers to the ratio of the fixed carbon mol (C) in coal to the reducible oxygen mol (O) in iron oxides. The FC/O ratio not only affects the compressive strength of LN-CCHB, but also has an important impact on the subsequent reduction of metal oxides and the coke ratio. The range of FC/O ratio selected in the experiment is 0.75 ~ 2.00. The hot briquetting temperature is 450 °C, and the hot briquetting pressure is 70 MPa. The experimental results are shown in figure 1. It can be seen from the experimental results that in the experimental range, the carbon ratio has little effect on the compressive strength of LN-CCHB. This may be because in the experimental range, the influence of other process
parameters on LN-CCHB is much greater than the FC/O ratio. Therefore, when other hot briquetting parameters remain unchanged, the compressive strength changes less with the FC/O ratio.

![Figure 1. Effect of different FC/O ratio on compressive strength of LN-CCHB.](image1)

![Figure 2. Effect of different hot briquetting pressure and temperature on compressive strength of LN-CCHB.](image2)

3.2. Effect of hot briquetting pressure and temperature on compressive strength of LN-CCHB

Hot briquetting pressure and temperature are the two parameters that have the greatest impact on energy consumption in hot briquetting process. It is of great significance to study their impact on the compressive strength of LN-CCHB. The hot briquetting pressure range is 50 ~ 80Mpa and the hot briquetting temperature range is 300 ~ 500 ℃. The experimental results are shown in figure 2. Under different pressure conditions, the compressive strength of LN-CCHB has the same trend with the change of temperature, which first increases and then decreases with the increase of temperature, and reaches the peak at about 450 ℃. This is because at about 450 ℃, bituminous coal can produce a large number of colloids with good fluidity. At this time, bituminous coal has the best adhesion to the surrounding mineral powder, so the compressive strength of the carbon-based hot briquetting block is the best when the hot briquetting temperature is about 450 ℃. At different temperatures, the compressive strength of carbonaceous hot pressed blocks also has the same trend with temperature. In the range of experimental conditions, the compressive strength increases with the increase of hot briquetting pressure. This is because the higher the pressure, the denser the LN-CCHB and the larger the contact area between the powders. At the same time, the higher the pressure, the more conducive to the flow of colloid and more effective bonding powder.

3.3. Effect of heat treatment temperature on compressive strength of LN-CCHB

According to the above research, the compressive strength of LN-CCHB after hot briquetting is relatively low, between 300 ~ 1400N. At the same time, LN-CCHB also contain a large amount of volatiles, which are not conducive to blast furnace smelting. Because bituminous coal will carbonize during heating, remove volatiles and improve compressive strength, it is necessary to heat treat LN-CCHB to improve quality. The selected heat treatment temperature range is 500 ~ 700 ℃, and the heat treatment time is 2 hours. The experimental results are shown in figure 3. Within the experimental range, the compressive strength after heat treatment first increases and then decreases with the increase of heat treatment temperature, and reaches the peak at about 550 ℃. This is because with the increase of temperature, it is conducive to the carbonization reaction, but too high temperature will destroy the strength of the formed semi coke. At the same time, the reduction reaction of metal oxide will begin, which will further destroy the tight bonding state inside the hot briquette.
3.4. Effect of FC/O ratio on compressive strength of LN-CCHB after heat treatment

In the process of heat treatment, the increase of compressive strength of LN-CCHB is mainly due to the formation of semi coke by carbonization of bituminous coal. Therefore, it is of great significance to study the effect of carbon ratio on the compressive strength of carbon containing hot pressed blocks after heat treatment. The heat treatment temperature is 550 °C and the heat treatment time is 2 hours. The FC/O ratio ranges from 0.75 to 2.00. The experimental results are shown in figure 4. Within the experimental range, the compressive strength of LN-CCHB after heat treatment increases first and then decreases with the increase of carbon ratio. This is because with the increase of carbon blending ratio, more semi coke with higher strength will be formed, and the compressive strength of hot pressed block will be improved. However, when the carbon ratio is too high, the amount of volatile during carbonization also increases, which makes more pores form in the LN-CCHB and destroys the internal dense structure, so as to reduce the compressive strength.

3.5. Microstructure of LN-CCHB before and after heat treatment

The scanning electron microscope image of the microstructure of the LN-CCHB before and after heat treatment is shown in figures 5. It can be seen from figures 5 (a) and figures 5 (b) that the coal powder inside the LN-CCHB before heat treatment is closely combined with the mineral powder, and there are few internal holes. However, since the coal is formed after cooling by colloid, its strength is weak. The appropriate temperature and large hot briquetting pressure will make the pulverized coal and mineral powder in the hot briquetting block more evenly and densely bonded together, so as to enhance the compressive strength of LN-CCHB.

It can be seen from figures 5 (c) and figures 5 (d) that the pulverized coal in the LN-CCHB after heat treatment forms a semi coke with greater strength, so the compressive strength of the Hot Briquette after heat treatment is significantly improved. But at the same time, more holes are formed in it, and the close combination state of pulverized coal and mineral powder is also destroyed. Therefore, too high heat treatment temperature and too high carbon ratio will also reduce the compressive strength of LN-CCHB.
4. Conclusions

(1) In the hot briquetting process, the change of FC/O ratio within the experimental range has little effect on the compressive strength of LN-CCHB, while the hot briquetting temperature and hot briquetting pressure have great effect on the compressive strength of LN-CCHB. This is because the pulverized coal and mineral powder in the LN-CCHB before heat treatment are closely combined, and there are few internal holes. However, the appropriate temperature and large hot briquetting pressure will make the pulverized coal and mineral powder in the LN-CCHB more evenly and tightly bonded together. The optimum process parameters are: FC/O ratio 1.25, hot briquetting temperature 450 °C, hot briquetting pressure 80MPa.

(2) In the heat treatment process, the change of FC/O ratio within the experimental range and the influence law of heat treatment temperature on the compressive strength of LN-CCHB after heat treatment are first enhanced and then reduced, which is due to the simultaneous formation of semi coke, holes and the destruction of internal structure during heat treatment. The optimum process parameters are: FC/O ratio 1.50, heat treatment temperature 550 °C.

(3) In the experimental range, the mixture of laterite nickel ore and coal can obtain LN-CCHB with compressive strength of more than 1300N after hot briquetting. After heat treatment, LN-CCHB with compressive strength of more than 1800N can be obtained. The compressive strength of LN-CCHB basically meet the use needs of small and medium-sized blast furnaces.

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