

Experimental Study on Mineral Phase Structure and Metallurgical Properties of Pellets

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Abstract

Pellet is an important part of raw materials for blast furnace. The quality of the pellet directly affects the quality of molten iron. The mineral composition and microstructure of pellets are important factors affecting their metallurgical properties. In order to improve the metallurgical properties of the pellets, this experiment studied the influence of the addition of bentonite and the calcination temperature on the mineral phase structure of the pellets. The optical microscope was used to deeply analyze the root cause of the mineral structure affecting the quality of the pellets, and the best roasting conditions are obtained. The results show that when the addition amount of bentonite is 1.4% and the roasting temperature is 1150 °C, the Fe_2O_3 grains are well developed and recrystallized, the grains are closely related, the pores are closed and uniformly distributed, the structure of the pellets is strong and resistant high compressive strength.

Keywords

Pellets, Bentonite, Roasting temperature, Metallurgical properties, Mineral phase structure

Introduction

Pellet is superior to sinter in particle size uniformity, anti-wear and iron content. It is an ideal burden structure for blast furnace [1] to be smelted with high basicity sinter. The low strength and poor reducibility of pellets produced in China affect the effect of blast furnace iron making [2-4]. Most pellets need to be imported [5-8]. Most scholars have studied the influence of roasting process parameters, roasting raw material composition and roasting equipment on the metallurgical properties of pellets [9-11]. However, there are few studies on the influence of mineral composition and microstructure on the quality of pellets.

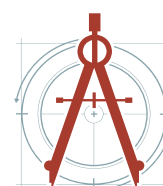
The mineral composition and microstructure of pellets are closely related to their metallurgical properties [12-14]. In this experiment, the effects of bentonite addition and roasting temperature on the properties and phase structure of pellets were investigated. The phase composition and microstructure of pellets were analyzed by polarizing microscope, and the internal influence rules were revealed, which provided theoretical basis for improving pellet quality and optimizing raw material structure.

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Accepted: March 29, 2022; **Published:** March 31, 2022

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Yang et al. *Int J Nanoparticles Nanotech* 2022, 7:038



Citation: Yang S, Sun H, Zhang T, Liu S (2022) Experimental Study on Mineral Phase Structure and Metallurgical Properties of Pellets. *Int J Nanoparticles Nanotech* 7:038

Table 1: Chemical composition of iron fines.

Composition	TFe	SiO ₂	CaO	MgO	Al ₂ O ₃	S	P	H ₂ O
Content/(%,ω)	63.52	6.21	0.42	2.10	1.12	0.568	0.11	10.86

Table 2: Particle size composition of iron fines.

Particle size	-80	-100	-200	-325
Content/(%,ω)	> 90	> 80	> 80	> 40

Table 3: Chemical composition of bentonite.

Composition	SiO ₂	CaO	Al ₂ O ₃	MgO	Fe ₂ O ₃
Content/(%,ω)	63.26	1.60	13.46	1.60	2.50

Table 4: Bentonite of addition scheme.

Number	1#	2#	3#	4#	5#	6#
Bentonite content (%,ω)	1.2	1.4	1.6	1.8	2.0	2.2

Test Materials and Methods

Test materials

The raw materials for this test are iron ore powder and sodium bentonite. The chemical composition and particle size composition of iron ore powder have been shown in Table 1 and Table 2, and the chemical composition of bentonite is shown in Table 3. It can be seen from Table 3 that the main components of bentonite are Montmorillonite $\text{Al}(\text{SiO}_4 \cdot \text{O}_{10})(\text{OH})_2 \cdot n\text{H}_2\text{O}$, and contain a small amount of quartz, mica, feldspar and kaolinite.

Test method

This experimental ingredient scheme can be found in Table 4.

Firstly, the green pellets were prepared on a disc pelletizer with a diameter of 1200 mm and an inclination of 45° according to the proportioning scheme. During the pelletizing process, the moisture content of the green pellets was controlled at 8~9%. After pelletizing test, the green pellets with diameter of 8~12 mm were selected to test the compressive strength and falling strength, at last, the pellets with different proportions were divided into five groups, which were calcined at 1000 °C, 1050 °C, 1100 °C, 1150 °C and 1200 °C. After the pellets were raised to the preset temperature, they were kept for 1 hour. The representative pellets with good test results were selected and

their phase composition and microstructure were analyzed, the optimum amount of bentonite and calcination temperature was found.

Test Results and Analysis

Effect of bentonite on metallurgical quality indices of green pellets

Bentonite is a high-quality additive, which can not only improve the drop strength and compressive strength of the green pellets, but also can regulate the moisture when the moisture of the pellets material is too high, and more importantly, it can increase the burst temperature when the green pellets is dry [15]. In this experiment, the addition of high-quality bentonite can increase the compressive strength by 2.2% under the same drying condition, the relationship between the addition amount and metallurgical properties in Figure 1.

It can be seen from Figure 1a that with the increase of bentonite content, the moisture content of green pellets increases, which is due to the fact that bentonite is easy to disperse in water after encountering water, which enhances the ability of green pellets to keep water. The suitable moisture range of magnetite pellets is 8~9%. So the optimum addition amount of bentonite is about 1.4%.

It can be seen from Figure 1b that the bursting temperature increases with the increase of bentonite content, but the increase gradually slows down, this is because the bentonite acts as a buffer in the drying stage of pellets, which can release water slowly, prevent rapid dehydration, and avoid bursting of pellets due to excessive internal steam pressure. The bursting temperature of green pellets is generally no less than 450 °C, and all the six groups of tests can meet the production requirements.

It can be seen from Figure 1c and Figure 1d that the compressive strength and falling strength of green pellets are improved to varying degrees with the increase of bentonite addition. This is because montmorillonite in bentonite can promote the formation of liquid phase, and bentonite can

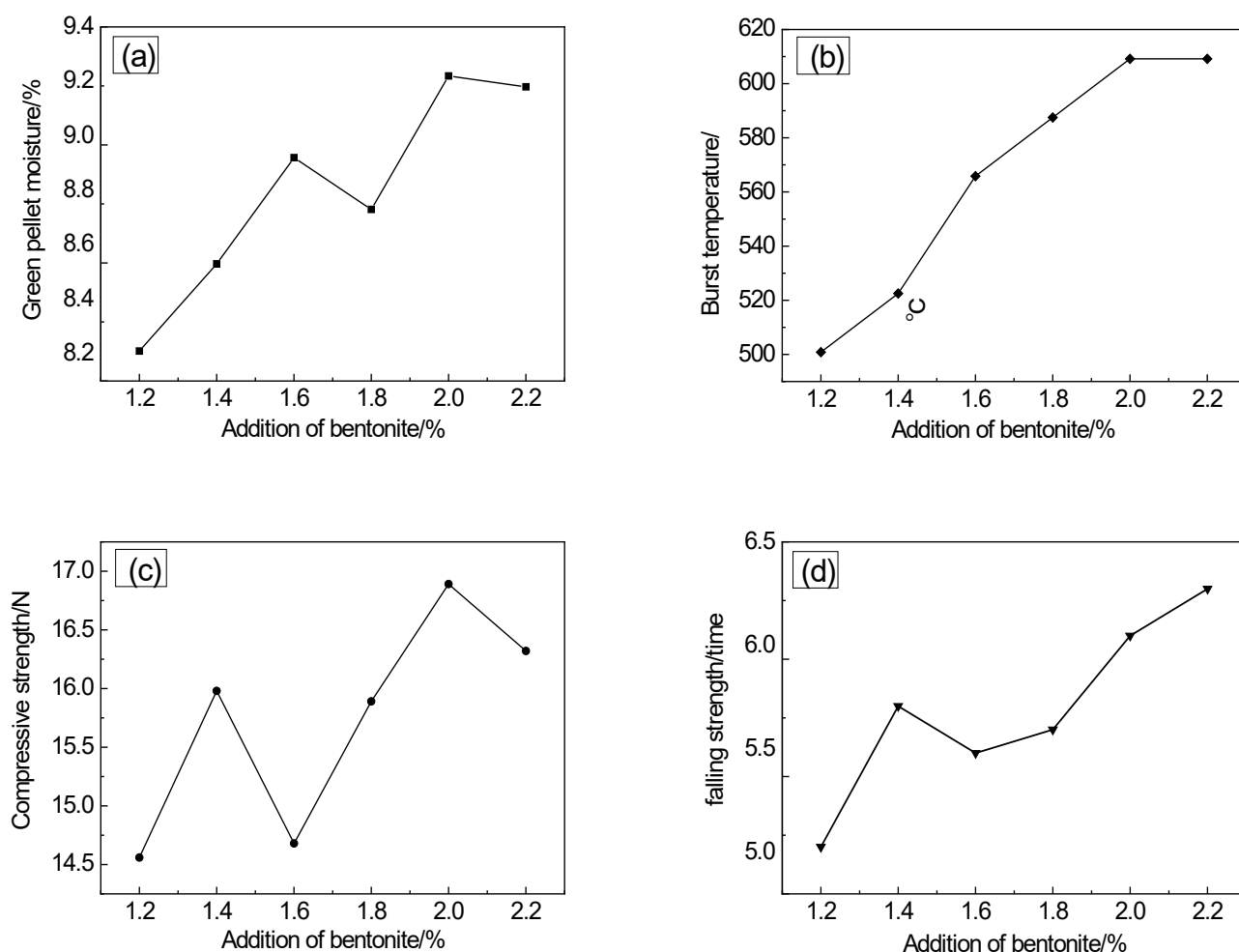


Figure 1: Effect of bentonite on quality indices of green pellets. a) Green pellet moisture; b) Burst temperature; c) Compressive strength; d) Falling strength.

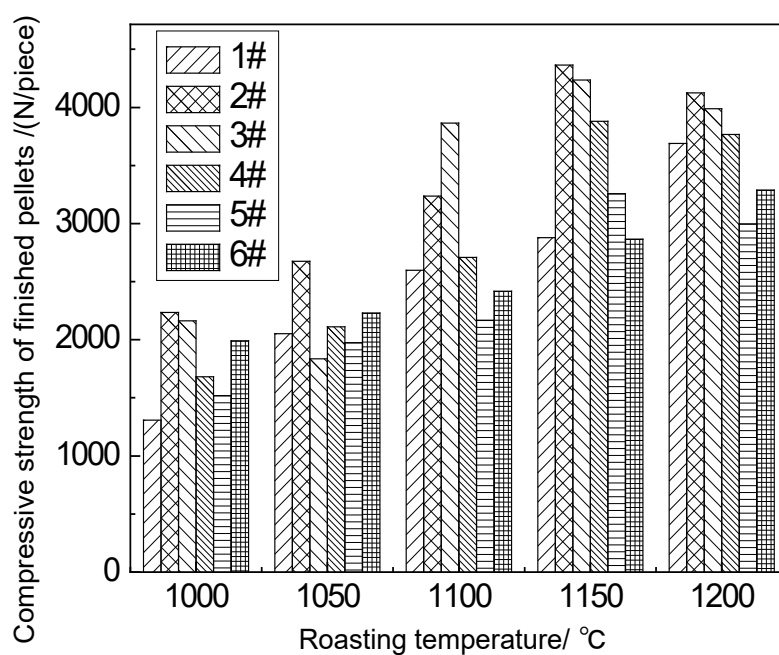


Figure 2: Effect of calcination temperature on compression strength of pellets.

change the water content in the pellet, and the water will gather in the pellet, which will reduce the distance between particles and reduce the porosity. On the whole, the six groups of samples can meet the requirements.

Effect of roasting temperature on compressive strength

In the process of pellet roasting, the change of strength reflects the essential change. In order to study the influence of roasting temperature on the compressive strength of pellets after roasting, roasting tests were carried out on six groups of samples, and then the compressive strength of finished pellets was measured. According to the test data, the comparison of compressive strength of pellets at different roasting temperatures was shown in Figure 2.

It can be seen from Figure 2 that the effect of roasting temperature on the compressive strength of pellets is more significant. When the temperature is lower, the compressive strength of each group of samples is generally low, and the effect of roasting consolidation is not achieved. With the increase of roasting temperature, the compressive strength of pellets is improved in different degrees, this is due to the oxidation of magnetite, the growth and recrystallization of Fe_2O_3 microcrystals. Slag crystallization is formed between pellets through consolidation and diffusion. When the temperature rises to complete oxidation of magnetite, the amount of recrystallization of Fe_2O_3 will increase, grow and form flakes, when the roasting temperature increases to a certain value, the compressive strength of pellets will not increase anymore.

It can also be found from Figure 2 that the compressive strength of pellets with bentonite addition between 1.4% ~ 1.8% is generally good at each roasting temperature. When the roasting temperature is 1150 °C, the compressive strength of pellets with bentonite ratio of 1.4%, 1.6% and 1.8% reaches the maximum value. Considering the economic cost, it is better to choose 1.4% bentonite.

Mineral Phase Analysis of Pellet

The metallurgical performance of pellet is the external characterization of the difference of ore phase structure. In order to study the relationship between the ore phase structure and the metallurgical properties of pellets, the ore phase of representative pellets was detected. The samples selected in this experiment are: 1000 °C, 1050 °C, 1100 °C, 1150 °C, 1200 °C in 2 ore blending scheme; 1100 °C, 1200 °C in 3 ore blending scheme; 1050 °C, 1150 °C in 4 ore blending scheme; 1000 °C, 1100 °C, 1200 °C in 5 ore blending scheme. Each group of samples was magnified 200 times under XJP-6A type polarizing microscope and then photographed for mineral composition and microstructure analysis. The analysis is as follows:

(1) At 1000 °C, the microstructure of two kinds of pellets with bentonite ratio of 1.4% and 2.0% is shown in Figure 3.

It can be observed from Figure 3 that due to the low roasting temperature, magnetite is not completely oxidized, and the crystallization of Fe_2O_3 is not perfect, resulting in more individual particles of Fe_2O_3 recrystallization. The grain development of Fe_2O_3 in Figure 3a is more perfect and evenly distributed than that in Figure 3b, and the structure

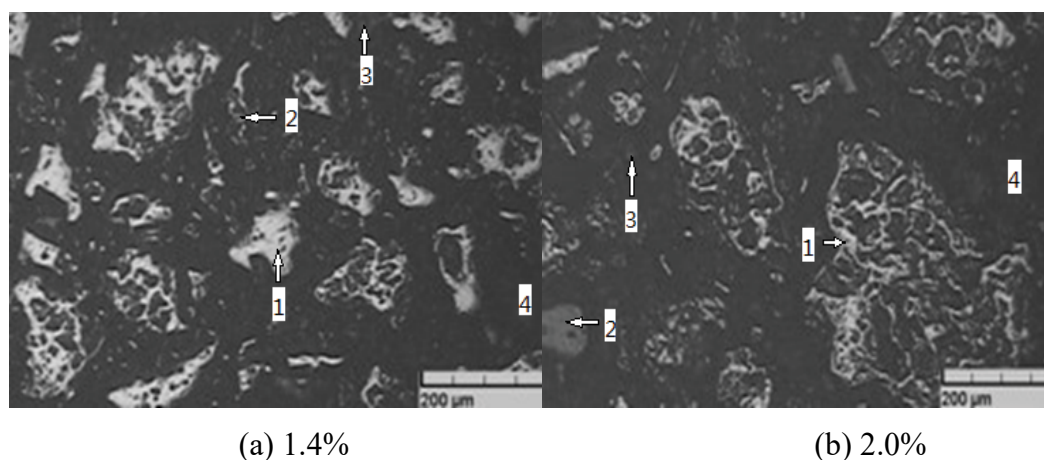


Figure 3: Pellet microstructure 1) Hematite; 2) Magnetite; 3) Calcium ferrite; 4) Hole.

of **Figure 3a** is relatively dense, the pellet strength is also higher, and the structure of **Figure 3b** is loose. The results show that Fe_2O_3 grain is still in the growth stage, there is no crystal connection and the pore size is different, so the pellet strength is also low.

(2) At 1050 °C, the microstructure of two kinds of pellets with bentonite ratio of 1.4% and 1.8% is shown in **Figure 4**.

It is observed from **Figure 4** that the grain growth angle of Fe_2O_3 in **Figure 4b** is better than that in **Figure 4a**, but the grains are not related to each other, and there are many single grains, and the structure is loose and the porosity is high. In **Figure 4a**, some Fe_2O_3 grains begin to connect with each other and the shape is regular, so the strength is higher, but the grains are still in the growth stage.

(3) The microstructure of three kinds of pellets with bentonite ratio of 1.4%, 1.6% and 2.0% at 1100 °C is shown in **Figure 5**.

It is observed from **Figure 5** that the Fe_2O_3 grains in **Figure 5a** are uniformly distributed and closely connected, and the grains are well developed and the crystal form is coarse. The grains in **Figure 5b** and **Figure 5c** are weakened. Only a few grains in **Figure 5c** develop and grow, and no large areal intergranular grains are formed. The recrystallization of most Fe_2O_3 grains is still in the development stage, and the porosity is different. In some areas, Fe_3O_4 is not oxidized completely, and the grain angle is obvious.

(4) At 1150 °C, the microstructure of two kinds of pellets with bentonite ratio of 1.4% and 1.8% is shown in **Figure 6**.

It is observed from **Figure 6** that hematite grains in the two pellets have been closely related to each other and become interconnected crystals. The grains are coarse and closely connected, which shows that the structural force of pellets is strong and the compressive strength is high. Compared with **Figure 6b**, the size of holes in **Figure 6a** is

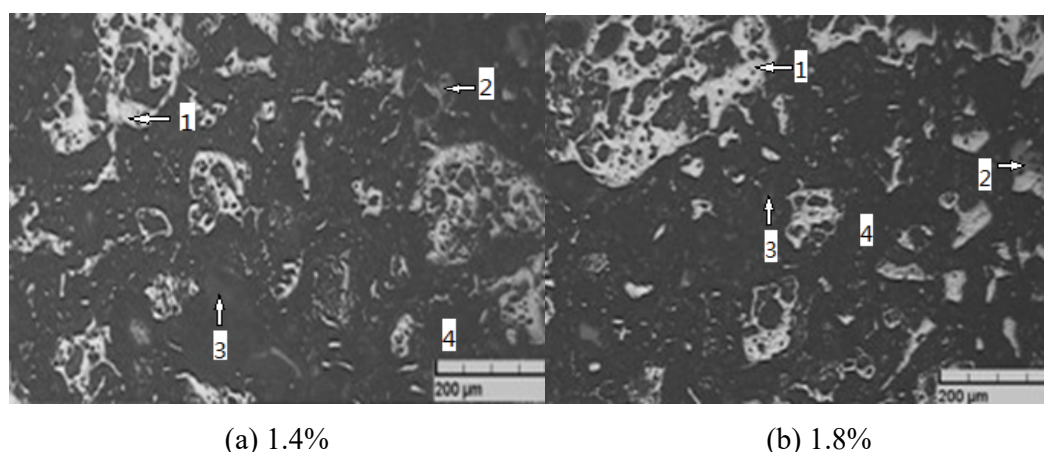


Figure 4: Pellet microstructure 1) Hematite; 2) Magnetite; 3) Calcium ferrite; 4) Hole.

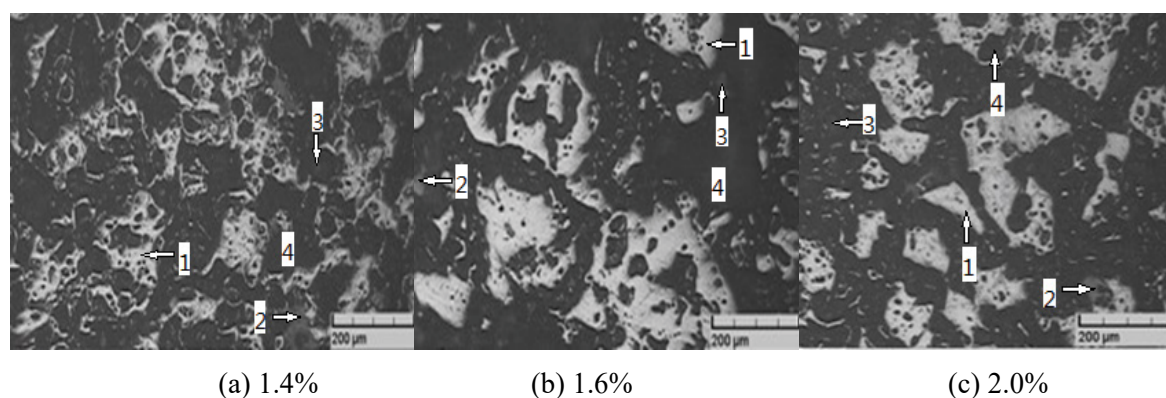
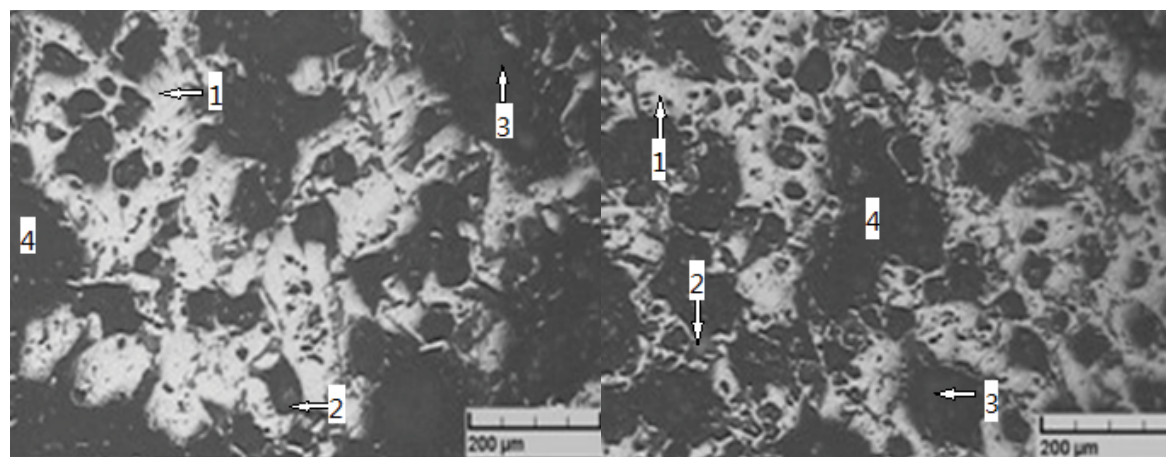
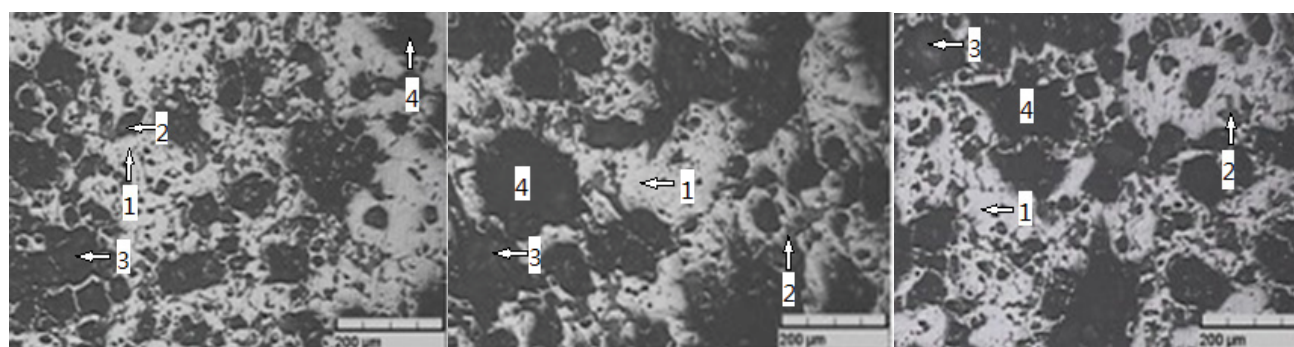


Figure 5: Pellet microstructure 1) Hematite; 2) Magnetite; 3) Calcium ferrite; 4) Hole.



(a) 1.4%

(b) 1.8%

Figure 6: Pellet microstructure 1) Hematite; 2) Magnetite; 3) Calcium ferrite; 4) Hole.

(a) 1.4%

(b) 1.6%

(c) 2.0%

Figure 7: Pellet microstructure 1) Hematite; 2) Magnetite; 3) Calcium ferrite; 4) Hole.

not uniform, and some grains still need to be interconnected. **Figure 6b** is a whole interconnected crystal with closed pores. Therefore, the pellet has high degree of consolidation and high strength.

(5) The microstructure of two kinds of pellets with bentonite ratio of 1.4%, 1.6% and 2.0% at 1200 °C is shown in **Figure 7**.

It can be observed from **Figure 7** that the Fe_2O_3 grains in **Figure 7a** have completely become intergranular crystals, and the pellet strength has been greatly improved; while the morphology of **Figure 7b** and **Figure 7c** are similar. Although the grains have been completely connected, a small part of Fe_2O_3 grains need to be fully oxidized and recrystallized to form interconnected crystals. However, the pellets in **Figure 7b** and **Figure 7c** still have high strength.

To sum up, the law of pellet consolidation

change can be obtained. That is, the effect of pellet roasting and consolidation is gradually improved with the increase of temperature. The higher the roasting temperature is, the more complete the green pellet oxidation is, and the higher the pellet strength is. And at the same roasting temperature, the consolidation effect of the sample with bentonite ratio of 1.4% is better.

Conclusion

- 1) The addition of bentonite can increase the moisture content and bursting temperature of green pellets, and improve the compressive strength and falling strength of green pellets in varying degrees. Increasing the roasting temperature can obviously improve the compressive strength of pellets, but when the temperature is higher than 1150 °C, the compressive strength will decrease.

- 2) Through roasting test and phase analysis of pellet, the optimum bentonite ratio and roasting temperature for pellet production are determined: Bentonite ratio is 1.4%, roasting temperature is 1150 °C.
- 3) The oxidation of Fe_3O_4 to Fe_2O_3 grains is a process of growth and development. Fe_2O_3 grains recrystallize and interconnect to form a whole for consolidation. The degree of consolidation gradually improves with the increase of temperature, and the strength of corresponding pellets also increases.

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