Research on Ore Blending Optimization based on the Basic Characteristics of Iron Ore Powder

Baoping Chen[1,2]
[1]*Hebei Engineering Research Center for the Intelligentization of Iron Ore Optimization and Ironmaking Raw Materials Preparation Processes, North China University of Science and Technology, Tangshan 063210, China*
[2]*College of Metallurgy and Energy, North China University of Science and Technology, Tangshan 063210, China*

Abstract: In order to explore the impact of the chemical ingredients of ore powder on basic properties and guide production to optimize ore blending. This article takes common mineral powder raw materials produced by a steel company as the research object, and conducts experimental tests on the features of high-temperature sintering of raw materials. The result shows that the chemical composition of ore powder itself will have a great impact on its high-temperature basic properties. The high mass fraction of SiO_2 will improve the assimilation performance and flow performance of ore powder. The bonding phase strength first rises and subsequently falls as the SiO_2 mass fraction increases. Iron ore powder containing a higher MgO mass fraction will deteriorate the basic performance. Based on the research results, an ore blending optimization experiment was conducted to adjust the raw material ratio, increase the ratio of E mineral powder with superior high-temperature performance, and reduce the content of F mineral powder.

Keywords: Sintering; Basic Characteristics; Iron Ore Powder; Ore Blending Optimization

1. Introduction

With the massive mining of ore containing iron, the grade of iron ore available in the market continue to decline. As a crucial component in the production and smelting processes of blast furnaces, sinter's quality will directly affect whether blast furnace production can proceed smoothly. Therefore, how to achieve a reasonable combination of iron ore powders to optimize the ore blending has become the focus of current research. Practice has proved that the basic properties of mixed mineral powder raw materials can directly affect the performance of the final sintered ore. Many scholars have conducted in-depth research, Liu Donghui et al. Explored the correlation between the fundamental characteristics of ore powder and those of sinter using micro-sintering tests and sintering cup tests. [1] . Ma Hui et al. Examined the impact of mineral phase structure and chemical ingredients on the assimilation of commonly used iron ores in Angang, and carried out optimization experiments for ore blending [2] . Liu Chengsong et al. Explored the high-temperature characteristics and influencing factors of six types of iron ore powder, and introduced the principle of complementary optimization for ore blending. This theoretical foundation contributes to the optimization of sintering ore blending[3] . This article conducts research experiments on the fundamental sintering properties of eight commonly used types of ore powders in a steel company. The aim is to investigate the connection between the chemical ingredients of the raw materials and key sintering properties. By adjusting the raw material ratio of mineral powder to improve the basic characteristics of the mixture, the purpose of optimizing the ore blending is achieved. Finally, sintering cup experiments are conducted to verify the raw material ratio schemes before and after the change.

1.1 Experimental Raw Materials

The ore powder raw materials used in this test are all from ore powder often used in actual production by a steel company. Among them, A, D, F, G, and H are from Australia, B is from South Africa, C is from India, and E is from Brazil. Table 1 presents the primary chemical composition and burning loss of raw materials.

Table 1. Main Chemical Ingredients of Mineral Powder Raw Materials

Mineral powder	TFe(%)	CaO(%)	SiO_2(%)	Al_2O_3(%)	MgO(%)	P(%)	S(%)	LOI
A	59.02	0.11	6.05	3.15	0.13	0.052	0.031	5.2
B	57.07	0.02	12.39	2.50	0.07	0.047	0.034	1.0
C	56.10	0.06	6.35	6.78	0.08	0.057	0.010	6.5
D	60.50	0.01	4.46	2.64	0.19	0.102	0.037	4.9
E	55.54	0.02	11.98	2.89	0.12	0.068	0.013	3.4
F	60.30	0.07	4.26	2.46	0.20	0.096	0.004	4.5
G	56.82	0.05	6.63	2.94	0.09	0.068	0.016	9.0
H	59.95	0.01	4.83	2.47	0.09	0.075	0.009	6.6

The iron content in the experimental ore powder exceeds 55%, among which D iron grade is the highest, reaching 60.50%; B and E mineral powders have the highest SiO_2 content, 12.39% and 11.98% respectively; Mineral powder F and mineral powder D have relatively high MgO contents, 0.20% and 0.19% respectively; mineral powder C has the highest Al_2O_3 content, accounting for 6.78%. the content of other ingredients is relatively low.

1.2 Experimental Method

Using micro sintering test to test the basic properties of iron ore, mainly refer to the high-temperature physical and chemical properties presented during the sintering process. Before the experiment, all experimental iron ore powders were sieved with a sieve reduce to a particle size smaller than 0.075 mm, and dried at 120°C for 120 minutes prior to utilization. The results of each set of experiments below are the average results of three experiments.

1) Assimilation performance: First, take 0.8g of ore powder to make a 8mm diameter cylinder, then take 2g of CaO sample to make a 20mm diameter cylinder, place the prepared iron ore powder cylinder in the center position directly above the CaO cylinder. Enter the heating stove and heat in accordance with the established parameters. the temperature when the ore powder cylinder and CaO form an obvious liquid phase is used as the minimum assimilation temperature of the iron ore powder.

2) Liquid phase fluidity: Mix the ore powder and CaO according to the binary alkalinity R=4.0, then take 0.8g of the ore powder raw material to make an 8mm diameter cylinder and put it into the test furnace for sintering at 1280°C for 4 minutes. The formula for calculating the liquid phase fluidity index is as follows:

$$L = \frac{(S_2 - S_1)}{S_1} \quad (1)$$

In the formula: L is the liquid phase fluidity index; S_2 is the flow area; S_1 is the original area of the cake.

3) Bonding phase strength: Mix CaO and mineral powder raw materials according to R=2.0, make a sample cake with a diameter of 8mm, and then put it into the test furnace for sintering at 1250°C for 4 minutes. Place the sintered sample cake on the crush strength device and measure its compressive strength value. Use this value to indicate the intensity of its bonding phase.

2. Experimental Results and Analysis

2.1 Assimilability

Assimilation reflects the capability of ore powder to interact with CaO in other substances (usually flux or other solid materials) during high-temperature processes such as smelting or sintering. The lower the assimilation temperature of mineral powder raw materials, the easier it is to produce more liquid phases during high-temperature smelting[4] . Figure 1 shows the test results of the lowest assimilation temperature for the ore powder raw materials for testing, from high to low is D>F>H>A>G>C>E>B. Among them, D and F iron ore powders have higher assimilation temperatures, while B and E iron ore powders have lower assimilation temperatures. the experimental iron ore powder assimilation temperature is between 1230°C~1290°C.

The variation in basic properties among different ore powders primarily stems from the differing chemical compositions of the raw materials. Figure 2 illustrates that the lowest assimilation temperature of ore powder shows a negative correlation with the SiO_2 mass fraction. When the SiO_2 content is low, the ore powder's minimum assimilation temperature is elevated. With increasing SiO_2 content, the assimilation temperature gradually decreases. SiO_2 promotes the formation of a liquid phase and its high reactivity with CaO plays a vital role in the creation of calcium ferrite. Significantly raises the assimilation temperature of ore powder. As depicted in picture 3, the minimum assimilation temperature of ore powder exhibits an ascending pattern with the rise in the mass score of MgO, and the content has a negative impact on the assimilation temperature. MgO possesses a high melting point, which requires a higher heat to melt during sintering. the increase in MgO content will affect the oxidation of Fe_3O_4, reduce the generation of calcium ferrite, resulting in the deterioration of the assimilation temperature of the mineral powder[5] . As Figure 4 illustrates, due to the experimental challenges in isolating the impact of a single factor on assimilation temperature, no consistent correlation is found between the Al_2O_3 percentage and the assimilation temperature of ore powder.

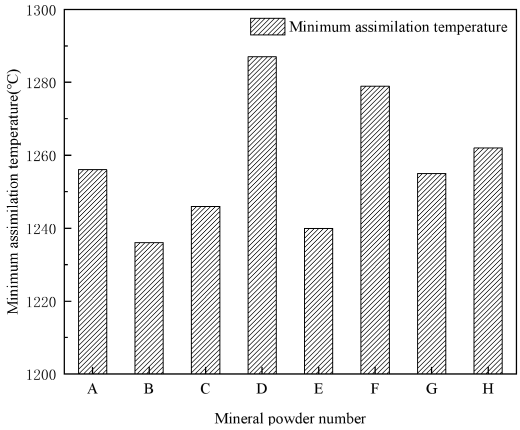

Figure 1. Minimum Assimilation Temperature of Test Raw Materials

2.2 Liquid Phase Fluidity

The liquid phase fluidity index expresses the flow characteristics resulting from the interaction between mineral powder and CaO during high-temperature processes like sintering and smelting. the larger the fluidity index value, the stronger the ability to generate a liquid phase[6] . Figure 5 illustrates the liquidity index experimental test outcomes of the test raw materials. The fluidity index of the test raw materials is arranged in descending order: B>E>A>G>C>H>F>D. Among them, B has the best flow performance, which is 9.61, and D has the worst flow performance, which is 0.1.

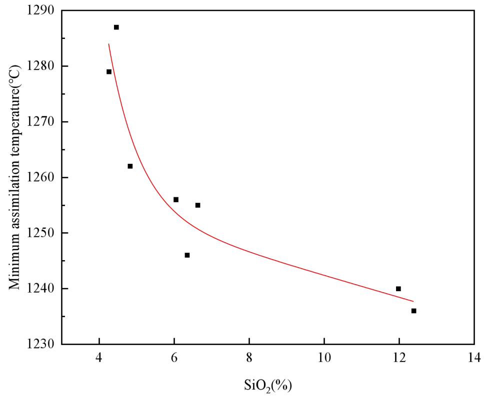

Figure 2. The Relationship Between the Minimum Assimilation Temperature of Test Mineral Powder Raw Materials and SiO_2 Content

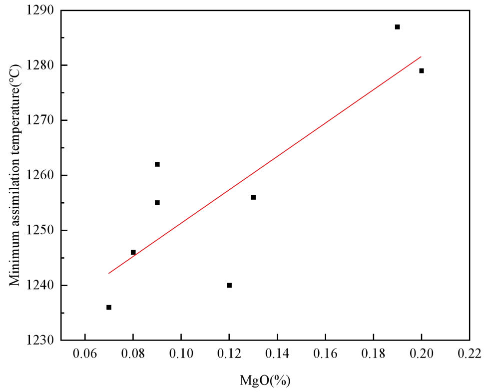

Figure 3. The Relationship Between the Minimum Assimilation Temperature of Test Mineral Powder Raw Materials and MgO Content

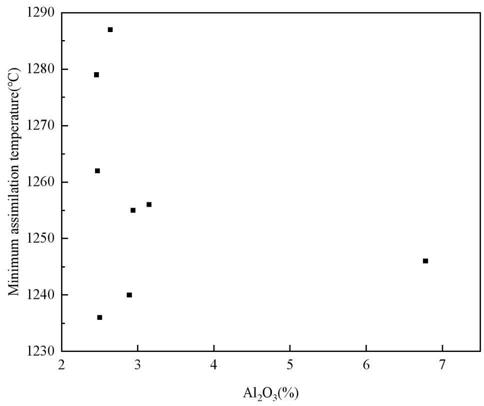

Figure 4. The Relationship Between the Minimum Assimilation Temperature of Test Mineral Powder Raw Materials and the Al_2O_3 Content

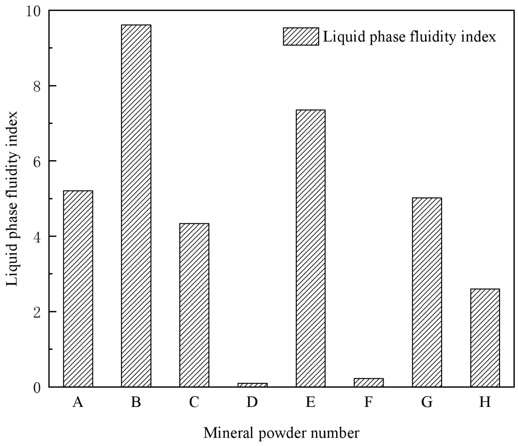

Figure 5. Liquid Phase Fluidity Index of Test Mineral Powder Raw Materials

Figure 6 reveals a positive correlation between the liquidity index and the SiO_2 mass fraction. SiO_2 is the main factor forming the bonding phase during high-temperature smelting. Under certain conditions of alkalinity, A high SiO_2 content promotes the creation of low melting point compounds like fayalite, leading to the formation of a liquid phase and consequently increasing the liquid phase fluidity index[7] . Figure 7 illustrates a decrease in the liquidity index with increasing MgO content. The rise in MgO content elevates the melting temperature of ore powder, this reduction in the quantity of liquid phase produced at the same temperature subsequently affects the liquidity index of ore powder.

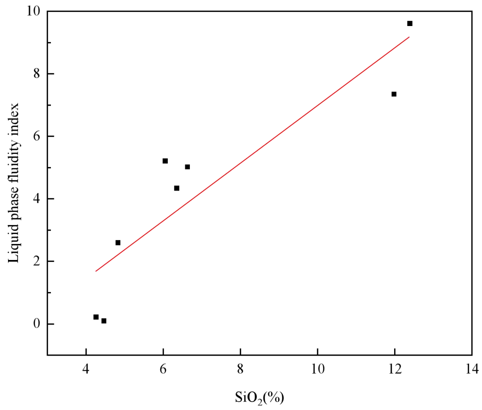

Figure 6. Effect of SiO_2 Content of Test Mineral Powder Raw Materials on Liquid Phase Fluidity

2.3 Bonding Phase Strength

The bonding phase strength pertains to the capacity of the liquid phase formed during the cooling process in sintering and smelting to bond with the surrounding ore. In contrast, the assimilation and liquidity index showcase how ore powder affects the quantity of the bonding phase during sintering, at the same time, the bonding phase strength reflects the quality of the bonding phase within the iron ore itself[8] . The bonding phase strength test results for ore powder are illustrated in Figure 8. In terms of bonding phase strength, the order from highest to lowest is G > C > A > B > H > E > F > D.

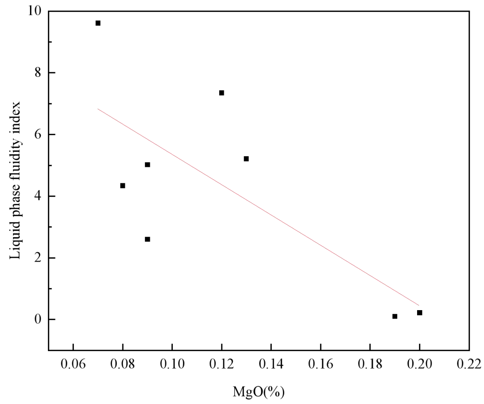

Figure 7. Effect of MgO Content of Test Mineral Powder Raw Materials on Liquid Phase Fluidity

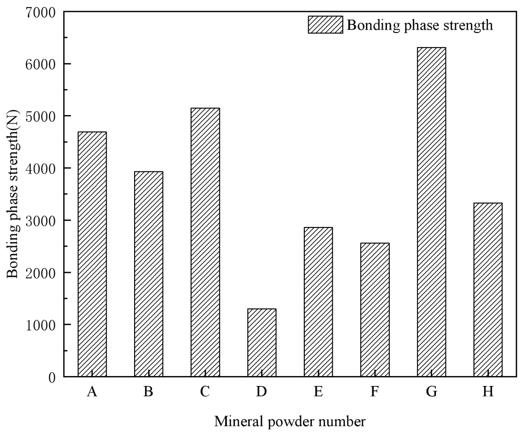

Figure 8. Test the Bonding Phase Strength of Mineral Powder Raw Materials

Figure 9 reveals that the bonding phase strength of iron ore powder initially rises and then declines with a raise in the SiO_2 mass score. Adding SiO_2 content in moderation facilitates the creation of a liquid phase, subsequently enhancing the bonding phase strength. However, if the SiO_2 is too high, a large amount of dicalcium silicate will be generated during the sintering process. Dicalcium silicate experiences a phase transition and expands in volume during the cooling stage, affecting bonding phase strength of the ore powder. Figure 10 illustrates that an elevated mass fraction of MgO results in a decline in the bonding phase strength. The melting point of MgO is as high as 2852°C. During the sintering process, free MgO will not melt to form a liquid phase, affecting the bonding phase strength.

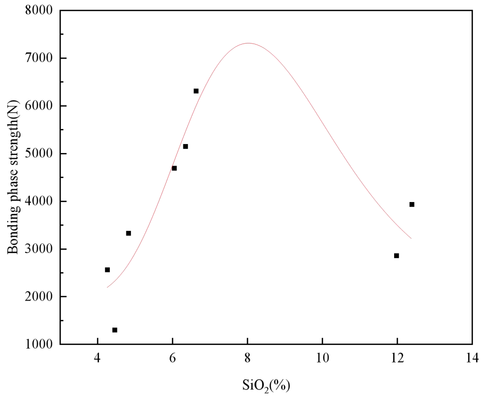

Figure 9. Relationship Between Iron Ore Powder Bonding Phase Strength and SiO_2 Content

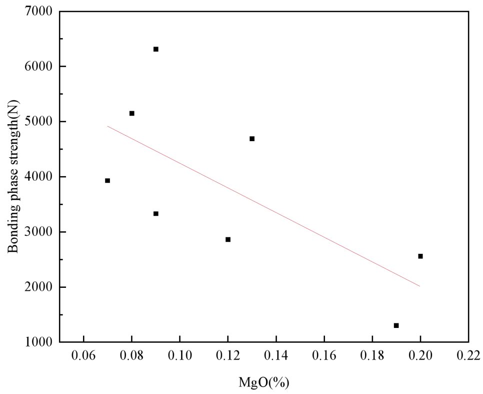

Figure 10. Relationship Between Iron Ore Powder Bonding Phase Strength and MgO Content

Utilizing the experimental findings regarding the fundamental characteristics of experimental raw materials, adjustments and optimizations were made to the percentage of sintered ore powder, and the sinter cup experiment was conducted to verify the optimization results. Table 2 shows that the ore blending optimization experiment involved an increase in the proportion of E ore powder and a reduction in the percentage of F ore powder. Compared with F, Mineral powder E has a lower assimilation temperature and better liquid phase fluidity, which makes up for the lack of basic sintering properties of mineral powder F. Since the SiO_2 content of E ore powder is high, while adjusting the ore powder ratio, adjust the limestone ratio to ensure consistent alkalinity, and keep the alkalinity at 1.9 for the ore blending optimization experiment. Table 3 indicates that the drum index of the optimized sinter has increased by 1.2 percentage points, the yield has increased by nearly 1 percentage point, and the low-temperature reduction powdering rate and load softening performance have been improved. The optimized experimental findings demonstrate that this approach of proportionally adjusting the ore powder can successfully attain the overarching objective of enhancing sintering performance. Moreover, this method obviates the need for laborious calculations and exhibits notable applicability and superiority in optimizing sintering performance. As a result, it can be effectively applied to promote and advance steel enterprises.

3. Ore blending Optimization Research

Table 2. Iron Ore Powder Ratio before and after Optimization

Mineral powder	E	F	A	C	D	G	Limestone
Before adjustment	4.0	15.0	21.0	4.0	16.0	9.0	3.4
After adjustment	11.0	8.0	21.0	4.0	16.0	9.0	4.2

Table 3. Comparison of Sintering Performance before and after Optimization

Sintering properties	Drum index	Yield	$RDI_{+3.15}$	Softening start temperature	Softening range
Before adjustment	68.0	78.7	75.0	1162	106
After adjustment	69.2	79.6	78.1	1155	111

4. Conclusions

1) An investigation was conducted into the basic characteristics of eight types of iron ore powders universally employed in real-world production by a steel company. The findings reveal a strong association between the basic characteristics of iron ore powder and its unique chemical ingredients. Variations in chemical composition among different iron ore powders lead to significant disparities in high temperature basic characteristics.

2) With an increase in mass percentage of SiO_2 in ore powder, there's a rise in the liquid phase quantity production, facilitating the formation of low-melting point compounds.

Consequently, this leads to a reduction in the minimum assimilation temperature of iron ore powder and an augment in the liquidity index. An appropriate SiO_2 content enhances the bonding phase strength. However, excessive SiO_2 can result in the generation of dicalcium silicate, which in turn diminishes the bonding phase strength.

3) An excessively high MgO content elevates the melting point of ore powder, leading to an increase in assimilation temperature. This, in turn, reduces the amount of liquid phase produced, resulting in poor fluidity of the liquid phase, and ultimately weakening the bonding phase strength.

4) The ratio of iron ore powder in the sintered cup was optimized using the test results of the fundamental characteristics of sintering raw materials. The drum index of the optimized has increased by 1.2 percentage points, the yield has increased by nearly 1 percentage point, and the low-temperature reduction powdering rate and load softening performance have been improved.

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