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SINTERING CHARACTERISTICS OF IRON ORES WITH ADDITION OF LATERITE NICKEL ORES

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Abstract

A great deal of iron ores which have special elements have been applied in the sintering process with the decreasing of high-grade quality iron ores resources. In this paper, the laterite nickel ores were added into three different kinds of iron ores respectively to make liquid phase formation research by software of Factsage and high temperature characteristic sintering experiments. The results showed that the adding proportion of laterite nickel ores should be less than 15% when the high temperature properties of the mixing ores were well. Increasing the mixing ration of laterite nickel ores in the sintering blending would play an important role in the reduction of the sintering cost.

Introduction

With the decreasing profit of the steel industry, the iron ores that have special elements have been used in the sintering ore blending process to decrease the cost of production in the iron and steel plant in China. The iron ores that have special elements have low TFe and high gauge content while the special elements are beneficial to the special steel-making with the advantages of low cost and so on. Hence, some researchers have studied the sintering process with adding the laterite nickel ores, sea sand ores, etc. in the sinter blending process to obtain the proper blending ratio of the iron ores that have special elements in order to decrease the cost and increase the production efficiency of iron-making system [1-3].

In present, the laterite nickel ores are used in the sintering blending production in some sinter plants of China. The nickel content varies in different laterite nickel ores. In some researches, when the adding ratio of high Fe low nickel of laterite nickel ores was less than 5% in the sinter blending, the various economic indicators and blast furnace production were well. The RDI could be improved and the cold strength and RI would be worse with the high proportion of laterite nickel ores. It is beneficial to lower the cost and improve the value of hot metal by increasing the adding ratio of laterite nickel ores in the sinter blending process [4-5].

In this article, the laterite nickel ore which is high nickel, low Fe and high water content (33.47%) was used to study the addition available of blending in the sintering process. The basic characteristic of the laterite nickel ore and three other typical iron ores were studied, and the high temperature characteristic experiments by adding the different proportion of laterite nickel ore to the other three iron ores were carried out as well. The proper laterite nickel ore blending ratio range can be obtained by analyzing the behavior of high nickel and low Fe of laterite nickel ore in the sintering process and the influence trend of the high temperature characteristic of iron ores.

Experimental

Materials

Hematite Ore A, limonite Ore B, magnetite Ore C and laterite nickel Ore D were used in the present experiment. Chemical compositions of each iron ore are listed in Table I. Ore A was a typical Brazilian hematite with TFe 63.26% and low silica and aluminum. Ore B was a typical Australian limonite characterized with high silica, burning loss and porous structure. Ore C was a kind of magnetite which was from Peru with TFe 69.43% and low gauge content. Ore D was a high nickel low TFe kind of laterite nickel with high silica and magnesium.

Table I Chemical compositions of iron ores (mass %)

Material	TFe	FeO	SiO_2	Al_2O_3	CaO	MgO	Ni	Ig	Type
Ore A	63.26	0.27	3.11	1.38	1.58	0.5	-	3.68	hematite
Ore B	57.23	0.40	5.59	1.36	0.22	0.21	-	9.46	limonite
Ore C	69.43	29.30	1.43	0.28	0.53	0.74	-	0.03	magnetite
Ore D	22.96	0.27	36.98	2.58	0.20	14.78	2.11	11.51	laterite nickel

Methods and facilities

The amount of liquid phase formation of the four iron ores was calculated by Factsage thermal software. The calculation temperature range was between 900~1300°C. The iron ores were crushed into the size less than 100 mesh, and then analyzed by X-ray diffraction analysis (XRD) to make a qualitative mineral composition analysis. The facility of X-ray diffraction was TTRIII multifunctional X-ray diffraction which used CuKα, scanning angle 10~90°, wavelength 0.15406nm. The high temperature characteristic experiments included the assimilation and fluidity. The iron ore which was less than 100 mesh was mixed firstly based on the different adding ratio of the Ore D into the other three iron ores. After that, the mixing iron ore was poured into the mold and agglomerated in a diameter of 8mm and 5mm high by a hydraulic jack to make the sinter sample. The pressure of the hydraulic jack was about 15MPa and the weight of each sample was 0.8g.The analytical CaO was compressed into a tablet with a diameter of 10mm and 2mm high as well under the iron ore sinter sample. In sequence, the material was sent to an infrared image furnace to simulate sintering thermal profile. Hence, the assimilation temperature of each iron ore was obtained by observing the iron ore reacts with the CaO tablet. The fluidity experiment was carried out with the mixing iron ore by adding analytical CaO and the same sinter sample making process as the assimilation experiment. The binary basicity and weight of each sample was 4.0 and 0.8g. Then the sample was set on the surface of the sheet which was made by alloy steel and heated to three different peak temperature in the infrared image furnace. The area of the melt formed on the sheet was measured with projection method. The fluidity index of the iron ore was calculated by the Eq. (1).

$$Fluidity = \frac{S_2 - S_1}{S_1} \tag{1}$$

Where, S_1 is the vertical projection area of original sinter sample, mm^2. S_2 is the vertical projection area of the sintered sample. The sintered sample was made into light sheet and analyzed by the reflective microscope to get the mineral structure of the sintered sample.

Results and Discussion

Liquid phase formation

Figure 1 shows the amount of liquid phase formation with the temperature range of 900~1300°C. It shows that the amount of liquid phase formation of Ore D was the highest with the number of 46.287% and the other three iron ores were almost 0 when the temperature was 900°C. With the temperature increased, the amount of liquid phase formation was with a linear increasing trend and the amount of it was 86.892%. The amount of liquid phase formation of Ore B increased sharply from the temperature of 1150°C and the amount of it was highest of the four iron ores with the number of 97.816% at the temperature of 1300°C which was related with the limonite Ore B itself. The crystal water of Ore B decomposed tremendously and formed larger pores with the temperature increasing which resulted in the rise of liquid formation. The liquid phase formation ability of Ore D was weak at the low temperature and it started to form liquid at 1150°C. Before the temperature of 1150°C, the liquid phase line of Ore A was same as Ore B while the liquid phase formation ability of Ore A was weaker with the temperature increased compared with Ore B which was consistent with the liquid formation characteristic of hematite and limonite ores.

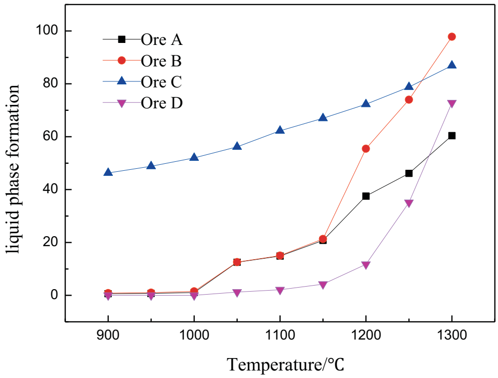


Figure 1. The relationship between the liquid formation and temperature of iron ores

XRD analysis

Figure 2 and 3 show the XRD results of the 4 iron ores. It can be seen that most of the characteristic peaks of Ore A, B and C is consistent with the chemical composition of each iron ore. As shown in Figure 3, there exists many different kinds of mineral types of Ore D which includes garnierite($(Ni, Mg)_3Si_2O_5(OH)_4$), clinochrysotile($Mg_3Si_2O_5(OH)_4$), antigorite($(Mg, Fe)_3Si_2O_5(OH)_4$), goethite, hematite, magnetite, quartz and the like.

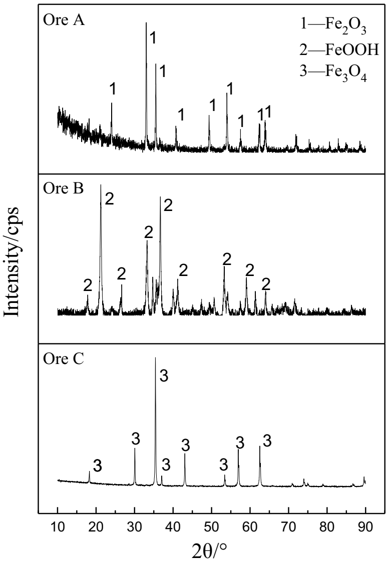


Figure 2. XRD results of the Ore A, B and C

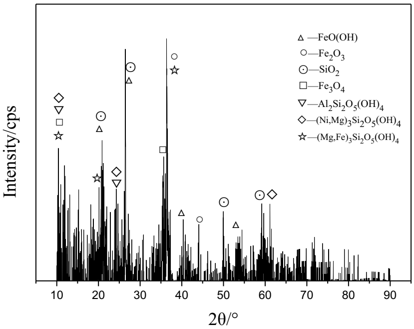


Figure 3. XRD result of Ore D

Assimilation

The assimilation of the iron ore is defined as the reaction ability of iron ore with CaO during the sintering process which represents the ease of generating liquid phase. The low assimilation temperature (LAT) usually represents the assimilation ability and the lower LAT is, the better assimilation of the iron ore. The three mixed iron ore LAT results are shown in Figure 4.

As shown in Figure 4, the LAT of Ore A, B and C is consistent with the study results before. The LAT of Ore B is the lowest due to the crystal water decomposes and increases the porosity of the limonite Ore B which promotes the reaction between the iron ore and CaO. In contrast, Ore C is a typical magnetite iron ore which is high TFe and relatively dense result in the worse reaction ability. In addition, the higher MgO content in Ore C inhibits the generation of calcium ferrite which is bad to the assimilation and the LAT of the Ore C is the highest. The LAT of Ore A is moderate which is similar to the hematite type iron ore.

The LAT of the three mixed ore increases with the adding ratio of Ore D. The influence of Ore D on the mixed ore assimilation mainly reflected in its crystal water content and chemical composition. Ore D contains an amount of crystal water and high burning loss. When the temperature increases, the crystal water decomposes and the porosity increases which makes the assimilation easier to carry out. But there exists higher MgO content in the Ore D results in the generation of high-melting substances which influences the assimilation of iron ore. The MgO also promotes the decomposition of hematite to magnetite which inhibits the calcium ferrite formation. According to the assimilation results, the inhibitory effect of the high-melting material generated by the MgO is much greater than the promotion effect of the porosity generated by the decomposition of crystal water on the assimilation of the iron ore.

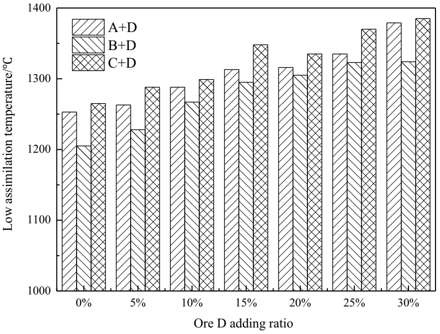
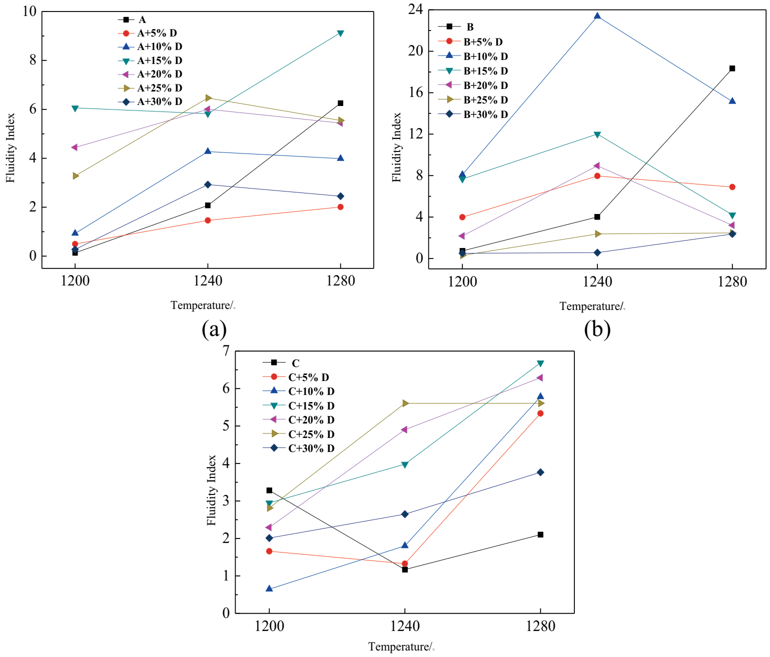


Figure 4. The assimilation temperature comparison of the three mixed iron ores

Fluidity

Figure 5 shows the three mixed ore fluidity index (FI) results. It can be seen that the FI of Ore A and D increases with the temperature increases when the adding ratio of Ore D less than 15% while the FI increases then drops with temperature increasing when the adding ratio more than 15%. The mixed ore FI is higher than that of Ore A when the Ore D blending ratio is 15% at 1280°C, R=4.0, thus the addition of Ore D inhibits the fluidity of Ore A. The FI of Ore B and D firstly increases and then decreases with temperature increasing when the blending Ore D 10% is the mostly obvious which is beneficial to improve the fluidity of Ore B. The FI of Ore C and D is gradually rising trend with increasing temperature. It is obvious to find that the adding ratio of Ore D more than 10%, the FI of mixed ore increases and the fluidity of Ore C improves as well. The fluidity ability plays a complementary effect when added the Ore D to Ore B or C, respectively. The Ore B liquid phase formation drops with the Ore D added because the large amount of MgO content in Ore D results in more high-melting material formation. The Ore B liquid phase formation increases with the Ore D added due to a great deal of SiO_2 in Ore D which makes more low-melting material formation in Ore C.



(a) (b)

(c)

Figure 5. The fluidity index comparison of the three mixed iron ores

Calcium ferrite formation characteristic

The mineral phases were detected based on the assimilation and fluidity experiment results of some mixed ore sintered samples. The amount of silicon ferrite calcium and aluminum (SFCA) and mineral phase distribution are shown in Table 2 and Figure 6, respectively.

Figure 6(a) shows that a great deal of corroded calcium ferrite exists and some calcium ferrite, hematite and magnetite corroded together with little silicates existence. Figure 6(b) indicates that a little block calcium ferrite distributes with magnetite and the amount of silicates increase sharply.

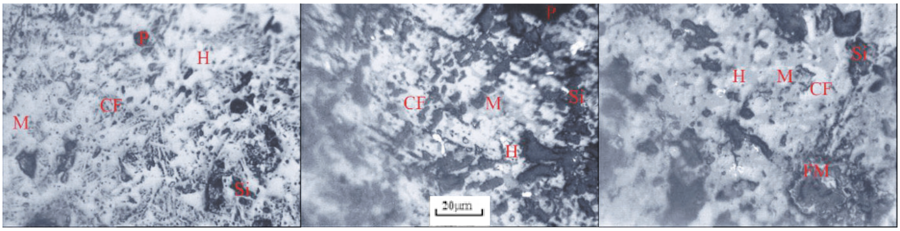
As shown in Figure 6(c), the amount of calcium ferrite is small and most of it distributes with magnetite together while there exists a large amount of magnesium ferrite. Figure 6(d) shows that hematite and silicates distribute together densely and the amount of silicates increases heavily.

Figure 6(e) indicates that magnetite is the major mineral phase with magnesium ferrite and silicates distribute in it and there exists some pitting like calcium ferrite. As shown in Figure 6(f), the calcium ferrite bonding phase is little while the magnesium ferrite and silicates are the main bonding phase.

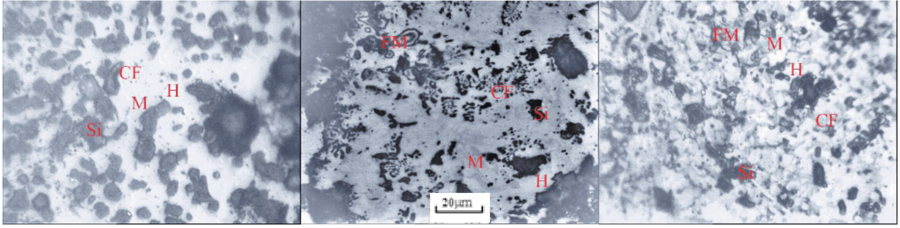
It can be included that there exists a large amount of corroded calcium ferrite when the adding ratio of Ore D is less than 5% which indicates that the Ore D almost has no impact on the sinter mineral phase. There still exists some pitting like calcium ferrite which ensures the bonding phase of the sinter mineral phase when the adding ratio of Ore D is 15%. But there is also some existence of magnesium ferrite that is related to a certain MgO content of Ore D. Not only the amount of calcium ferrite decreases rapidly but the amount of silicates and magnesium ferrite increase sharply when the adding ratio of Ore D more than 20% which reduces the sinters strength significantly.

Table II The amount of SFCA in sintered specimens，%

Number	a	b	c	d	e	f
SFCA amount	22.3	13.3	12.8	5.7	11.5	3.5



(a) A+5%D (b) A+15%D (c) B+15%D



(d) B+20%D (e) C+15%D (f) C+25%D

H-hematite，M-magnetite，CF-calcium ferrite，Si-silicates，FM-magnesium ferrite，P-pores

Figure 6. Calcium ferrite formation characteristics comparison of some sintered samples

Conclusions

(1)The basic characteristic of different kinds of iron ore varied widely based on the chemical composition, XRD and Factsage thermal calculation analysis. The liquid phase formation ability of Ore B was better and Ore A was worse. The liquid phase formation ability of Ore C and Ore D was moderate.

(2)The high temperature characteristic of different kinds of iron ore varied as well. The LAT was gradually rising of the mixed sintering ore with the Ore D adding ratio increasing. The liquid phase formation ability of Ore B and Ore C was improved by adding Ore D.

(3)When the ratio of the added Ore D was less than 15% in the mixture, it would have little effect on the high temperature characteristic of the blending iron ores, which contributed to lower the sinter blending cost.

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