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INFLUENCE OF MINERALOGICAL CHARACTERISTICS OF IRON ORE ON FORMATION AND FLOW OF LIQUID PHASE

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Abstract

The mineralogical characteristics of iron ores can influence their high temperature sintering performance. In this study, eight iron ore samples from Brazil, Australia, and South Africa were characterized by their chemical composition, mineral types, particle morphology, and gangue dispersity. Meanwhile the influence rules between the mineralogical characteristics and the high temperature characteristics were evaluated and analyzed. The results showed that the effect of SiO_2 on assimilation characteristic of iron ores was relatively complex, Al_2O_3 and LOI of iron ores had negative correlation with assimilation temperature of iron ores, the dense slab-flaky mineral granule restrained to the assimilation characteristics of iron ores; liquid phase of iron ores with high SiO_2 content and low Al_2O_3 content had high fluidity, and the higher dispersity of gangue minerals in iron ores was good to the fluidity of liquid phase.

Introduction

Iron ore fines are important raw material for sintering. Its basic characteristics would influence the yield and quality of sintering product. Therefore, it's necessary to study fundamental features of iron ore to improve the quality of sinter. The basic characteristics of iron ore include the mineralogical characteristics of iron ore (e.g. the raw material condition, micro-characteristic) and the high temperature characteristics of iron ore (e.g. assimilation, liquid phase fluidity).

Research shows that the high temperature properties of iron ore fines, such as assimilation characteristics and liquid phase fluidity, played an important role in behaviors at high temperature during sintering and had important influence on quality of sinter [1, 2]. There is evidence of a relationship between the mineralogical characteristics of iron ore and its high temperature characteristics. And through these researches, can summarize some impact rules to guide the sintering manufacturing practice. However, few of researchers study the micro-characteristics of iron ore influences the high temperature properties.

Therefore, in this paper, based on mini-sintering test experiments, the high temperature characteristics of eight import iron ore fines which commonly used in China were measured. Then compared and analyzed the effect of mineralogical properties of iron ore fines, particularly the micro-characteristics, on the assimilation characteristics and liquid phase fluidity.

Experimental

Experimental Materials

The chemical compositions of the eight kinds of imported iron ore fines are shown in Table I. IOA~IOD are from Brazil, IOE~IOG are from Australia, IOH is from South African.

Table I. Chemical Compositions of Iron Ore Powders

Ore	TFe	FeO	SiO_2	CaO	Al_2O_3	MgO	LOI
IOA	63.42	0.59	5.64	0.01	1.34	0.06	1.81
IOB	63.10	0.73	5.56	0.06	0.97	0.27	1.86
IOC	64.14	0.58	5.19	0.02	0.86	0.07	1.68
IOD	64.81	0.17	2.77	0.02	1.24	0.06	2.12
IOE	58.60	0.20	4.44	0.04	1.63	0.07	10.07
IOF	61.44	0.29	3.68	0.03	2.26	0.08	5.45
IOG	60.77	0.32	4.19	0.02	2.28	0.06	6.07
IOH	64.44	0.32	5.21	0.11	1.33	0.03	0.55

* Mass Fraction

Experiment Method

In this experiment, XRD and SEM methods were employed to analyze mineral composition, micro-structure of iron ore. The mini-sintering test equipment (as shown in Figure 1) was used to research assimilation temperature and liquid phase fluidity of the iron ore, the concrete steps are as follows.

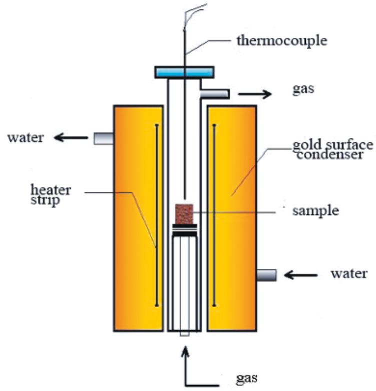

Figure 1. Mini-sintering test equipment

Assimilation Characteristics. The lowest assimilation temperature (LAT) in the interface of the iron ore fines and CaO reagents was measured to evaluate the assimilation capacity of different iron ore. The lower LAT indicated the stronger the assimilation characteristics it was. The CaO and ore fines were extruded to two cakes respectively, and the ore cake was positioned on the CaO cake. Then the sample was heated in air according to the sintering temperature variation curve. The start of melting was taken as the start of assimilation, and the lowest start reaction temperature of different iron ore were measured. The sketch map of the test for assimilation capacity is shown in Figure 2 [1~3].

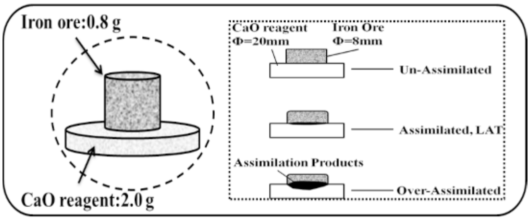

Figure 2. Schematic diagram of the assimilation capacity experiment

Fluidity of Liquid Phase. The index of fluidity of liquid phase (IFL) of the sample composed of different iron ore fines and CaO reagents was used to evaluate the liquid phase fluidity. The lower IFL, the poorer the liquid phase fluidity is. The ore and CaO were mixed according to binary basicity was 4.0, and then extruded into a cylindrical cake sample. The vertical projected area of the cake after the test was measured to calculate the index of fluidity of liquid phase (IFL). The sketch map of the experiment for the liquid phase fluidity is shown in Figure 3. The IFL is the data which the projected area of the sample after heated decrease the projected area of the sample before heated, divide the projected area of the sample being before heated [4].

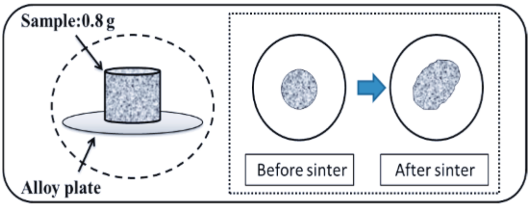

Figure 3. Schematic diagram of the fluidity experiment

Results and Discussion

The results of XRD (shown in Figure 4), assimilation and liquid phase fluidity of the 8 kinds of iron ore are shown in Table II.

Table II. Results of XRD,LAT and FI of Iron Ore Fines

Ore	Iron-containing minerals	Gangue minerals		LAT/℃	IFL/-- (1280℃)
		Si	Al		
IOA	Hematite and few goethite	Quartz	Gibbsite	1263	1.949
IOB	Hematite and few goethite	Quartz	Gibbsite	1290	2.183
IOC	Hematite and few goethite	Quartz	Gibbsite	1285	1.917
IOD	Hematite and few goethite	Quartz	Gibbsite	1270	0.000
IOE	Goethite and few hematite	Quartz	kaolinite	1215	1.824
IOF	Hematite and goethite	Quartz	kaolinite	1235	1.123
IOG	Hematite and goethite	Quartz	Gibbsite	1225	1.656
IOH	Hematite	Quartz	kaolinite	1237	2.859

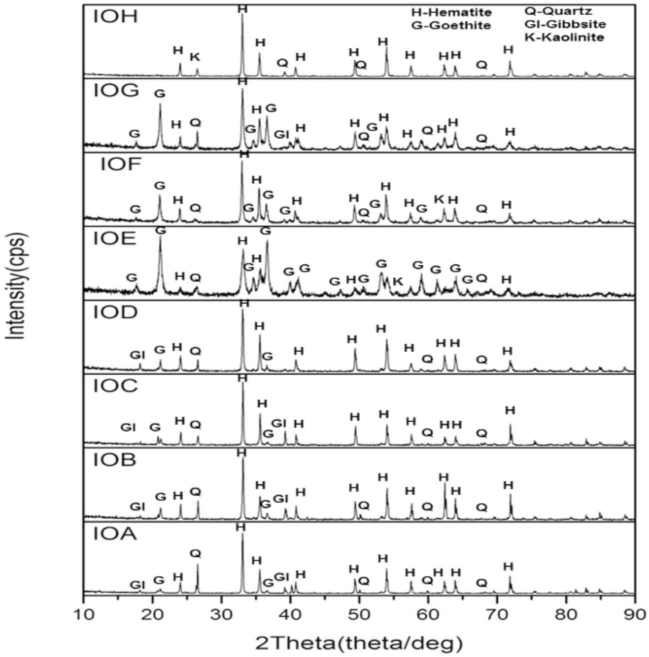

Figure 4. X-ray diffraction spectra of iron ores

Influence of Mineralogical Characteristics on Assimilation

Effect of Chemical Composition. The main chemical composition factors which influence the assimilation temperature were the content of SiO_2, Al_2O_3 and LOI (shown in Figure 5). According to the previous research [3], the more SiO_2, the higher assimilation temperature the ore was. However, this law was adapted when the SiO2 less than 4.5 mass%. With the resources of iron ore become inferior grade, gangue content ascend, for some iron ores, the content of SiO_2 has climbed around to 6 mass%. Figure 5-A is shown the relationship between SiO_2 contents of the iron ores and their LATs. It manifested that SiO_2 contents were not a simple linear relationship with LATs. In the condition of SiO_2 content under a value (e.g. $w(SiO_2)\approx4.5\%$),the LATs become higher with more SiO_2 in ores; When exceed the value, the law was contrasted to the previous. This was thought that increased SiO_2 content has benefited to produce low melting point substances, such as the series of Fe_2O_3-CaO-SiO_2 eutectic melt, its melting point is 1192℃. But with the content of SiO_2 continued to increase and arrived at higher level, the SiO_2 was relative excess, and then produced higher melting point substances, such as the series of CaO-SiO_2. Moreover, SiO_2 elevated the melting point of the system, as SiO_2 was a high melting point substance.

The relationships between the content of Al_2O_3, LOI and the LATs are illustrated in Figure 5-B and 5-C, respectively. When Al_2O_3 content and LOI of iron ores increased, their LATs showed a descending trend.

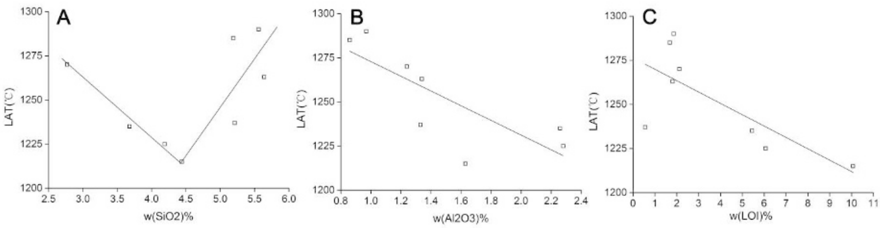

Figure 5. Influence of SiO_2, Al_2O_3 and LOI on LATs

The increased of Al_2O_3 promoted to produce low melting point substance, SFCA, moreover, the primary SFCA enhanced the contact between CaO cake and ore particles, improved the chemical kinetic parameters. Therefore, it reduced the LATs. The iron ores of high LOI commonly possessed loosen structure and higher porosity [5],such as limonite, after the crystal water and carbonate resolved. This improved dynamic condition of Ca^{2+} diffuseness through increased reaction contact area, thus promoted to produce low melting point materials, lessened the LATs.

Effect of Mineral Types. Iron-containing mineral types largely influenced its assimilation characteristics. Different types of minerals have obviously distinction in aspect of assimilation, as shown in Figure 6-A. Because of the limonite has loosen and porosity structure, the assimilation reaction dynamic condition was better than hematite. According to the compare in Figure 6-A, this order of assimilation capacity for the different iron mineral types is: Limonite> Half-Limonite> Hematite.

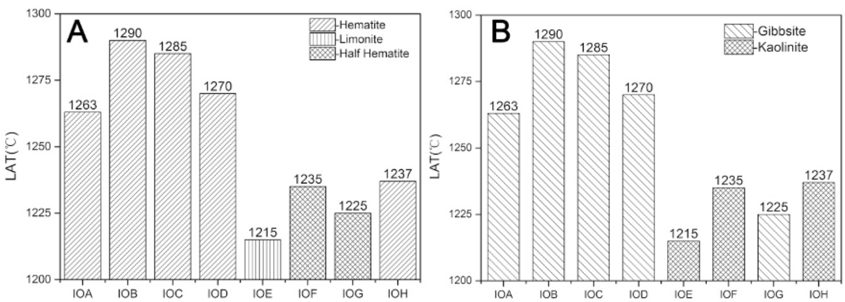

Figure 6. Comparison of the LATs of iron-containing and gangue minerals

Figure 6-B indicated gangue mineral types also have some influences on assimilation characteristics, though it's not notable as iron-minerals. In general, the assimilation temperature of iron ore fines which gangue minerals are quartz and gibbsite were higher than gangue minerals are quartz and kaolinite. The reactivity of kaolinite was higher than gibbsite [6], result into the LATs were lower. In addition, IOG was a special case which needed to be researched further.

Effect of Particle Morphology. Through microscopy observed the particle morphologies of iron ores, as shown in Figure 7 indicated that granules of IOB and IOC have dense slab-flaky structure. Compared IOB, IOC with IOA, have similar chemical composition and same mineral types, but LAT of IOA was obviously lower than IOB and IOC. It indicated the dense slab-flaky granules have inhibition function to assimilation characteristics. Not only because the dense and glazed surfaces of particles dropped down kinetics condition of the reaction with CaO, but also they could cause more void in iron ore fines cake, influenced the contact of iron ore granules, the primary melted liquid couldn't father developed. Therefore, influence the assimilation temperatures of ores. The results shown the iron ore granules have bulk or pisolitic structure which have good uniformity would have better assimilation characteristics.

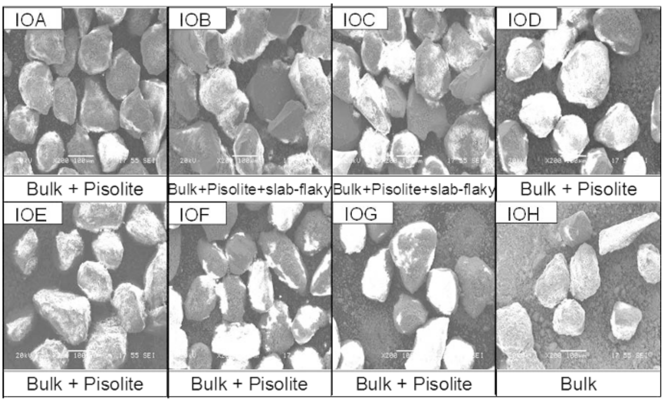

Fig 7. Images of particle morphologies of iron ore fines

Influence of Mineralogical Characteristics on Liquid Phase Fluidity

Effect of Chemical Composition. The influence tendencies of SiO_2, Al_2O_3 and LOI on liquid phase fluidity were respectively shown in Figures 8. According to Figure 8-A shown the IFLs ascend with the increase of SiO_2. Because a certain amount of SiO_2 were benefited to produce low temperature substances, such as a series of Fe_2O_3-CaO-SiO_2 mixture or SFCA, accelerated to liquid phase generate, enhanced the IFLs. For another, in the situation of fixed binary basicity, the additive amount of CaO was proportional to SiO_2 content. The increased content of CaO promoted to produce low melting point materials, thus it enhanced liquid phase fluidity [7, 8].

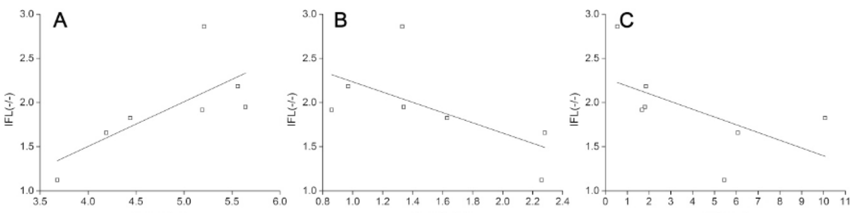

Figure 8. Relationship between SiO_2, Al_2O_3,LOI and the IFLs

With Al_2O_3 content increased, IFLs descended, as shown in Figure 8-B. The content of Al_2O_3 has dual function to liquid phase fluidity. On the one hand, Al_2O_3 is benefit to produce SFCA which is low melting point, enhanced the liquid phase fluidity capacity. On the other hands, Al_2O_3 is a high melting substance, with the content ascended, the melting point of liquid phase also arose, meanwhile, increased the viscosity of liquid phase.

In addition, the content of LOI also influenced the fluidity of iron ore. As the Figure 8-C indicated that the IFLs descend with the LOI content ascend. Because of the iron ore fines formed new gaps and holes after calcination process. Primary liquid generated and penetrated into cracks, decreased the volume of outflow liquid phase, descended the fluidity index [9].

Effect of Gangue Minerals. In this study, SiO_2 of iron ore fines main exist modes was quartz, and Al_2O_3 was gibbsite or kaolinite. The previous researches shown [2, 4], the gangues in the form of clay minerals have higher reactivity. It could enhance the liquid phase fluidity. Kaolinite belongs to clay minerals. It has higher reactivity and easier produced low melting point liquids than gibbsite. Compared with the 4 ores (IOA, IOB, IOC, IOH) which have similar content of SiO_2 (shown in Figure 9), the results correspond with this law.

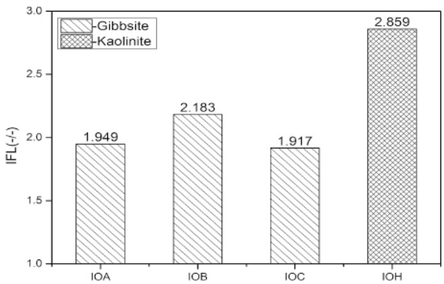

Figure 9. Comparison of the IFLs of gangue minerals

Effect of Gangue Dispersity. Adopted iron ore of IOA, IOB and IOC which own the similar chemical component and the same mineral types to compare to the influence of gangue dispersity on liquid phase fluidity. The research founded that the gangues of IOA and IOC were relatively concentrated and the sizes were bigger. The gangues of IOB were tiny and tight integrated with iron minerals, as shown in Figure 10. The quartz granules could obviously find in ore of IOA and IOC.

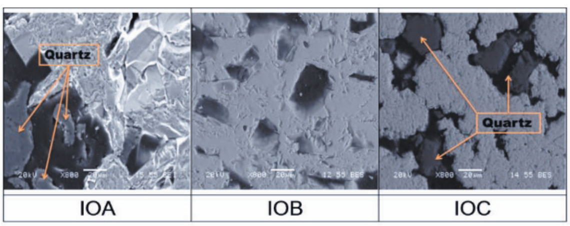

Figure 10. SEM images of IOA, IOB and IOC

According to the results of LATs and IFLs of the iron ores, IOB has the highest LAT of 1290 ℃. This is an indication that the IOB needs a higher temperature to melt and produce liquid phase. Under the same heating mechanism, it should have produced less liquid phases. But the IFL of IOB is the highest in these ores. Even though the LATs of IOA and IOC were lower than IOB, and they would have produced more liquid phases than IOB, but the gangues of IOA and IOC were concentrated and the sizes were bigger. The gangue granules could not completely dissolved into liquid phase in the relatively short time. These gangue particles in the liquid phase would ascend the viscosity of liquid phase [10], hindered the flowing.

Conclusions

In summary, the main factors which influence of mineralogical characteristics of iron ore on assimilation characteristics and liquid phase fluidity were chemical composition, mineral types, particles morphology and gangue dispersity. $w(SiO_2)\%<4.5$, the assimilation characteristics of iron ores arose with the increased of SiO_2, but dropped down if the excessive content of SiO_2. Al_2O_3 and LOI were conducive to assimilation characteristics, but not propitious for fluidity of liquid phase. Gangues exited mainly in the form of kaolinite would better than gibbsite to liquid phase fluidity capacities. In the micro-characteristics of iron ores aspect, the dense slab-flaky granules of iron ores inhibited the assimilation capacities in dynamics conditions, and independently accumulated gangue particles which have digger sizes restrained the liquid phase fluidity.

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