

Slag/metal Separation Process of Gas-reduced Oolitic High-phosphorus Iron Ore Fines

Hui-qing TANG, Long MA, Jun-wei WANG, Zhan-cheng GUO

(State Key Laboratory of Advanced Metallurgy, University of Science and Technology Beijing, Beijing 100083, China)

Abstract: Slag/metal separation process of the highly reduced oolitic high-phosphorus iron ore fines was investigated. Samples were prepared using the reduced ore fines (metallization rate: 88%) and powder additives of CaO and Na₂CO₃. Slag/metal separation behavior tests were conducted using a quenching method and the obtained metal parts were subjected to direct observation as well as microstructure examination with SEM and EDS; iron recovery and phosphorus distribution tests were conducted using a Si-Mo high temperature furnace and the obtained metal parts were examined by ICP-AES analysis and mass measurement. Thermodynamic calculation using coexistence theory of slag structure was also performed. Results show that temperature for slag/metal separation must be higher than 1823 K and a satisfying slag/metal separation of the highly reduced ore fines needs at least 4 min; phosphorus content of hot metal is mainly determined by thermodynamics; temperature of 1823–1873 K and Na₂CO₃ mixing ratio of about 3% are adequate for controlling phosphorus content to be less than 0.3 mass% in hot metal; temperature, time and Na₂CO₃ mixing ratio do not have significant effect on iron recovery, and iron recovery rate could be higher than 80% as long as a good slag/metal separation result is obtained.

Key words: oolitic high-phosphorus iron ore fine; slag/metal separation; iron recovery; phosphorus partition

A number of technical routes have been proposed on processing the oolitic high-phosphorus iron ore in China^[1–4]. Gaseous reduction followed by melting separation to directly produce low-phosphorus hot metal, which was proposed by the authors of current study^[5], is one of the feasible routes. Metallization rate of the fines could exceed 85% by applying microwave pretreatment to the ore fines in gaseous reduction stage^[6]. Because of the high reduction degree of the fines, the subsequent step, slag/metal separation process, needs further study to maximize iron recovery rate and minimize phosphorus level in hot metal. Many factors could affect phosphorus partition ratio and iron recovery rate in slag/metal separation process. For example, additive CaO can significantly change phosphorus partition ratio in melting separation of the ore fines with a metallization of 65% in the previous tests of current authors^[5].

In the present research, effects of temperature

and time on the slag/metal separation were studied. Additionally, Na₂CO₃ as a new additive was introduced for its low cost and has been found effective for dephosphorization of molten pig iron and hot metal^[7,8], therefore its effect on the slag/metal separation process was investigated as well.

1 Experimental

1.1 Sample preparation

The oolitic high-phosphorus iron ore was supplied by Wuhan Iron and Steel Company. Composition of the ore sample is listed in Table 1. The ore sample was crashed and ground to a size less than 1 mm.

The ore fines were reduced using an intensified

Table 1 Composition of oolitic high-phosphorus iron ore sample

mass%						
TFe	CaO	SiO ₂	MgO	MnO	Al ₂ O ₃	P
49.2	1.97	12.4	0.48	0.38	6.2	0.81

gaseous reduction method as described in Ref. [5]. Average final metallization rate of the fines for this research was about 88%. Powder additives (chemically pure CaO and Na₂CO₃) were then well mixed with the reduced fines to prepare samples. Mixing ratio of CaO to the reduced fines satisfied that basicity ($w_{\text{CaO}}/w_{\text{SiO}_2}$ in mass%) of the sample was 1.0 and mixing ratio of Na₂CO₃ varied for different purposes.

1.2 Slag/metal separation behavior trials

Quench method was adopted in these runs. Firstly, an Si-Mo high temperature furnace was heated to a predetermined temperature, and then highly pure argon at a flow rate of 200 mL/min was introduced into the chamber of the furnace. Sample with basicity of 1.0 and Na₂CO₃ mixing ratio of 2.0% was used. In each run, 5–7 g sample was put in an Al₂O₃ crucible ($\phi 30 \text{ mm} \times 45 \text{ mm}$) which was protected by a graphite crucible. It was then inserted quickly into the chamber and slag/metal separation test started. Melting time was calculated when the furnace temperature returned back. The sample was quenched after holding in the chamber for a given time. Thereafter its cross-section image was taken for examination of slag/metal separation result; its microstructure was examined by SEM and EDS.

1.3 Phosphorus distribution and iron recovery trials

After time and temperature for satisfying slag/metal separation were determined, experiments on phosphorus distribution and iron recovery were carried out. Samples with basicity of 1.0 and different Na₂CO₃ mixing ratios were used. In each run, 30–35 g sample was put in an Al₂O₃ crucible ($\phi 45 \text{ mm} \times 115 \text{ mm}$) which was also protected by a graphite crucible. It was then placed in the chamber of the Si-Mo furnace. The sample was heated up to the pre-

termined temperature at a heating rate of 10 K/min. After holding for the predetermined time, the sample was allowed to cool down to 773 K at 10 K/min and then to room temperature naturally. During the whole separation process, inert gas atmosphere was kept by highly pure argon flow of 200 mL/min in the chamber. The obtained metal part was weighed and iron recovery rate was estimated by Eq. (1).

$$\eta = \frac{m_{\text{obt}}}{m_{\text{tot}}} \times 100\% \quad (1)$$

where, η is iron recovery rate; m_{obt} is mass of the obtained metal part; and m_{tot} is total iron mass in the sample.

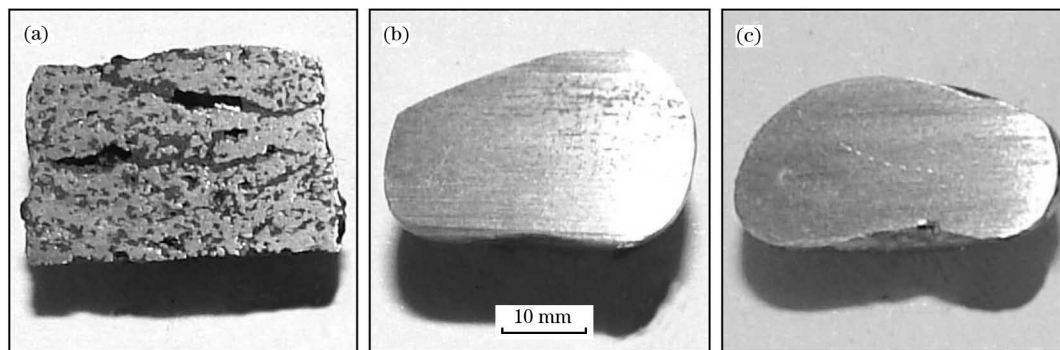
Phosphorus contents of the metal and the slag were measured using ICP-AES analysis.

2 Results and Discussion

2.1 Slag/metal separation behavior

2.1.1 Effect of melting temperature

Three temperature levels were examined. Fig. 1 shows cross-section images of the obtained metal parts and Fig. 2 shows their microstructures. From Fig. 1(a), it could be seen that, at 1773 K, shape of the metal part is near the melting crucible; slag particles in the metal are clearly visible and many pores and flaws spread on its cross-section. From Fig. 2(a), it could be seen that a distinct boundary exists between metal phase and slag phase as indicated by EDS results (Points 1 and 2). It is thus judged that the sample was only partially melted at 1773 K. At 1773 K, unmelted solid phase inhibits coalescence and growth of slag droplets and hot metal droplets; therefore, these droplets could move only in a short distance and slag/metal separation failed. From Figs. 1(b) and 1(c), it could be seen that the slag/metal separation is greatly improved when melting temperature is higher than 1823 K. Slag particles and flaws



Melting time: 10 min; Na₂CO₃ mixing ratio: 2%.

(a) 1773 K; (b) 1823 K; (c) 1873 K.

Fig. 1 Cross-section images of the metal parts obtained at different melting temperatures

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