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Formation of Hearth Sediment during Vanadium Titano-magnetite Smelting in Blast Furnace No.7 of Chengde Iron and Steel Company

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Abstract: The large quantity of sediment produced in the hearth during vanadium titano-magnetite smelting in a blast furnace (BF) affects the stability of the blast furnace operation. Testing and analysis of the sediment in the hearth of Chengde Iron and Steel Company′s BF No.7 revealed that it was mainly concentrated in the location below the tuyere and above the iron notch. Notably, some of the bonding material (sediment) consisted of greater than 50% pig iron, and the pig iron distributed in the slag was granular. It is proposed that a large quantity of TiC and Ti(C,N) are deposited on the surface of the pig iron. These high melting point materials mix with iron drops, preventing the slag from flowing freely, thus leading to the formation of bonding materials. In addition, the viscosity and melting temperature of the slag in the tuyere areas fluctuate greatly, and thus the properties of the slag are unstable. Moreover, the slag contains large quantities of carbon, which results in the reduction of TiO_2. The resultant precipitation of Ti is followed by the formation of TiC in the slag, which also leads to an increase in the viscosity of the slag and difficulty in achieving separation of the slag-iron. In fact, all of these factors interact with each other, and as a result, sediment is formed when the operating conditions in the hearth fluctuate.

Key words: vanadium titano-magnetite; hearth sediment; slag; pig iron; Ti(N,C)

For blast furnaces used for the smelting of ordinary iron ore, sediment produced by adding a certain amount of vanadium titano-magnetite provides protection and prolongs service life[1-5].

To date, most studies[6-8] of blast furnace sediment have focused on the smelting of the schreyerite of high titanium slag. The slag of the Chengde Iron and Steel Company, however, is medium-titanium slag[9,10]. When the operating conditions for the blast furnace vary, unmelted bonding materials remain on the brickwork between the tuyere and the iron notch, which causes an obvious reduction in the hearth surface, anomalous flows of the slag-iron, difficultly discharging the slag and iron, frequent suppression of the air flows, unfavorable tapping, and so on. Because the buildup of sediment affects the operating stability of the blast furnace[11-15], the blast furnace must be shut down and cleaned when sediment levels are high. Therefore, controlling the formation of sediment is a key issue for blast furnace production.

Using both experimental analyses and theoretical calculations, the components, mineral composition, structure, and mechanism of formation of the hearth sediment were investigated in this paper. The obtained results provided the theoretical foundation and operating parameters for controlling the production of hearth sediment during vanadium titano-magnetite smelting in blast furnace.

1 Location, Shape, and Composition of Bonding Material

The effective volume of the blast furnace (BF) No.7 at Chengde Iron and Steel Company, which is a small blast furnace for experiment, is 450 m^3. It has a utilization coefficient of approximately 3.28 t/(m^3·d), and the average daily output can reach 984.7 t. The feed grade is approximately 55.8%, and the iron-bearing materials are composed of sinter, pellet, and raw ore in a ratio of 74.99:23.63:1.38. The average vanadium content of the pig iron is 0.318%.

Fig. 1 shows the locations and shapes of the residual bonding materials formed between the hearth and the iron notch in the blast furnace No.7 of Chengde Iron and Steel Company, which were determined after the furnace was taken down.

The remaining brickwork in the hearth generally had a thickness of 200 to 300 mm, although at the front of the

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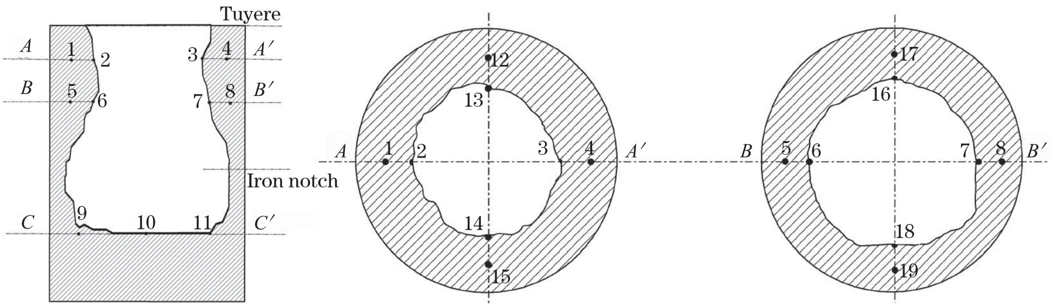

Fig. 1 Sampling points for collection of residual bonding materials in the hearth

brickwork, some bonding materials had different thick nesses. The thickest material (up to 400 mm) was mainly formed under the tuyere and gradually thinned with the bonding material. There was also a significant amount of TiC below the salamander.

2 Results and Discussion

2.1 Composition of the sediment

The results of qualitative spectrochemical analyses of the materials collected at the main sampling points shown in Fig. 1 are listed in Table 1. It can be seen that the hearth sediment contained significant amounts of Ti, Fe, and C, and in particular, the Fe content reached 58.10%. More detailed results for the chemical composition of the material collected at typical sampling site No. 2 are listed in Table 2. In this case, the elements with contents greater than 0.1% included Si, Al, Ca, Mg, Mn, Ti, Fe, C, S, Cr, V, Cu, K, N, O, and so on. The combined qualitative carbon and chemical analysis indicated that the main components of the bonding materials were TFe (51.87%), SiO_2 (7.41%), $A1_2O_3$ (8.05%), CaO (8.45%), MgO (2.96%), TiO_2 (8.16%), and C (14.8%), with each remaining element present at less than 1% .

Table 1 Elemental composition of the sampled bonding materials mass%

Sampling point	O	Mg	Al	Si	K	Ca	Ti	Fe	C
2	10.35	1.84	4.41	3.60	0.30	6.24	5.06	53.70	
5	13.03	1.07	7.49	12.68	3.65	5.44	5.51	43.31	7.83
7	8.78	2.24	6.89	9.25	0.36	29.33	10.58	27.51	5.06
10	1.74	2.66	11.60	12.49	1.93	7.97	7.26	51.32	3.02
11	3.24	2.67	7.24	9.48	0.28	10.48	11.32	50.82	4.48
13	41.10	0.24	20.01	14.50	0.00	7.79	1.04	8.67	6.65
14	36.50	0.34	32.79	2.06	0.05	0.97	2.04	18.41	6.83
16	35.66	0.24	24.89	13.10	0.03	7.66	2.04	11.96	4.42
19	38.63	1.11	37.87	2.57	0.12	1.73	2.06	10.73	5.16

Table 2 Elemental composition of the bonding material collected at sampling site No. 2 mass%

Si	Al	Ca	Mg	Mn	Ti	Fe	C	S	Ni	Cr	W
3.48	4.26	6.03	1.78	0.33	4.89	51.87	14.00	0.42	0.09	0.529	0.01
Mo	V	Cu	K	N	O	Na	Zn	F	Cl	P	Burning loss
0.05	0.615	0.315	0.29	0.86	10	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1

2.2 Iron-bearing materials

The phases of the bonding material were analyzed, and the mineral characteristics of the metallic iron were determined (Table 3). The results revealed that the mass percent of pig iron (γ-Fe + eutectic) in the sample was approximately 53%, and the pig iron was based on Fe. The composition of the γ-Fe + eutectic phase is presented in Table 4. If the pig iron accounted for 100% of the sediment, the elemental contents would be C 2.4%, Si 0.4%, Mn 0.50%, Cu 0.32%, Ti 1.06%, V 0.58%, Cr 0.76%, Ni 0.12%, Mo 0.03%, and W 0.02%. According to the Fe-C balance, therefore, the terminal melting temperature of the pig iron is 1 300 °C.

From the above analysis, it was concluded that, during operation of the blast furnace, the pig iron in the bonding material in the hearth would be a liquid and