Application practice of BOF Slag tailings in steelmaking process

Fuliang WANG, Chunxin WEI, Jun WANG, Lei ZHAO, Chao LI and Guoyi XU
Department of Steelmaking, Ansteel Bayuquan Iron and Steel Subsidiary, 115007,China

Abstract: The present paper introduces the steel production and BOF slag processing techniques in Steelmaking Sector of Bayuquan Iron and Steel Subsidiary, Ansteel. The technology of slag tailings utilization has been developed under the consideration of the properties of slag tailing and the characteristics of slag forming in BOF steelmaking operation practice. The processing of the BOF slag includes hot disintegration，a magnetic separation and transports of the separated beneficiate block steel and slag tailing. The results of BOF production practice show that the application of slag tailings as slag forming materials is benefitial to the acceleration of slag forming, the dephosphorization, as well as natural resources and cost saving. Therefore, its utilization as slag forming materials in BOF operation practice is a good way for the cycling BOF slag, and can reduce the pressure to the environment by BOF production.

Keywords: Steelmaking, slag tailings, dephosphorization, utilization

1. Introduction

With the rapid development of iron and steel enterprise and continuous expansion of iron and steel company scale, Ansteel enterprise is transforming to an enterprise of large-scale, benefitial, environmental protection, as well as economical society type. The 900000 t/a tons steel slag are produced by Ansteel Bayuquan Iron and Steel Subsidiary steel making plant. If so much quantity slag was not utilized reasonably, the local ecological environment would be damaged, and the resources would be wasted. How to effectively recover the iron resource in steel slag and protect the environment is always the focus of converter plant at home and abroad. The present effective way is to recover the slag steel of converter slag and the slag tailing is used to construction industry, which includes the road bed filling and cement production and so on. Because of the low added value and small utilization amount, the value of the steel slag as secondary resource cannot be fully realized. The utilization ratio of steel slag is hot high in our country. The problems of land occupation and environment are very prominent. So the steel slag can be reused in metallurgical industry because its main composition is similar to that of part of raw materials, which not only improves the utilization ratio of steel slag and solves the environmental problem, but also saves the metallurgical resources.

2. The production technology of slag tailings with their use in BOF process

In Department of Steelmaking, Ansteel Bayuquan Iron and Steel Subsidiary, three BOF converters of 260t in capacity, three skipping-desulphurization equipments, as well as two RH, a LF, and a CAS-OB, two RH devices are equipped there. The annual production of curial steel designed is 650 million ton/year. Counting with the slag/steel ratio of 140 kg/ ton steel, the annual slag production of various types can reach 910,000 tons. Steelmaking Sector of Bayuquan Iron and Steel Subsidiary, Ansteel built 12 closed and tank-typed containers, which can be used for molten BOF slags to subject to water quenching. When the temperature is lowered to 1100^{o}C, the tank will be closed to start water

fogging. The following reactions would proceed:

$$f\text{-}CaO + H_2O \rightarrow Ca(OH)_2 \qquad (1)$$

$$f\text{-}MgO + H_2O \rightarrow Mg(OH)_2 \qquad (2)$$

The first reaction occurs with a volume expansion by 97.8%,while for the second reaction-148%.The foregoing treatment leads to a pulverization of the molten slag which make it easier to separate the BOF slag with the steel covered by the slag. The use of pulverized slag can avoid the expansion due to the f-CaO and/or f-MgO meet the water or moisture, which might happen if the slag was directly used without pulverization. Following the hot disintegration is the magnetic separation step. With the separation, block steel can be returned taken out from the slag powder for reuse in converter as ferrous charges, and the slag tailing after screen separation is transported from lower bunker to upper bunker, and then charged into converter.

3. The feasibility of BOF Slag tailings in steelmaking process

3.1 The chemical composition and physical characteristics of BOF slag tailings

After hot disintegration，a magnetic separation of the BOF slag，two intermediate products can be obtained. One is the so-called slag-steel containing total iron grade of 40%. The other is the slag tailings, powder and blocks, with an low metallic iron content less than 2%. Table 1 is the composition of the BOF slag tailings. The free CaO content in the BOF slag tailings is less than 2.5%. As the BOF slag tailings contain $2CaO{\cdot}SiO_2$ and $3CaO{\cdot}SiO_2$, so it possesses higher castability.

Table 1 Chemical composition of BOF slag tailings (in wt%)

CaO	SiO_2	MgO	TFe	MFe	P_2O_5	S	Al_2O_3	Fe_2O_3
42.12	12.36	8.92	20.66	1.61	2.03	0.026	6.07	18.97

3. 2 The mechanism of slag formation in BOF process with addition of BOF slag tailings

As the slag tailings contain large amount of FeO and Fe_2O_3, which results in an rapid increase of the FeO content in the initial slag in the BOF process, and in tern, a promotion of silica-melting. All these would accelerate the formation of the initial BOF slag, and be benefitial to the dephosphrization reaction. At the middle of the oxygen blowing, along with the temperature rising, carbon starts to be oxidized in a large extent, and FeO in slag is reduced, so the addition of iron-containing law materials can be reduced. The higher contents of CaO and MgO make the basicity of the molten slag higher enough, which is favorable for slag splashing to protect the BOF lining.

At initial stage of the oxygen blowing, the main chemical reactions along with the melting pint of the products are as follows:

$$(Fe_2O_3)+[Fe]=3(FeO) \qquad (3)$$

$$(FeO)+CaO+SiO_2=(CaO\bullet FeO\bullet SiO_2) \qquad (4)$$

$$T_{f,(CaO\bullet FeO\bullet SiO2)}=1208℃$$

$$2(FeO)+SiO_2=(2FeO\bullet SiO_2) \quad (5)$$

$T_{f,(2FeO\bullet SiO2)}=1205℃$

$$CaO+SiO_2+(MnO)=(CaO\bullet MnO\bullet SiO_2) \quad (6)$$

$T_{f,(CaO\bullet MnO\bullet SiO2)}=1355℃$

$$CaO+MgO+SiO_2=(CaO\bullet MgO\bullet SiO_2) \quad (7)$$

$T_{f,(CaO\bullet MgO\bullet SiO2)}=1485℃$

$$CaO+(Fe_2O_3)=(CaO\bullet Fe_2O_3) \quad (8)$$

$T_{f(CaO\bullet Fe2O3)=}1230℃$

As the molten slag contain oxides, like FeO,Fe_2O_3,SiO_2,MgO and MnO, when these oxides get to the inside of the lime particles, the reaction occurs and produces the complex oxides with lower melting temperature. This would facilitates the melting of the lime.

The reaction of dephosphorization at the initial stage of the oxygen blowing is as follows：

$$5(FeO)+2[P]+4(CaO)=(4CaO.P_2O_5)+Fe \quad (9)$$

At the initial stage of the oxygen blowing, the reagent for slag forming is added. This reagent contains some amount of ferric and ferrous oxides which rises the content of FeO in the initial slag and is favorable for dephosphorization.

At the middle stage of the oxygen blowing, the following main reactions occur:

$$(FeO)+[C]=Fe+CO \quad (10)$$

$$(FeO)+CO=Fe+CO_2 \quad (11)$$

Due to the carbon oxidation, FeO in slag is reduced, the metallic iron produced gets into the liquid steel bath.

4. The application practice and the effects of BOF slag tailings in steelmaking operation

4.1 The addition techniques of BOF slag tailings

The adding quantity of slag tailing is decided by the basicity and the slag tailing is charged into converter in two batches. The first one is within 2min during oxygen blowing and the second one is decided by the smelting situation and its quantity is ≤1 ton/batch.

In order to evaluation of BOF slag tailings utilization, several calculations and measurements are necessary. During the trials, the consumption quantity of the melting flux was calculated. The dephosphorization effect, the composition of final slag and the splashing effect were measured. The lining corrosion situation was also considered.

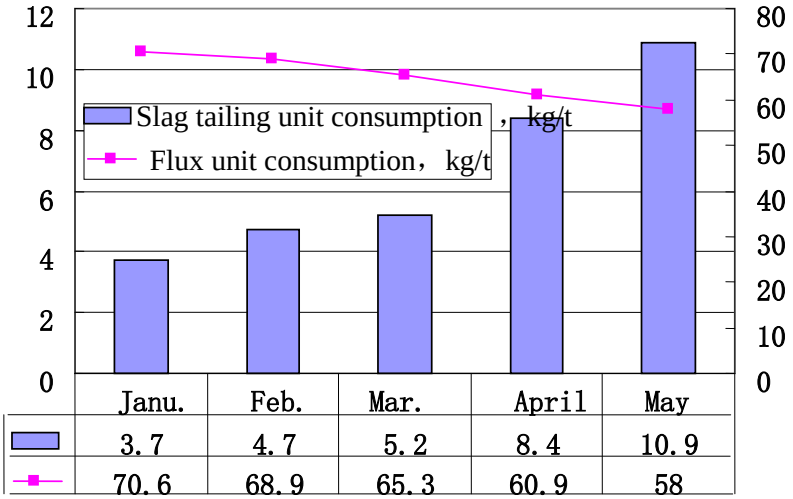

Fig.1 Relationship between the slag tailing consumption and the flux unit consumption

Fig. 1 shows the relationship between the adding quantity of slag tailing and the consumption quantity of melting flux. From this figure it is seen that with the increase of unit consumption of slag tailing, the unit consumption of melting flux decreases.

4.2 Dephosphorization effect

Table 2 shows the phosphorus distribution ratio and dephosphorization ratio after the using of slag tailing. As shown in Table 2, when the slag tailing is used, dephosphorization effect becomes evident and the distribution ratio of phosphorus between the slag and liquid steel increases. The consumption of lime and light-burned dolomite can be reduced therefore reducing the cost of the production.

Table 2 Comparison between the heats with slag tailing and those without slag tailing

Items		Dephosphorization ratio，%	Distribution of P，P_2O_5/[P]
Heats with slag tailing	average	91.23	146.5
	range	79.5-94.4	47.7-250.6
Normal heats (without slag tailing)	average	87.88	125.5
	range	73.5-93.6	35.5-191.9

4.3 Composition of final slag and splashing slag effect

Table 3 shows that the addition of slag tailing cannot increase the FeO of final slag, which cannot affect the oxidative performance of final slag.

Table 3 Composition of final slag with and without slag tailings

Items		CaO	SiO2	MgO	TFe	P2O5	S	basicity
Heats with slag tailing	average	46.8	11.47	9.96	17.65	1.87	0.047	4.1
	range	37.2-53.9	8.9-18.2	7.6-13.9	11.1-25.7	1.17-2.54	0.023-0.112	2.2-4.9
Normal heat(withoutt slag tailing)	average	46.7	12.27	10.6	16.9	1.68	0.049	3.9
	range	34.9-52.8	8.5-18.1	8.08-18.7	11.5-26.7	0.78-2.26	0.022-0.092	1.9-4.9

Table 4 Fluidity of final slag and splashing slag effect

Items	Fluidity of final slag（ratio）/%			Splashing slag effectt（ratio）/%		
	very good	good	ordinary	Very good	good	ordinary
With slag tailing	67.33	22.44	10.23	68.65	19.47	11.88
Without slag tailing	60.46	20.34	19.20	59.03	23.78	17.19

As shown in table 4, when the slag tailing is charged into converter, the heats with better fluidity of final slag increases by 6.87% and the heats with better splashing slag effect increases by 9.62%.

3.3 Effect of slag tailing addition on the lining corrosion

In order to study the effect of slag tailing addition on the lining corrosion, the LaCam laser thickness gauge was introduced. Lining thickness was measured average 50 heats, the results was shown in Fig. 2 and Fig. 3.

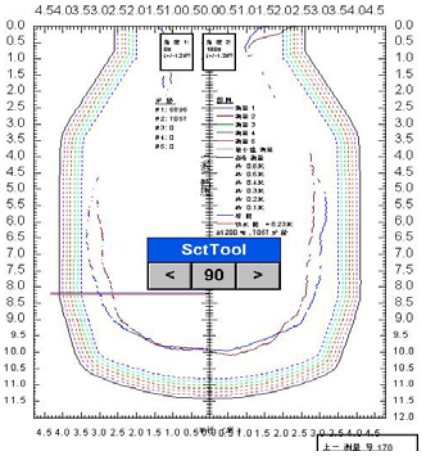

Fig.2 change of converter lining

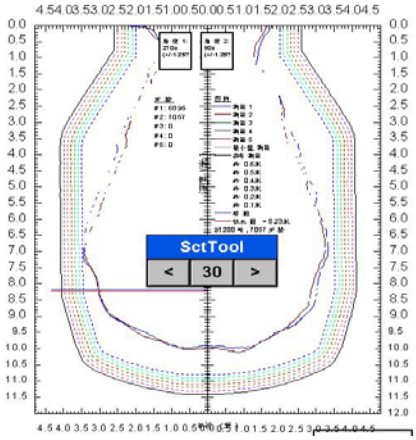

Fig.3 change of converter trunnion

Table 5 comparison of lining corrosion with and without slag tailing

Items	Corrosion rate（mm/heat）				
	Side of charging	Side of tapping	trunnion	bottom	Slag line
Heats with slag tailing	0.02	0.02	0.01	-0.05	0.03
Heats without slag tailing	0.02	0.03	0.02	0.17	0.04

The results in Table 5 show that there is certain improvement on the converter lining and slag line and there is no obvious corrosion on the converter bottom.

5. Discussion

Because there is 18% TFe in slag tailing, it makes the FeO of initial slag in oxygen blowing of BOF process increase rapidly. The quantity of FeO and Fe_2O_3 in slag tailings, which promotes the CaO melting, and proper basicity is benefit to the formation of initial slag of a heat in of BOF process. The melting of CaO can increase the basicity of slag rapidly and can also improve the fluidity of slag. So the adding slag tailings as slag flux is favorable to dephosphorization, and it can substitutes part of slag flux, which decrease the consumption of CaO and light-burned dolomite. The cost of converter flux decreases accordingly. At the middle age of the oxygen blowing, carbon begins to oxidize largely, which makes the FeO reduce into liquid steel, which is benefit to decrease the consumption of steel and iron charge. There are

high CaO, MgO and SiO_2 in slag tailing, which is benefit to lining protection by slag splashing because of enough basicity.

6. Conclusions

1) The application of slag tailings in converter decreases the time of slag formation, increases the dephosphoriaztion rate.

2) The application of slag tailings cannot affect the oxidizability of final slag and the splashing slag effect.

3) The application of slag tailings effectively recovers the iron resource of converter slag tailing and plays the important role in decreasing the consumption of ferrous charge.

References

[1] Peiran Zheng. Steel making.Beijing: Metallurgical Industry Press, 2004.

[2] Shizhou Liu. Study and application of converter sludge-based combined slag flux. Iron and Steel making, 1990, 10.