STUDY ON THE RECYCLING OF HOT DECARBURISATION SLAG IN DEPHOSPHORISATION CONVERTER

Yan-hui SUN[1], Xuefeng BAI[1], Chang-liang ZHAO[2], Lei LUO[2], Zhi-hong TIAN[2], Guo-Zhong PENG[2]

[1] Collaborative Innovation Center of Steel Technology, University of Science and Technology Beijing, Beijing 100083, P. R. China

[2] ShouGangJingTang Iron & Steel United Co., Ltd, Tangshan 063200, Hebei, P. R. China

baixf90@163.com

Introduction

The recycling technology of the decarburisation (De-C) converter slag which can be reused in the dephosphorisation (De-P) converter plays a significant role in producing clean steel with high efficiency and low cost[1,2]. In Sumitomo metal industry and Baosteel, the pre-treated De-C slag is charged into the De-P converter. Furthermore, operation with remaining slag is applied in Kimitsu Works of Nippon Steel and Fukuyama Works of NKK[3,4]. Several researchers have explained the mineralogical and melting characteristics of slag in the De-C converter[5,6]. However, the direct recycling of hot decarburisation slag in De-P converter is scarcely reported in public literature.

In the current study, industrial research on the recycling of hot De-C slag in De-P converter were performed based on desilication and dephosphorisation pretreatment process in De-P converter and less slag smelting technology in De-C converter in Shougang Jingtang. The dephosphorisation effect and the appropriate amount of hot recycling slag were also discussed with the help of thermodynamic calculation.

Industrial Experiment

Industrial experiments were carried out using 300 t De-P converter at Shougang Jingtang Iron & Steel Co. Ltd. in China. All hot metal must be desulphurised through KR stirring process to ensure the content of sulphur less than 0.002 wt% before dephosphorisation. In De-P converter, hot metals were charged after around 10 wt% scrap addition. The refining time and the basicity (wt% CaO)/(wt% SiO_2) of the end refining slag were about 45 minutes and 2.0, respectively. The slag forming materials were lime, light-burned dolomite and cold-bonded pellet. In addition, a new slag pot with a special division mouth was designed for the charging of hot slag in the De-P converter. The chemical composition of the hot metal and slag taken in the trials were determined by Optical Emission Spectrometer and X Ray Fluorescence (XRF) method, respectively.

Results and Discussion

Slag-Steel reacting status in De-P converter

The typical compositions of hot slag were CaO about 43.64 wt%, SiO_2 about 11.62 wt%, MgO about 8.71 wt%, P_2O_5 about 1.65 wt%, MnO about 1.72 wt%, TFe about 19.74 wt%, Al_2O_3 about 3.08 wt% and the basicity about 3.70. It can be seen that high basicity and low P_2O_5 content were applied, which can improve the phosphorus distribution between slag and steel and reduce the consumption of lime in De-P converter[7]. In addition, the iron loss could be decreased to some extent through recycling De-C slag.

The hot slag test was performed on 119 heats in order to make a comparison with 886 normal heats during one period to analyse the compositions of hot metal and semi-steel. The results are shown in Table 1.

It could be seen from Table 1 that the final phosphorus content of the experiment heats was 0.0364 wt%, which was about 0.006 wt% lower than that in the normal heats. Moreover, the average tapping temperature was 6°C higher than the normal smelting heats.

The XRF results of end slag are listed in Table 2. As shown in Table 2, the slag in different processes had the same content of CaO and basicity. The heats for hot slag test had 3.39 wt% lower TFe content than normal heats, which demonstrated that the loss of iron was reduced obviously during recycling test.

Table 1: The main parameters of Hot Slag Test

		C/wt%	Si/wt%	Mn/wt%	P/wt%	S/wt%	T/°C	η_P/%
Test Heats	Hot Metal	4.29	0.158	0.201	0.1085	0.0006	1345	66.37
	Semi-Steel	3.24	0.026	0.053	0.0364	0.005	1333	
Normal Heats	Hot Metal	4.25	0.158	0.197	0.1070	0.0007	1343	60.43
	Semi-Steel	3.29	0.022	0.038	0.0421	0.005	1327	

Table 2: Slag Composition in De-P converter

		CaO/ wt%	SiO_2/ wt%	MgO/ wt%	P_2O_5/ wt%	MnO/ wt%	FeO/ wt%	TFe/ wt%	Al_2O_3/ wt%	R
Test Heats	Maximum	42.87	20.90	7.26	8.85	12.43	34.92	27.17	6.40	2.45
	Minimum	22.80	13.34	4.96	2.47	5.30	7.93	6.17	1.74	1.15
	Average	31.81	16.18	5.91	5.87	8.69	12.17	9.36	2.92	2.00
Normal Heats	Average	31.64	15.63	5.38	6.70	9.95	16.58	12.75	2.49	2.04

Thermodynamic for dephosphorisation capacity of the slag

The phosphorus state could be estimated by the phosphate capacity which can be calculated from formula (1)[8]. As shown in Figure 1a, the dephosphorisation capacity between the test slag and normal slag in De-P converter was not remarkable.

$$\lg C_{PO_4^{-3}} = 0.0938\{(\%CaO) + 0.50(\%MgO) + 0.30(\%Fe_tO) + 0.35(\%P_2O_5) + 0.46(\%MnO)\} + 54180/T - 15.87 \quad (1)$$

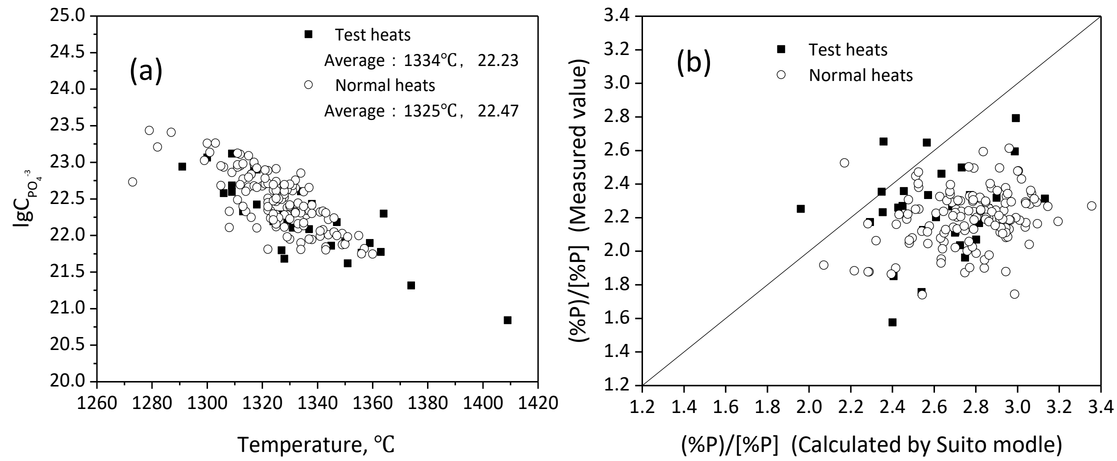

Figure 1: Change of phosphorus capacity (a) and phosphorus partition ratio (b) between slag and steel during blowing process

Phosphorus distribution ratio between slag and hot metal was an important parameter to evaluate the dephosphorisation effect. According to Suito model [8], the value of phosphorus distribution ratio could be expressed as the follows.

$$\lg \frac{(\%P)}{[\%P](\%TFe)^{5/2}} = 0.0720[(\%CaO) + 0.3(\%MgO) + 0.6(\%P_2O_5) + 0.6(\%MnO)] + \frac{11570}{T} - 10.520 \quad (2)$$

It can be seen in Figure 1b, the measured value is closer to the calculated value for test heats compared with normal heats. That means the hot slag can promote the reaction equilibrium between slag and steel.

Hot slag and auxiliary material consumption

The theoretical amount of hot slag charged was calculated mainly based on Si content of molten iron and the end slag basicity of 2.0. Furthermore, too much hot slag always led to metal splash. In addition, the slag output in De-C converter was only 12 t per heat when less slag smelting technology was applied in the decarbonisation converter. The appropriate amount of hot slag charged into dephosphorisation converter was 15~25 t per heat under comprehensive consideration.

During normal smelting process, 3.54 t per heat of lime and 1.58 t per heat of light-burned dolomite were added in De-P converter. While the amount of lime and light burned, dolomite reduced by 2.75 t and 0.03 t for each heat when the returned slag

was used in De-P converter. More than half of the test heats achieved zero consumption of lime and light burned dolomite.

Conclusions

1. Comparing the normal smelting process, the phosphorus content reduced by 0.006 wt%, semi-steel temperature increased by about 6°C and TFe content in end slag decreased by 3.39 wt% when hot slag was charged into De-P converter.
2. Process of the De-C hot slag recycling was closer to the equilibrium values of slag and steel reaction than normal smelting process in De-P converter according to the thermodynamic calculation.
3. The appropriate amount of hot slag charged into De-P converter was 15~25 t/heat, which depends on the Si content of pig iron, end slag basicity and decarburisation slag output.
4. The amount of lime and light burned dolomite reduced by 2.75 t and 0.03 t for each heat after using returned slag in De-P converter. More than half of the test heats achieved zero consumption of lime and light burned dolomite.

Acknowledgement

The authors are grateful for financial support provided by the National Natural Science Foundation of China (Grant No. 51574026)

References

1. C. Yang, G. Wei, J. Liu and J. Song, "High efficiency low cost platform for clean steel production practice", *Steelmaking*, **28** (3) 1-6 (2012).
2. J. Li, X. Hao, S. Qiu and P. Zhao, "Dephosphorisation technique of converters by multi-functional refining", *J Univ Sci Technol B*, **31** (8) 970-73 (2009).
3. H. Pärkkä, T. Meriläinen, J. Vatanen, P. Tuominen and J. Kärjä, "Improvement of BOF Bottom Stirring at Ruukki, Raahe Steel Works", in *Proceedings of the Unified International Technical Conference on Refractories* (*UNITECR 2013)*, Edited by D. G. Goski and J. D. Smith, the American Ceramic Society (ACerS), Victoria, Canada, 2013.
4. L. Sun, "Duplex melting process of converter and its features", *Shanghai Metals*, **27** (2) 44-46 (2005).
5. G. Li, B. Wu, Y. Zhang and T. Jiang, "Mineralogical characteristics and comprehensive utilization of converter steel slag", *J Cent South Univ T*, **41** (6) 2065-71 (2010).
6. W. WU, H. Meng and L. Liu, "Melting characteristics of recycling slag in decarburisation converter and its application effects", *J Iron Steel Res Int*, **20** (6) 7-12 (2013).
7. K. Xu, L. Xiao, Y. Gan, L. Liu and X. Wang, "Theory analysis on the new generation of clean steel production process", *Acta Metall Sin*, **48** (1) 1-10 (2012).
8. H. Suito and R. Inoue, "Phosphorus distribution between MgO-saturated CaO-FetO-SiO_2-P_2O_5-MnO slags and liquid iron", *ISIJ Int*, **24** (1) 40-46 (1984).