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ScienceDirect
Acta Metall. Sin.(Engl. Lett.)Vol.22 No.6 pp454-460 December 2009
ACTA METALLURGICA SINICA (ENGLISH LETTERS)
www. amse.org.cn

Mechanism of zinc damaging to blast furnace tuyere refractory

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Manuscript received 23 February 2009; in revised form 14 April 2009

The phenomena of tuyere upward-warp have been found at No.6 blast furnace in Kunming Steel Company China after its blow-in, which has made a great impact on the practical production of the furnace. Thus, a number of efforts have been made to elucidate the mechanism of this phenomenon. The results of investigation and tests revealed that the enrichment and expansion of zinc in the tuyere bricks is the main factor leading to the tuyere upward-warp. The eroding behavior of zinc is that the inner structure of the tuyere bricks turns from dense to loose with entering, enriching and expanding of zinc, which forms spot-like→stripe-like→ditch-like→vein-like→tumor-like eroding passage. Additionally, it is found that the sequence of deleterious elements entering the tuyere refractory is K, Na, Zn and Pb, respectively. Finally, the phenomena and process of zinc crystallization and growth in the refractory have been clearly observed and recorded during this investigation.
KEY WORDS Blast furnace; Tuyere; Refractory; Zinc; Erosion; Deleterious elements

1 Introduction

No.6 blast furnace in Kunming Steel China, with an inner volume of 2000 m^3, blew in in 1998. Totally, 26 tuyeres are set. And the furnace uses the ceramic cup structure of compound brown corundum brick and self-baking carbon block with half graphitization and low porosity. The total depth of the bottom is 3.05 m, in which the lowest first layer is big baking C-SiC block with half graphitization, the middle second-fifth layers are self-baking carbon block with half graphitization and low porosity and the top two layers are compound brown corundum brick. The side part of the hearth used self-baking carbon block from the seventh to fifteenth layer, big baking C-SiC block with half graphitization from sixteenth to twenty-first layers, and small baking C-SiC block with half graphitization in the region near the furnace shell. In addition, 8-layer compound brown corundum bricks

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DOI: 10.1016/S1006-7191(08)60123-4

and 12-layer tuyere assembled bricks are laid above the brickwork of the hearth.

Unexpectedly, some unusual phenomena have occurred since 2002. Table 1 listed the statistical data of the tuyere upward-warp in 2002. According to Table 1, remarkable upward-warp took place in each tuyere of No.6 blast furnace, with the range from 2.4° to 8.3°, and averaged value 5.79°[1]. Evidently, the upward-warp of tuyeres had a serious impact on the blasting and routine operation of the furnace[2].

In order to investigate the reason of tuyere upward-warp, the authors have laid the emphasis on the effects of the deleterious elements, mainly zinc, on the tuyere refractory, and make a number of experimental researches to elucidate the behaviors of zinc in the assembled bricks of the tuyeres through obtaining the sample of tuyere assembled bricks and analyzing the variation of the contents of K, Na, Zn and Pb.

Table 1 Measurement results of the tuyere upward-warp in No.6 blast furnace

No. of the tuyere	No.1	No.2	No.3	No.4	No.5	No.6	No.7	No.8	No.9	No.10	No.11	No.12	No.13
Upward-warp angle/deg	6.3	4.5	3.6	7.1	6.0	6.1	8.3	4.9	5.7	2.4	5.8	6.8	4.3
No. of the tuyere	No.14	No.15	No.16	No.17	No.18	No.19	No.20	No.21	No.22	No.23	No.24	No.25	No.26
Upward-warp angle/deg	6.7	5.2	7.5	7.1	7.9	6.9	3.3	4.5	5.2	5.5	7.2	5.7	5.7

2 Analysis of Zinc Damage and Zinc-enriched Region

With respect to the damage of deleterious elements on the brick lining of blast furnace, many blast furnace operators generally emphasized on K, Na and Pb but little on Zn, and even sometimes thought that zinc had no erosion on the furnace refractory. Some researchers, however, have found that zinc and its oxides bring great harm to the brick lining of blast furnace[3−5] since the volume will expand by 54%, 68% and 83% respectively in the reaction from Zn to ZnO, from ZnO to ZnS and from Zn to ZnS. Serious zinc accidents had once occurred on the blast furnace of one ironmaking plant in China[6]. At that time, the zinc load of the charged burdens attained to 0.54 kg/THM. The primary resource of the deleterious element of Zn in the blast furnace is from the charged burdens. During the operation, the Zn is circulated and enriched in the mixture of hot metal and molten slag in the hearth, and erodes the lining bricks, which finally resulted in the sticking of the furnace wall and the burnout of the tuyeres and consequently worsened the efficiency index and smooth running of the blast furnace. As a result, this plant put forth that the zinc load of the burdens should be controlled below 0.15 kg/THM[6].

Table 2 gives the zinc balance of No.6 blast furnace in Kunming Steel China[1]. For this blast furnace, the zinc load (0.81 kg/THM) is relatively high among the deleterious elements in the burdens while the zinc-removal ratio is low (only 88.52%). Thus, more emphasis should be laid on elucidating the effects of zinc on furnace refractory.

The melting point of zinc is 419 °C while the boiling point 907 °C. The zinc enters the furnace as ZnS with the charged iron-bearing burdens, then it transforms into ZnO in the furnaceand it is reduced in the zone with the temperature above 1000 °C, generating gaseous zinc[7−9] through the following reaction.

$$ZnO + C = CO_{(g)} + Zn_{(g)} \quad (1)$$