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STUDY ON DISTRIBUTION OF SULFUR ELEMENT IN BLAST FURNACE (BF) PROCESS WITH DIFFERENT PELLET PROPORTIONS

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In this study, a series of BF smelting industrial tests were conducted with different proportions of pellet in iron-bearing materials in a 450 m^3 BF in Hebei, China. The results showed that with increasing proportion of pellet, total sulfur(S) input amount of the raw materials in BF iron-making process decreased after a slight increase. The sulfur input of pellets increased while that of sinter, coke and coal tended to decrease. On the other hand, the quantity and proportion of sulfur element in BF gas had a small rise while those in BF slag did not change much, and the quantity of sulfur in BF dust and iron remained relatively stable. The result revealed that increasing the pellet proportion will not affect the quality of pig iron (PI), but also can reduce the sulfur load of BF.

Keywords: BF, pellet proportion, distribution of sulfur, reduce, quality

INTRODUCTION

In recent years, China has made remarkable progress in reducing emission of pollutants from the iron and steel industry, e.g. the control of haze weather in the Beijing-Tianjin-Hebei region (BTH) has achieved a marked improvement. However, BTH is still a highly polluted area [1]. Iron and steel industry, which produces large amounts of fine particulate matter (PM 2,5), sulfur dioxide (SO_2) and nitrogen oxide (NO_x) [2], remains a key source of air pollutants in BTH. SO_2 is an important source of air pollutants in iron and steel industry. According to an bottom-up integrated dynamic optimization model, Xu et al [3] forecasted the emission of SO_2 in iron and steel industry will be 0,14 million tons in BTH in 2020, which had undoubtedly contributed to total emissions of SO_2 in China.

At present, principal iron-bearing materials for BF iron-making process are sinter, pellet and lump ore [4]. Ma et al [5] have shown that the SO_2 emission factors of sintering and pelletizing are 1 ,374 and 0,395 kg per tonne of product, respectively. The production process of sinter contributes to the SO_2 emission much more than pellet to the SO_2 emission. Therefore, the increase of pellet proportion in the raw material structure of BF burden is generally regarded as an effective way to reduce the SO_2 emissions. Studies on industrial practice show that high pellet operation can achieve a better productive index by using fluxed pellet, altering charge rules of bell-less BF top, optimizing operating and adjusting tuyere layout [6-9]. However, only few studies have reported in industrial test on distribution of sulfur element in BF iron-making process with different pellet proportions.

This study focuses on the input and output of sulfur in BF iron-making process with different proportions of pellets in raw materials. A series of industrial tests were conducted in a 450 m^3 BF in Hebei, China. The sulfur contents in raw materials and products in different experimental conditions were sampled and measured respectively. The distribution of sulfur in BF iron-making process in different pellet proportions was evaluated.

MATERIALS AND METHODS

Raw materials used in this study were three kinds of pellets, two kinds of sinters, one kind of lump and one kind of limestone. The main chemical compositions and sulfur contents of the raw materials are presented in Table 1. Fuel used in the BF iron-making process were coke and pulverized coal, containing 1,01 % and 0,65 % (wt.%) of sulfur respectively.

The BF used in the test had an effective capacity of 450 m^3, and was equipped with 3 top-combustion hot blast stoves, bottom filtration slag treatment system, bell-less top distributing installation, and full cast iron cooling stave thin skinned lining.

The overall process of the test was divided into 5 phases as follows: phase 1is the reference period; in phase 2, pellet 2 was substituted for Pellet 1, and pellet proportion was raised to 30 %; in phase 3, pellet proportion was raised to 50 % with the addition of Pellet 3; in phase 4, pellet proportion was raised to 60 %; in phase 5, pellet proportion was raised to 80 %. The sinter and pellet proportions are showed on Figure 1.

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Table 1 **Main chemical compositions and sulfur contents of raw materials / wt.%**

Material	TFe	FeO	SiO_2	CaO	MgO	Al_2O_3	TiO_2	S
Sinter 1	55,81	9,13	5,26	10,70	2,10	1,56	0,18	0,025
Sinter 2	55,49	9,25	5,14	11,28	2,12	1,54	0,15	0,046
Pellet 1	63,10	0,40	5,80	1,80	1,40	0,53	0,50	0,010
Pellet 2	62,20	0,60	6,30	2,10	1,60	0,63	0,16	0,014
Pellet 3	61,00	1,00	4,50	4,40	1,80	0,79	0,70	0,033
Limestone	--	--	2,86	49,3	3,38	--	--	0,021

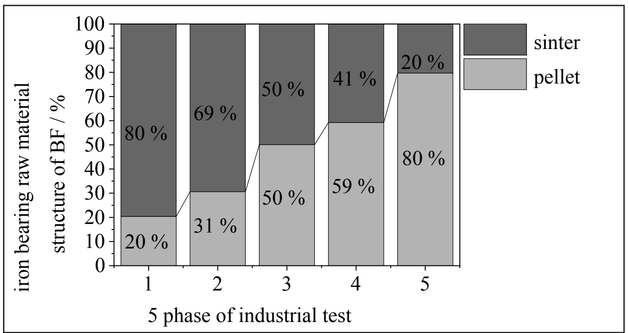

Figure 1 Sinter and pellet proportions in each phase.

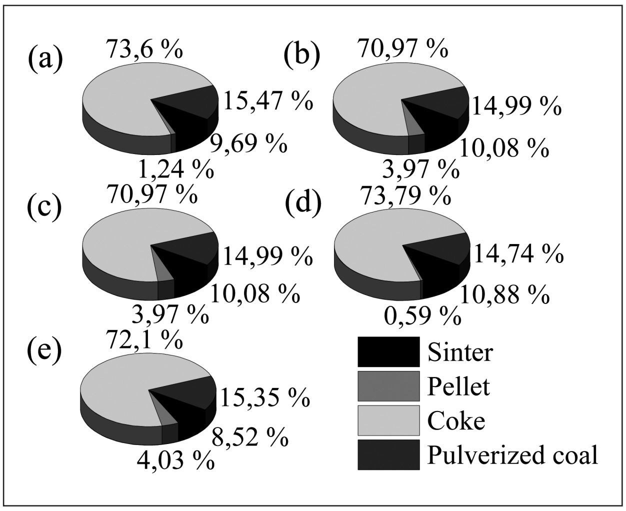

Figure 2 The proportions of sulfur input in each type of raw material with different pellet proportions of (a) 20 %, (b) 30 %, (c) 50 %, (d) 60 %, and (e) 80 %.

In the course of the test, the stable operation was guaranteed by continuous adjustment of BF operation parameters, such as regime of thermal balance, blasting, slag-making and charging.

Sulfur contents in the samples of pig iron (PI), blast furnace slag (BFS) and blast furnace dust (BFD) produced in phase 1 ~ 5 were measured. Since it was difficult to measure the actual SO_2 concentration in blast furnace gas (BFG) due to the interference from high concentration of CO, the sulfur output and content of BFG were calculated by taking the input sulfur amount as a reference value.

RESULTS AND DISCUSSION

The main sources of sulfur in BF iron-making process are pellet, sinter, coke, pulverized coal and limestone. Therefore, sulfur inputs need to be calculated for each source.

Consumptions of raw materials for every ton of PI are listed in Table 2. Sulfur inputs of each material were calculated based on data in Table 2. The proportions of sulfur input in each type of raw material with different pellet proportions are presented on Figure 2.

It is revealed from Figure 2 that the coke is the main sulfur element source in different pellet proportions experiments, accounting for 68 % ~ 72 % of the sulfur input. The second dominating factor to the sulfur input proportion is pulverized coal, which has an input proportion of 15 % ~ 16 %. The sum of the sulfur input proportions of the sinter and the pellet is 12 % ~ 17 %. The limestone was added in the phases containing 60 % and 80 % pellet proportions, where less than 1 % of the sulfur content was imported. Along with the increase of the pellet proportion, the amount of sulfur imported by sinter decreases. The sulfur brought by sinter had a slight growth when the pellet proportion was raised to 50 %, because sinter 2 had a higher basicity and sulfur content was used to replace sinter 1 to ensure steady production. Coke ratio decreased slightly with the increase of pellet proportion, mainly because the ferric content of pellet is higher than that of sinter. For this reason, the utilization efficiency of the coke is improved to some extent, and the coal injection rate of BF is basically stable when the pellet proportion was increased. The total sulfur load of BF increases with the increase of pellet proportion as shown in Figure 3.

The sulfur contents of PI, BFS and BFD generated in different phases were measured. The sulfur content of BFG was calculated on the reference of the sulfur input. The result is listed in Table 3.

It can be revealed from Table 3 that the BFS and BFG took away most of the sulfur element. The quality change of sulfur element caused by BFS fluctuates little, but overall is stable. The quality of sulfur element taken away by BFG decreased gradually. Although the yield of PI is high, the content of sulfur element in PI is very low. On the contrary, the content of sulfur in BFD is much higher than it in PI, it does not take away a lot of sulfur because of the low output of BFD.

CONCLUSIONS

The sulfur element in BF iron-making process mainly comes from coke and pulverized coal. Among them,

Table 2 **Consumptions of raw materials for every ton of PI produced**

Raw material	Consumptions of raw materials / kg				
	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5
Sinter 1	1 287	1 134	107	0	0
Sinter 2	0	0	744	675	430
Pellet 1	330	50	0	0	0
Pellet 2	0	450	0	291	366
Pellet 3	0	0	853	690	821
Limestone	0	0	0	14	35
Coke	408	401	397	395	390
Pulverized coal	126	131	129	129	128

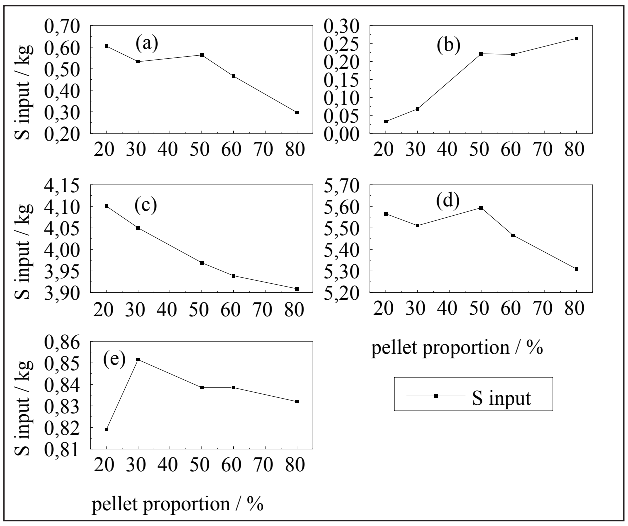

Figure 3 Sulfur input changes with different pellet proportions in (a) sinter, (b) pellet, (c) coke, (d) pulverized coal, and (e) all raw materials.

coke contributes to 70 % of the input of sulfur elements, while coal contributes to 15 %. The change of sulfur input of iron-bearing is not much, accounting for 12 % ~ 15 %, but pollutant emission in the process of pellet production is far lower than the sinter production process, thus it improves the pellet ratio in BF iron-making process. Using more pellet instead of sinter in BF iron-making process can reduce sulfur oxide emission.

About product in BF iron-making process, the quantity and proportion of the sulfur element in BFG decreased mildly while those in BFS did not change much, and the quantity of sulfur in dust and iron remained relatively stable.

Increasing the pellet proportion will not affect the quality of PI, but also can reduce the sulfur load of BF. This method is an effective way to reduce SO_2 emission from the source.

Acknowledgments

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Table 3 **The sulfur output of raw materials for every ton of PI / kg**

Pellet proportion	20 %	30 %	50 %	60 %	80 %
PI	0,26	0,23	0,27	0,25	0,27
BFS	2,72	2,76	2,83	2,81	2,86
BFD	0,17	0,10	0,07	0,10	0,11
BFG	2,41	2,42	2,42	2,30	2,07

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Note: Wenxiang Deng is the responsible for English language, Beijing, China.