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Influence of Lance Configuration Coal Combustion in Blast Furnace

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Abstract: In this paper, a numerical model simulating the lance—blowpipe—tuyere—raceway of a blast furnace has been developed. The coal flow and combustion along the coal plume are studied. The effect of the lance tip area and position on coal combustion is investigated.. The simulation results indicate that the coal burnout is increased with increase of the lance tip distance from the raceway. The coal burnout is also increased with increase of the lance tip area, and the influence is very obvious.

Introduction

The blast furnace (BF) is the main process to produce hot metal due to its high productivity and heat utilization compared to other ironmaking technologies[1,2]. In the production of hot metal, much pulverized coal is injected into the blast furnace to replace partial of coke to reduce the cost and emission of CO_2[3].Therefore, how to improve coal ratio has been a problem of ironmaking for a long time.

Practically, coal burnout can't be improved not because of lack of oxygen in raceway region, but because of lack of local oxygen around the coal particles. By adjusting the lance configuration and positioning, coal particles can distribute more uniformly in the raceway, and coal burnout can be increased to a certain degree.

The reactions in the raceway are complex, and the environment is harsh. Therefore, it is very difficult to carry out a trial of pulverized coal injection (PCI) in the BF. However, computational fluid dynamic (CFD) provides a new method for the investigation of PCI in BF. Many investigations on the coal combustion in blast furnace (BF) using CFD have demonstrated its reliability and superiority[6-10]. Therefore, in this study, the coal combustion in theBF is investigated using CFD. The simulation results provide a useful insight into the pulverized coal injection in the BF.

Mathematical Model

The gas-particle flow and coal combustion in the tuyere and raceway region were calculated based on the framework of software package ANSYS–FLUENT. The mathematical formulation is described elsewhere[6-8,11,12].The pulverized coal particles are treated as discrete phase, modeled using the Lagrangian method. The governing equations for the particle and gas phase are described elsewhere[12,11,6-8].

Geometry and Operating Conditions

The main operational parameters of the TBF are summarized in **Table 1**.

The model simulates the lance-blowpipe-tuyere-raceway of BF. The detailed parameters are shown in Fig. 1. The TBF of 120 m^3 was dissected in 2007. The results of the blast furnace dissection show that the depth of the raceway was about 700 mm. The raceway is designed as a tube of 700 mm long with a divergence angle of 3° referring to others[8].

Table 1Main Blast Parameters

Blast Volume (Nm^3/t)	Blast Temperature (K)	Volume (m^3)	Coal Ratio (kg/t)
1129	1473	120	150

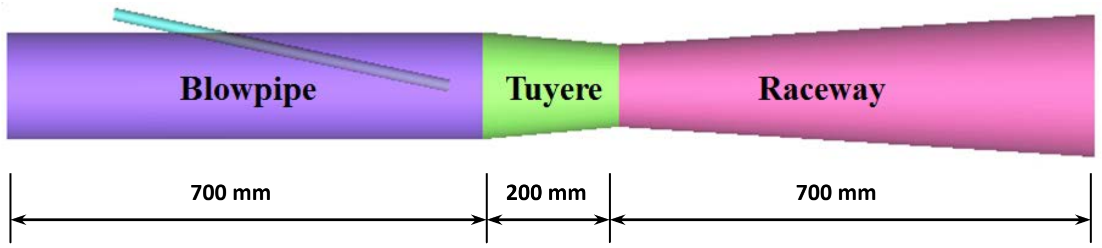

Fig. 1 Geometry of the model

Results and Discussion

Model Validation. CFD has been extensively used for the simulation of coal combustion, and the reliability of this approach has been fully proved[6-8,13,14,10,15]. Before investigating the coal combustion in OBF, the simulation on coal combustion in the TBF is carried out. The simulation results and phenomena are very similar to those of others[11,12]. These comparisons have fully illustrated the reliability of this model.

Effect of the lance tip position. In some cases, the combustion of pulverized coal in the raceway region is insufficient, partly because the local oxygen around the pulverized coal is lacking and partly because the residence time in the raceway is very short. The pulverized coal particles leave the raceway without burning completely. If the residence time of coal particles in the raceway is lengthened, coal burnout in the raceway may be improved. And by extending the distance of the lance tip from the tuyere, the residence time in the raceway will be lengthened. And the coal burnout may be improved. In this part, the effect of the distance of the lance tip from the tuyere on the coal combustion is studied.

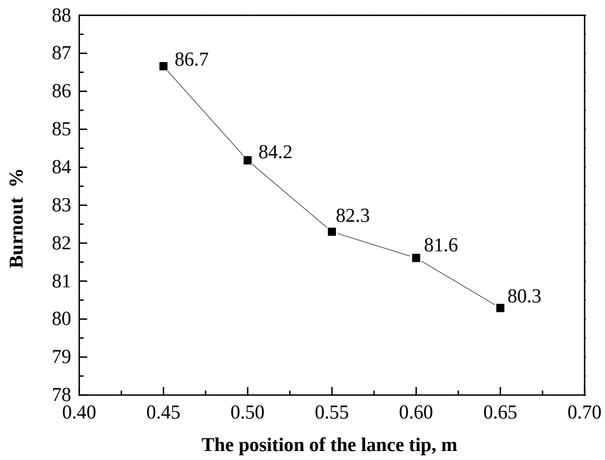

Fig. 2Effect of the lance tip position on coal burnout

Fig. 2 shows the effect of the lance tip position on the coal burnout. It is shown that the coal burnout is increased as increase of the distance of the lance tip from the raceway. When the distance increases from 0.05m to 0.25m, the coal burnout is increased from 80.3% to 86.7%. There is only slight increase in the coal burnout, from 80.3% to 82.3%, when the distance increases from 0.05m to 0.15m. There is obvious increase in the coal burnout, from 82.3% to 86.7%, when the distance increases from 0.15m to 0.25m. Practically, increasing the distance of the lance tip from the raceway extends the combustion distance. The coal particles can be sufficiently heated and burns vigorously.

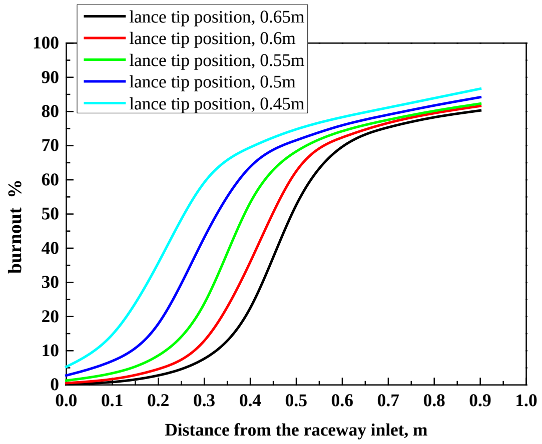

Fig. 3Effect of the lance tip position on coal burnout changes in the raceway

Fig. 2 only shows the effect of the lance tip position on final burnout, namely the burnout of the raceway outlet. In order to compare the effect of the lance tip position on coal combustion characteristics through the coal flow, the coal burnout at different locations of the raceway is calculated,as shown in Fig. 3. Fig. 3 shows that the coal burnout at each position is increased with increase of the distance of the lance tip from the raceway. In the direction of axis +X, the coal burnout increases gradually, and at a certain point the coal burnout increases rapidly. However, in position the increase rate slows down. When the distance of the lance tip from the raceway increases from 0.05m to 0.25m, at the distance of 0.3m, the coal burnout increases from 7.7% to 59.3%, and the burnout is increased by 51.6%; At the distance of 0.4m, the coal burnout increases from 22.5% to 69.5%, and the burnout is increased by 47%. From the distance of 0.5m, the effect of the lance tip position on the coal burnout is more and more small. At the outlet of the raceway, the coal burnout is increased only by 6.4%.

Effect of the lance tip area. In this part, effect of the lance tip area on coal combustion is investigated. The lance tip diameters are 15mm, 20mm and 25mm, respectively. The lance tip central position is 0.65m of the center line in the direction of axis +X.

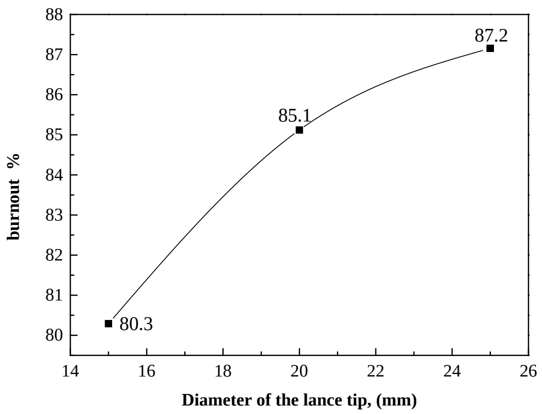

Fig. 4Effect of the lance tip area on coal burnout

Fig. 4shows effect of the lance tip area on coal burnout. It shows that the coal burnout increases with increase of the lance tip area. When the lance tip diameter increases from 15mm to 25mm, the coal burnout increases from 80.3% to 87.2%. The coal burnout increases by 6.9%. With increase of the lance tip area, the average velocity of coal particles flowing into the blowpipe reduces. On the other hand, with increase of the lance tip area, the distribution of the coal particles is more uniform, which is more favorable for combustion of the coal.

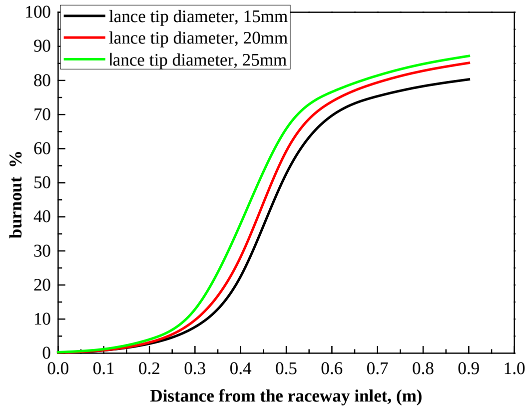

Fig. 5Effect of the lance tip area on the coal burnout changes in the raceway

To further study the behavior of coal combustion under different lance tip areas, the coal burnout at different positions of the raceway is calculated, as shown in Fig. 5. With increase of the lance tip area, the change trend of coal burnout has no significant difference. Before 0.2 m from the raceway inlet in the direction of axis +X, a slight increase of the coal burnout is observed. After 0.2m in the direction of axis +X, the coal burnout rapidly increases until about 0.5m. Then the increasing trend of the coal burnout begins to slow down. With increase of the lance tip area, the coal burnout has no obvious differences before 0.2m in the direction of axis +X. And at the distance of 0.2m, the obvious differences begin to appear. When the lance tip diameter is 15mm, the growth rate of the coal burnout slows down from the distance of 0.6m. However, when the lance tip diameter are 20mm and 25mm, the growth rate of the coal burnout do not reduce much compare with that of the diameter 15mm. We can analyze this phenomenon from two aspects. Firstly, with increase of the lance tip area, the coal burnout is higher and more heat is produced. At the end of the raceway, the coal particles absorb more heat and release more volatile matter. On the other hand, the coal stream moves upward and the local oxygen around the coal particles is added, which is helpful for the coal combustion.

Conclusions

In this paper, a numerical model of the coal combustion simulated the lance—blowpipe—tuyere—raceway of the blast furnace was developed. The effect of coal lance tip position and area on coal combustion is investigated. The main conclusions are as follows:

(1) The coal burnout gradually increases with increase of the lance tip distance from the raceway. In the first part of the raceway, this way is very effective in improving the coal burnout. However, the effect is not very obvious in the second part of the raceway. This is mainly because, with increase of the lance tip distance, the oxygen is consumed in advance and the coal combustion is limited at the end of the raceway.

(2)The coal burnout gradually increases with increase of the lance tip area. On the one hand, the residence time of the coal particles increases with increase of the lance tip area. On the other hand, the coal streams move upward, where the oxygen concentration is higher.

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