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SIMULATION STUDY ON THE JET CHARACTERISTICS OF COHERENT JET OXYGEN LANCE USED IN BASIC OXYGEN FURNACE (BOF)

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Coherent jet oxygen lance is a new type of oxygen lance. In this paper, numerical study on the jet flow of coherent jet oxygen lance was carried out with different protective gas out the circular gap around the steel supersonic oxygen lance nozzle. The simulation results showed that the protection gas density was smaller, the oxygen core length was longer. High temperature carbon dioxide and hydrogen gas had the same protection effect on the main oxygen core length. The main oxygen core length increased as the increasing of the temperature and the pressure of the carbon dioxide protection gas. The result of this paper provides a theoretical basis for the design of the coherent jet oxygen lance used in BOF.

Key word: BOF, coherent jet, oxygen lance, protective gas, carbon dioxide

INTRODUCTION

Coherent jet oxygen lance was used in electric furnace primarily, and there have been many study results about it [1,2] where have studied the coherent jet oxygen lance technique used in 30 t BOF. Comparing with the traditional one, the coherent jet oxygen lance has longer jet flow distance and less oxygen and steel consumption in the same conditions [3].The study results of here showed that the smelting effect of the electric furnace was improved and the smelting cycle of the electric furnace shortened after using coherent jet oxygen lance [4]. Meanwhile, the results showed that each consumption indicator of the electric furnace was improved. The research results of Kun Liu and Li-ming Bao showed that the coherent jet oxygen lance had shorter mixing time of molten iron, smaller splash and deeper impact depth [5,6]. The advantages of the coherent jet oxygen lance used in electric furnace, provided the possibility for this technique used in BOF. In this paper, with the accompanying holes opened around a traditional oxygen lance, a traditional oxygen lance was modified to be a coherent jet oxygen lance that used in BOF. The influence of the protective gas kind, gas pressure and temperature on the main oxygen core length were simulated by CFD software.

CALCULATION MODEL AND RELEVANT PARAMETERS

The coherent jet oxygen lance model was a laval tube, with the accompanying flow holes around it such as Figure 1. In practical, the pipes of the accompanying flow are a certain number of holes with uniform distribution, the diameter of the holes is 4 mm. In this paper, the accompanying holes were equal to be a circular gap with the method of equivalent area. The relevant parameters of the laval tube are: inlet diameter was 55 mm, throat diameter was 37,2 mm, outlet diameter was 50,8 mm, the length of the contraction section was 44,6 mm, the length of the expansion section was 97,2 mm, the length of the throat was 5 mm.

THE INFLUENCE OF THE DIFFERENT ACCOMPANYING GAS ON THE MAIN OXYGEN CORE LENGTH

The main principle of the coherent jet oxygen lance was that the oxygen lance nozzle was added burners that formed annular high temperature flame surround the main oxygen flow, which reduces the entrainment and increase the length of the core region. It was difficult to produce coherent jet by adding burners, because of the hole number of oxygen lance used in BOF are more than three. So in this paper, annular gap around

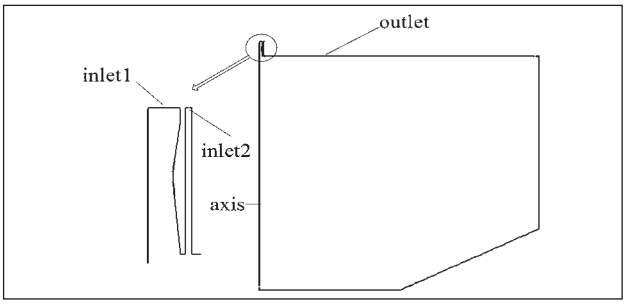

Figure 1 Model of the Coherent oxygen lance

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the nozzle hole is added, accompanying gas flowing instead of high temperature flame.

ANALYSIS OF ACCOMPANYING EFFECT WITH THE NORMAL TEMPERATURE GAS USED

Based on the model of Figure 1, the inlet1 was set as oxygen with the pressure of 0,8 MPa and the temperature of 300 K. The inlet2 was set as low density gas with the pressure of 0,18 MPa and the temperature of 300 K, and H_2, He and CO as the accompanying gas respectively. The simulation results are as Figure 2. In the Figure 2 to Figure 6, De is inlet diameter, x is the distance from the inlet of oxygen lance, um is the oxygen flow velocity at any distance, ue is inlet velocity.

It can be seen from the Figure 2, the length of main oxygen core was about 10 De, 15 De, 20 De, when the accompanying gas was CO, He, H_2 accordingly. It could be seen that the different accompanying gas has a certain influence on the velocity of the main oxygen jet. The length of main oxygen core was related to the density of the accompanying gas. Under the same conditions, the outlet velocity of the accompanying gas increased and the outlet density of the accompanying gas decreased with the decreasing of the accompanying gas molecular weight, which strengthened the protection effect for the main oxygen jet and decrease the entrainment that the main oxygen jet from the surrounding gas. Therefore, the gas with lower molecular weight is suitable for the accompanying gas that can protect the main oxygen jet to form coherent state.

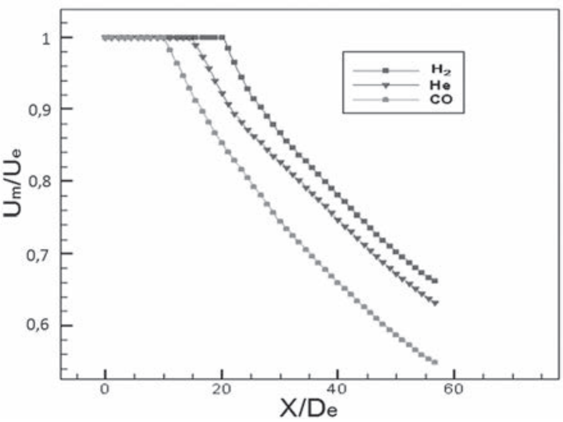

Figure 2 Velocity attenuation of the main oxygen flow along the axis with different gas accompanying

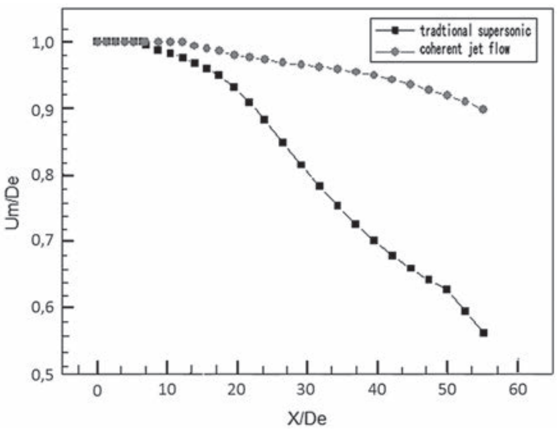

Figure 3 Velocity attenuation of the main oxygen flow along the axis with high temperature CO_2 accompanying.

Analysis of accompanying effect with high temperature CO_2 used

The main hole flowing condition was the same as the above.CO_2 with the pressure of 0,18 MPa and the temperature of 1 773 K passed through the accompanying hole, the environment temperature was set as 1 873 K. The velocity attenuation along the axis of traditional supersonic jet without accompanying flow and coherent jet with accompanying flow, were shown in Figure 3. It can be seen from the Figure 3, the length of the main oxygen core was 5 De, 14 De respectively, to the traditional supersonic jet and the coherent oxygen jet accordingly. The length of the main oxygen core of the coherent jet was close to three times the traditional supersonic jet's. Under the same distance from the nozzle outlet, the velocity of the coherent jet along the axis was greater than the traditional supersonic jet's. Which can be proved that adding accompanying flow arround the traditional oxygen lance hole can lengthen the main oxygen core length and form coherent jet.

The influence of the accompanying flow parameters variation on the main oxygen core length

By the contrasting Figure 2 with Figure 3, it can be known that there was little difference between the the accompanying effect of high temperature CO_2 and the accompanying effect of low molecular weight He. And high temperature CO_2 made the velocity attenuation of the main oxygen slow down. So high temperature CO_2 can be used as accompanying gas. In order to determine the appropriate pressure and temperature of the accompanying flow, this paper simulated and analyzed the influence of the accompanying flow with different pressure and temperature on the main oxygen core length.

The variation of the accompanying flow temperature

The inlet conditions of the main hole as the above. The accompanying flow inlet was set as CO_2, and the pressure was 0,18 MPa. Outlet pressure was 103 000 Pa and environment temperature was 300 K. The temperature of CO_2 was set as 2 073 K, 1 773 K, 800 K, 1 773 K respectively. The simulating results of the velocity field on jet axis under the four kinds of accompanying flow temperature were drawn in Figure 4.

It can be known that when the accompanying flow temperature increased from 300 K to 2 073 K, the beginning attenuation location of the jet velocity moved backward gradually. When the accompanying flow tem-

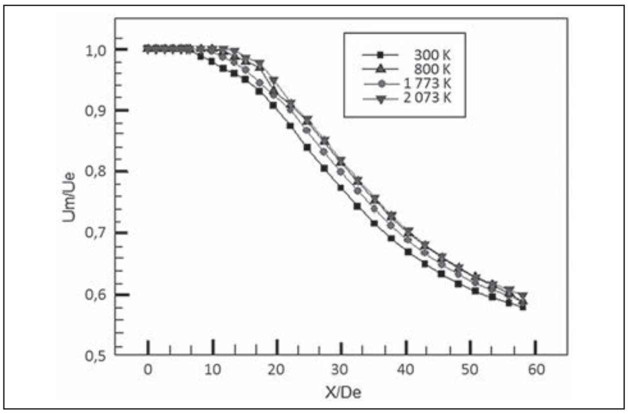

Figure 4 Velocity attenuation of coherent jet along the axis with CO_2 accompanying of different temperature

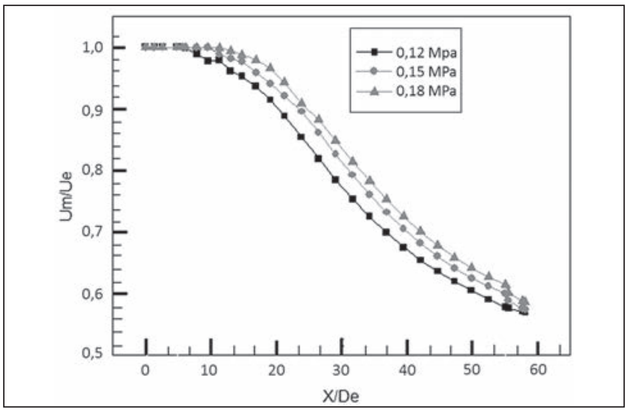

Figure 5 Velocity attenuation of coherent jet along the axis with CO_2 accompanying of different pressure

perature was 300 K, the velocity attenuation position began at about 6 De. When the accompanying flow temperature was 2 073 K, the velocity attenuation position began at about 16 De. The main oxygen core length increased successively with the increasing of accompanying flow temperature. As the accompanying flow density decreased with the increasing of its temperature, so the entrainment that the main oxygen from the surrounding gas would decrease. Finally, the main oxygen jet could keep initial velocity in a long distance.

The variation of the accompanying flow pressure

The inlet conditions of the main hole was also as the above. The accompanying flow inlet was set as CO_2, and the temperature was 1 773 K. The outlet pressure was 103 000 Pa and the environment temperature was 300 K. The pressure of CO_2 was set as 0,18 Mpa, 0,15 Mpa, 0,12 Mpa respectively. The simulating results of the velocity field along the axis under the four kinds of accompanying flow pressure were drawn in Figure 5.

It can be known from the Figure 5.that the accompanying flow pressure had a great influence on the main oxygen length. The higher the accompanying flow pressure was, the longer the main oxygen length. When the accompanying flow pressure was 0,12 Mpa,, the velocity attenuation position began at about 6 De. When the accompanying flow pressure was 0,18 Mpa the velocity attenuation position began at about 14 De. Under the same conditions, the beginning attenuation location of the jet velocity moved backward with the increasing of the accompanying flow pressure.

CONCLUSION

In this paper, with the accompanying holes opened around a traditional oxygen lance, a traditional oxygen lance was modified to be a coherent jet oxygen lance that used in BOF. The influence of the protective gas kind, gas pressure and temperature, circumstance temperature on the main oxygen core length were simulated by CFD software, the conclusions were drawn as following,

1) The low density accompanying flow gas can lengthen the main oxygen core length. CO_2 with high temperature can be used as the accompanying flow instead of the high temperature flame.
2) The main oxygen core length was increasing with the pressure and temperature of accompanying flow increasing, the coherent effect of the main oxygen jet was good.
3) For the porous oxygen lance, the flame accompanying flow can be replaced by the gas of CO_2 with high temperature, that make the difficulty of the manufacture for the porous coherent jet oxygen lance reduced.

Acknowledgments

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Note: L. H. Feng is responsible for English language, Anshan, China