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SIMULATION STUDY ON INFLUENCE OF ADJOINT FLOW TO CORE FLOW

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In the process of steel production, jet stirring is very important, and the core velocity of jet determines the stirring ability of jet. In jet flow, due to the influence of the gas viscosity, the kinetic energy of the jet will be dissipated, which makes the length of the velocity core region unable to reach a large length. In this paper, the adjoint nozzle is set around the main nozzle, which can protect the core jet by adjoint flow, slow down the energy consumption of the core flow and extend the length of the core area of the jet. The results show that the velocity attenuation of the jet with and without adjoint flow is not obvious compared with that of the non accompanying flow. When the temperature of the accompanying flow reaches a certain level, the protection effect of the wake on the core jet is more obvious.

Keywords: steel production, flow field, jet flow, numerical simulation

INTRODUCTION

In the steel-making process, the oxygen jet controls the molten bath agitation and the extent of reaction. So it influence the smelting condition directly. Along with capability of converter increase, a further request is set to the agitation ability of the oxygen jet. When smelting by top blowing, the attenuating of the core flow of the oxygen jet is more rapidly. And the stirring intensity to the molten steel is insufficient, and it is no good to the smelting condition. The adjoint flow system is added to the jet flow, and the adjoint flow can wrap the main jet up, and mitigate the attenuation of the axial line speed of it. Thus the strong penetrability and stirring intensity of the main jet will be got. In this paper, the character of the jet flow with adjoint flow is analyzed through numerical simulation.

CALCULATION MODEL ESTABLISHMENT

Geometric model and grid partition

In this paper, the flow field of the main nozzle with adjoint nozzle is studied. The geometric model is shown in Figure 1.

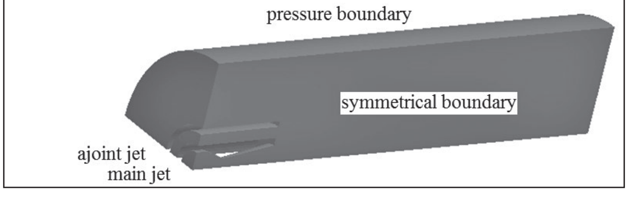

Figure 1 Geometric model

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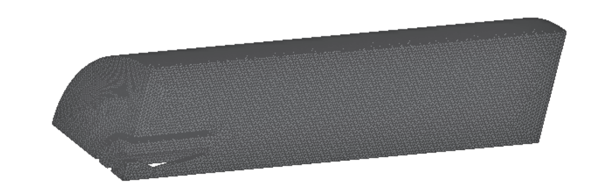

Figure 2 Model grid partition

The model grid partition is shown in Figure 2. The number of 2D elements is 39 400 and the number of tetrahedron elements is 438 238.

Governing equation and setting of simulation conditions

Continuity equation

$$\frac{\partial(\rho u)}{\partial x}+\frac{\partial(\rho v)}{\partial y}+\frac{\partial(\rho w)}{\partial y}=0$$

Momentum equation

$$\frac{\partial}{\partial t}\rho U+\nabla\cdot\left(\rho U^2\right)-\nabla\cdot\left(\mu_{eff}\nabla U\right)=$$

$$=-\nabla P+\nabla\cdot\left[\mu_{eff}\left(\nabla U\right)^T\right]+B$$

energy equation

$$\frac{\partial}{\partial t}\rho H+\nabla\cdot\rho UH-\nabla\cdot\lambda\nabla T=\frac{\partial P}{\partial t}$$

Equation of state

$$P=\rho RT$$

Where ρ is density, U is velocity, B is volume force, H is total enthalpy, λ is thermal conductivity, T is temperature, R is gas constant.

In the simulation, the boundary condition of the model is described as follow. The pressure boundary condition is set as 101 325 / Pa, the temperature is set as 298 / K. The inlet velocity is Mach 1,8.

SIMULATION RESULTS AND ANALYSIS

Comparison of flow field

Figure 3 and figure 4 show core of the jet under different situation. It can be seen from the figures that under the protection of adjoint flow, the core velocity of the main jet can be maintained to a longer distance, the core kinetic energy consumption is slower, and its range is obviously longer than that of the jet without adjoint flow.

Comparison of the main flow speed under different pressure

Figure 5 is the curve of core speed of main jet under different pressure when the temperature of the adjoint flow is 1 600 / °C

The Figure shows that, when the temperature of the adjoint flow is 1 600 / °C, the core space increases only a little when the pressure increasing. The reason is that

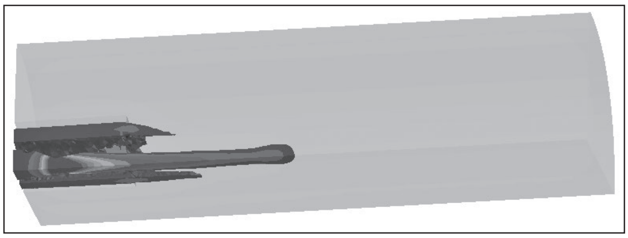

Figure 3 Core of the jet with adjoint jet

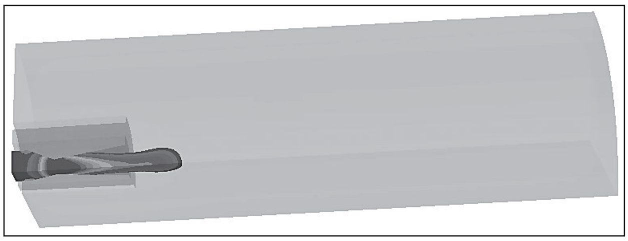

Figure 4 Core of the jet without adjoint jet

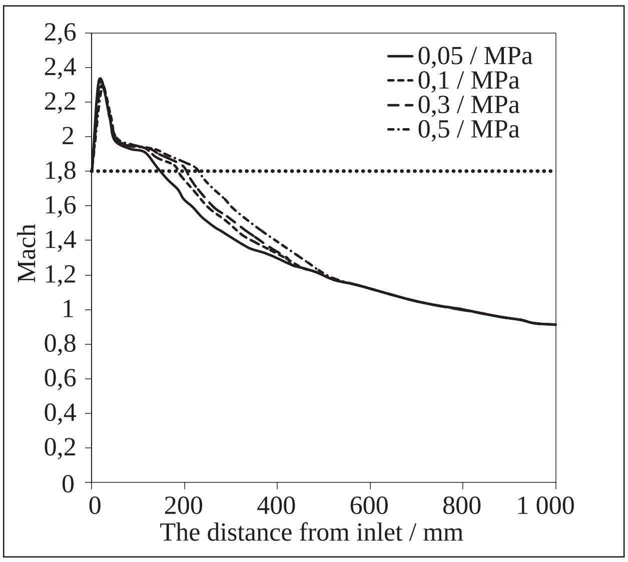

Figure 5 The main flow speed under different pressure when the temperature of the adjoint flow is 1 600 / °C

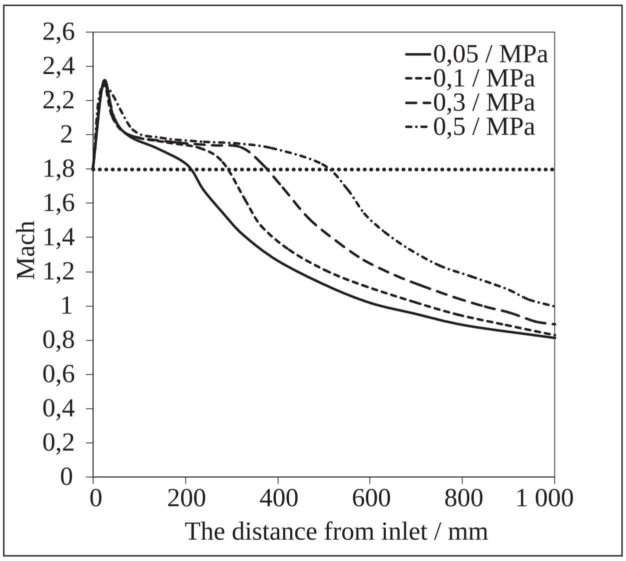

Figure 6 The main flow speed under different pressure when the temperature of the adjoint flow is 1 800 / °C

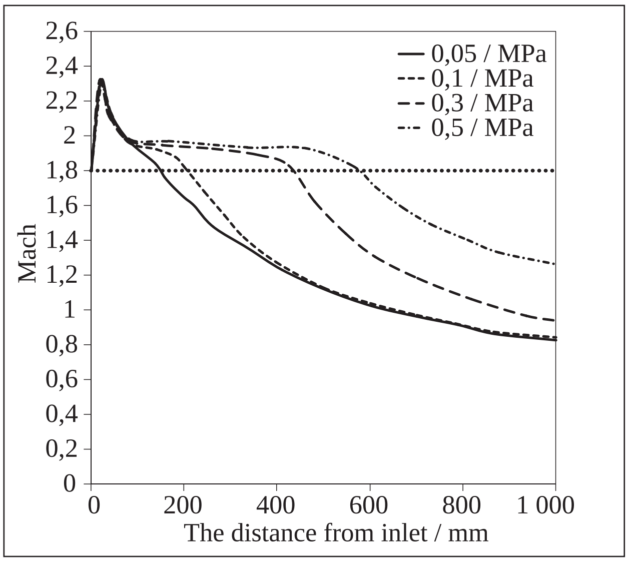

Figure 7 The main flow speed under different pressure when the temperature of the adjoint flow is 2 100 / °C

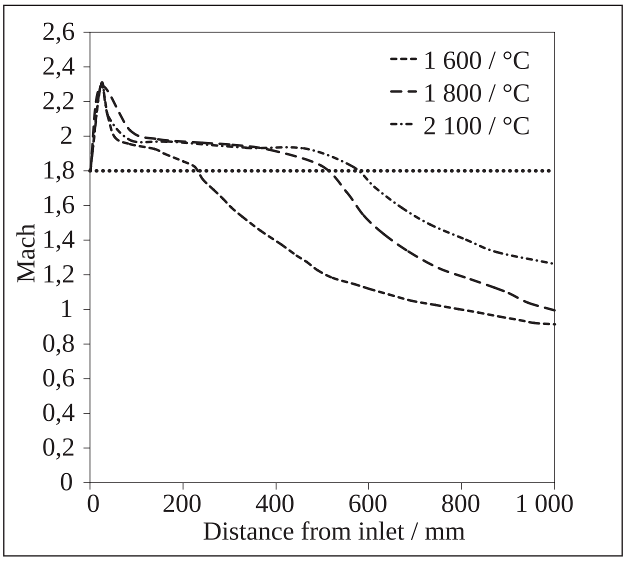

Figure 8 The main flow speed under different temperature of the adjoint flow is under different temperature when the pressure of the adjoint flow is 0,5 / MPa

the temperature of the adjoint flow is low, cause the density of the gas high. When the main jet entrains massive high density gas, the core speed attenuates rapidly.

Figure 6 is the curve of axial line speed of main jet under different pressure when the temperature of the adjoint flow is 1 800 / °C. The figure shows that the core space increases along with the pressure of the adjoint flow increasing obviously. The reason is that when the temperature achieves a certain level, the gas of the adjoint flow expends, and the density of the gas decreases. Because of the decreasing of the entrainment quality, the axial line speed of the main jet can keep the initial speed longer. And along with the increasing of the adjoint flow pressure, the protective function's distance increases.

Figure 7 is the curve of axial line speed of main jet under different pressure when the temperature of the adjoint flow is 2 100 / °C. The figure shows, like Figure 4, the core space increases along with the increasing of the adjoint flow pressure. The increasing of the core space is not obvious when the pressure increases from 0,05 / MPa to 0,1 / MPa, and it become obvious when the pressure increases above 0,3 / MPa.

Comparison of the main flow speed under different temperature

Figure 8 is the curve of axial line speed of main jet under different temperature when the pressure of the adjoint flow is 0,5 / MPa.

The Figures shows that the core space of the main jet increases obviously along with the temperature of the adjoint flow increasing (especially above 1 800 / °C). The reason is the density of the gas decreases because of the temperature increasing, and the entrainment quality decrease, the axial line speed of the main jet can keep the initial speed longer.

CONCLUSIONS

Comparing with the traditional lance jet, the attenuation of the axial line speed of the coherent jet is inconspicuous, and the impulse is enhanced obviously. When the temperature of the adjoint flow is 1 600 / °C, the protective function is not obvious because of the high tendency of the gas. When the temperature achieves certain level, the density of the gas decreases to a certain level, the protective function becomes obvious. The core space of the main jet increases along with the increasing of the adjoint flow temperature under certain pressure.

Acknowledgements

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REFERENCES

[1] G. Wei, R. Zhu, T. Cheng, K. Dong, R. Liu. Modelling on the penetration depth of the coherent supersonic jet in EAF steelmaking [J]. Ironmaking & Steelmaking (2017), 1-11.

[2] X. B. Zhou, M. Ersson, L. C. Zhong, P. Jonsson. Numerical Simulations of the Kinetic Energy Transfer in the Bath of a BOF Converter [J]. Metallurgical & Materials Transactions B 47(2016)1, 434-445.

[3] Q. Li, M. Li, S. Kuang, Z. Zou. Numerical Simulation of the Interaction Between Supersonic Oxygen Jets and Molten Slag–Metal Bath in Steelmaking BOF Process [J]. Metallurgical & Materials Transactions B 46 (2015) 3, 1494-1509.

[4] M. Alam, J. Naser, G. Brooks, A. Fontana. A Computational Fluid Dynamics Model of Shrouded Supersonic Jet Impingement on a Water Surface [J]. ISIJ International 52 (2012) 6, 1026-1035.

[5] F. Liu, D. Sun, R. Zhu, Y. Li. Effect of Shrouding Gas Temperature on Characteristics of a Supersonic Jet Flow Field with a Shrouding Laval Nozzle Structure [J]. Metallurgical & Materials Transactions B 49 (2018) 4, 1-13

[6] L. M. Bao, K. Liu, G. C. Lv. The Hydraulics simulation of the oxygen lance top-blown process used in BOF [J]. Special Steel 5(2007), 13-16.

Note: The responsible translator for English is Yan Wu, University of Science and Technology Liaoning, Anshan city, China