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SIMULATION STUDY ON FLOW FIELD IN TUNDISH AND THE INFLUENCE OF BAFFLE

YIXUAN LU and ZHENSHAN ZHANG

School of Electronic and Information Engineering
University of Science and Technology Liaoning
Anshan 114051
Liaoning
P. R. China

School of Applied Technology
University of Science and Technology Liaoning
Anshan 114051
Liaoning
P. R. China
e-mail: lnaszzs@163.com

Abstract

In this paper, simulation of the flow field in tundish is established by ProCAST. The results show that the deeper liquid level is beneficial to the flow stable. Compared with the tundish with baffle, the disturbance of molten steel without baffle is stronger than that with baffle in both bottom flow and free surface.

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The baffle can effectively limit the disturbance of molten steel near the submerged nozzle. Compared with the ordinary baffle, the kinetic energy diffusion of the liquid steel on the left side of the perforated baffle is more sufficient.

1. Introduction

As a transition vessel connecting ladle and mould, tundish can not only improve the temperature and composition uniformity of molten steel, but also play a role in promoting the floating of inclusions and purifying molten steel with the continuous development and improvement of tundish metallurgical technology [1-3]. The flow state and velocity distribution of fluid in tundish have important influence on the uniformity of fluid composition and temperature, and the floating and removing of inclusions [4-7]. The structure of tundish determines the flow state and velocity distribution of fluid in tundish. Therefore, adjusting tundish structure is an important measure to improve the flow field of molten steel in tundish [8].

In this paper, by setting and adjusting the baffle structure to affect the flow field of tundish, so as to obtain a better flow state of molten steel.

2. Principles in the Modal

Continuity equation:

$$\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho \vec{v}) = S_m;$$

Momentum equation:

$$\frac{\partial}{\partial t}(\rho \vec{v}) + \nabla \cdot (\rho \vec{v}^2) = \nabla_p + \nabla \cdot (\bar{\tau}) + \rho \vec{g} + \vec{F};$$

Energy equation:

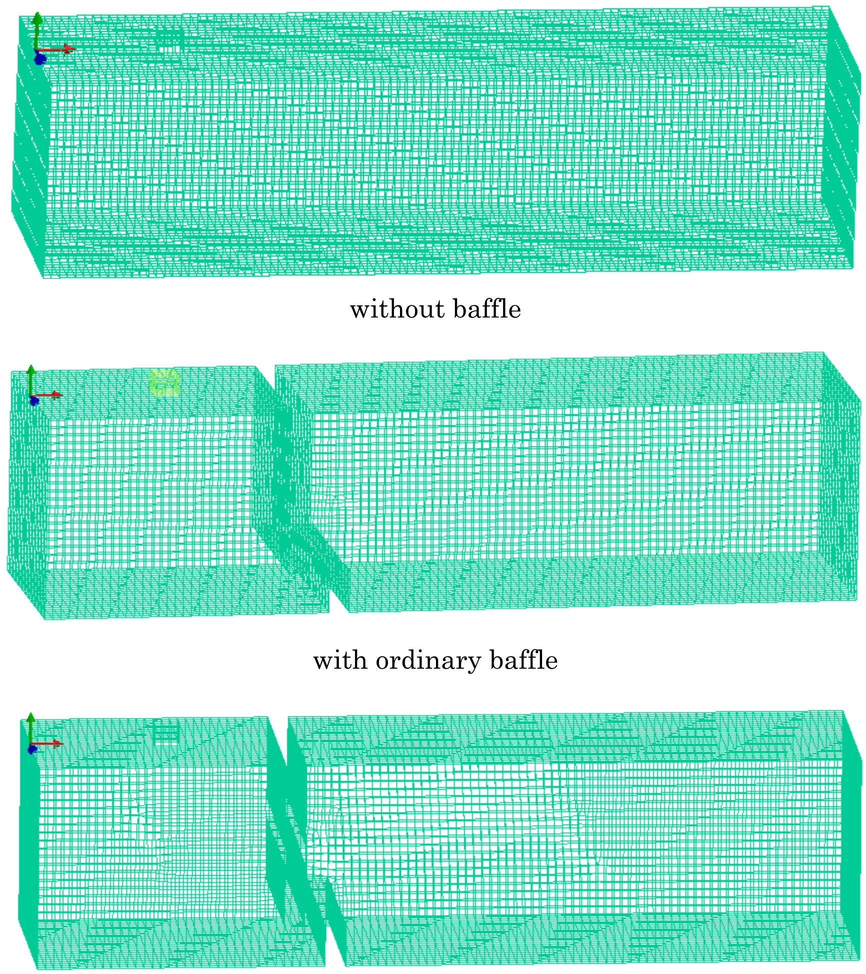
$$\frac{\partial}{\partial t}(\rho H) + \nabla \cdot (\rho \vec{v} H) = \nabla_p + \nabla \cdot \left(\frac{k}{C_p} \nabla H \right) + S_h,$$

where ρ is fluid density, $\mathrm{kg/m^3}$; ν is velocity vector, m/s; S_m, S_h are source phase; F is viscous force; and H is fluid momentum.

In this paper, it is assumed that the effect of covering agent on molten steel in tundish is ignored, molten steel is an incompressible fluid, and the flow process in tundish is steady flow, the temperature change of molten steel in the flow process is not considered, it is no slip boundary between liquid steel and the wall. The pouring temperature is set at 1600^{o}C.

3. Structure of the Modal and the Initial Condition

In this paper, the calculation region of tundish flow field is set as 2000mm in length, 500mm in width, and 1000mm in depth. Three kinds of tundish which is without baffle, with ordinary baffle and perforated baffle are designed. The 3D model of tundish flow field is discretized into hexahedral elements. In order to make the simulation results more accurate, all meshes refinement is carried out based on the smallest size. The grid generation effect is shown as follows.



without baffle

with ordinary baffle

with perforated baffle

Figure 1. 3D model and mesh generation.

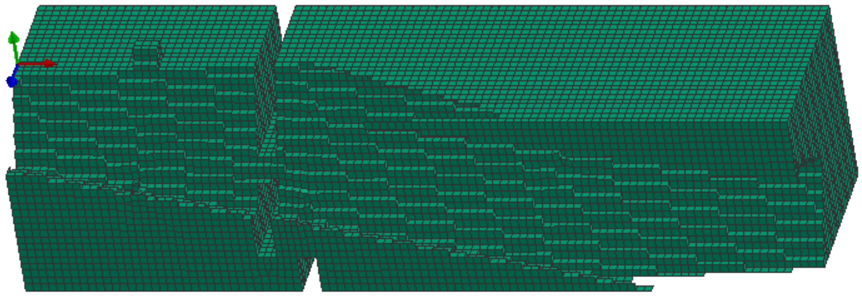


Figure 2. Internal grid state.

There are 62527 hexahedral meshes in tundish without baffle model, 61602 hexahedral meshes in tundish with ordinary baffle model, and 62427 hexahedral meshes in tundish with perforated baffle model.

4. Analysis of the Results

4.1. Analysis without baffle

4.1.1. Flow field of tundish with 500mm liquid level

Figure 3 shows the flow field of tundish without baffle when the liquid level is at 500mm. It can be seen from the figure that under the long nozzle, due to the large initial kinetic energy of molten steel, the flow is disordered and the disturbance is severe. Because there is no obstacle to the kinetic energy, the flow velocity of molten steel far away from the long nozzle is also very high. The higher velocity can be transferred to the outlet of tundish. The flow velocity is high in the surface of liquid region far from the long nozzle.

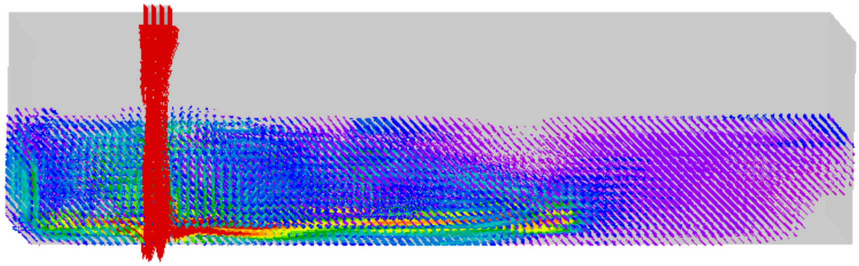


Figure 3. Flow field at 500mm liquid level.

Figure 4 is the flow field at the bottom of tundish. It can be seen from the figure that the liquid steel velocity is the fastest in the direct impact area of the injection flow, especially on the bottom. In addition, due to the viscous force of liquid steel, raceway appears near the injection flow. According to the measurement, the horizontal distance between the center of the right raceway and the center of the molten steel injection is 232.7mm; the position of the left raceway is shifted to the wall due to the influence of the nearby wall, and the horizontal distance from the molten steel injection center is 274.8mm. Due to the impact, the flow of molten steel in the pool is greatly affected. The obvious disturbance zone can extend to about three fourths of the length direction of tundish, and almost all the width direction is affected.

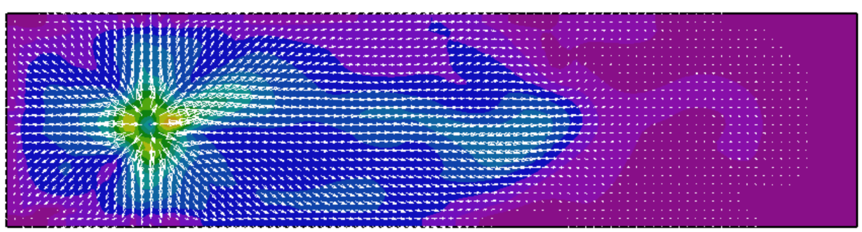


Figure 4. Flow field at the bottom of tundish.

The calculation results show that the maximum value is 1.4m/s at 400mm away from the left wall of tundish. In the region of molten steel injection, the velocity has obvious wave peak. Its width is about 150mm. And there is a second velocity step with an average velocity of 0.67m/s between 680mm to 1340mm away from the left wall. The velocity attenuates to a smaller level at a further distance from the injection location.

Figure 5 shows the flow field of the free surface in tundish. Due to the influence of viscous force and swirling flow, the velocity of molten steel is fast around the flow. However, the liquid steel flow on the surface far away from the injection point is different from that on the bottom. Due to the wall action, the liquid steel flows back, resulting in a higher surface velocity of liquid steel at the far region from injection point.

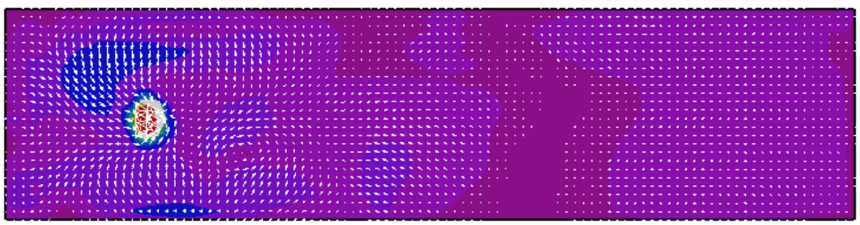


Figure 5. Flow field of free surface in tundish.

4.1.2. Flow field of tundish with 900mm liquid level

Figure 6 shows the flow field of tundish without baffle when the liquid level is at 900mm. It can be seen from the figure that under the long nozzle, due to the large initial kinetic energy of molten steel, the flow of molten steel is disordered and the disturbance is more severe. The flow velocity of molten steel far away from the long nozzle is smaller than that in 500mm liquid level, which is caused by the buffer effect of the molten steel. In the overall flow field results of tundish, it can be seen that the larger velocity can be transferred to the outlet of tundish.

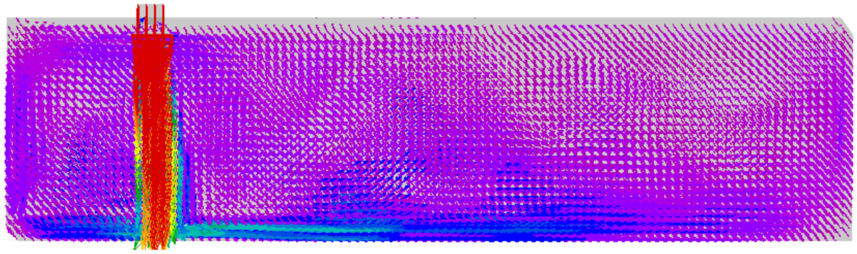
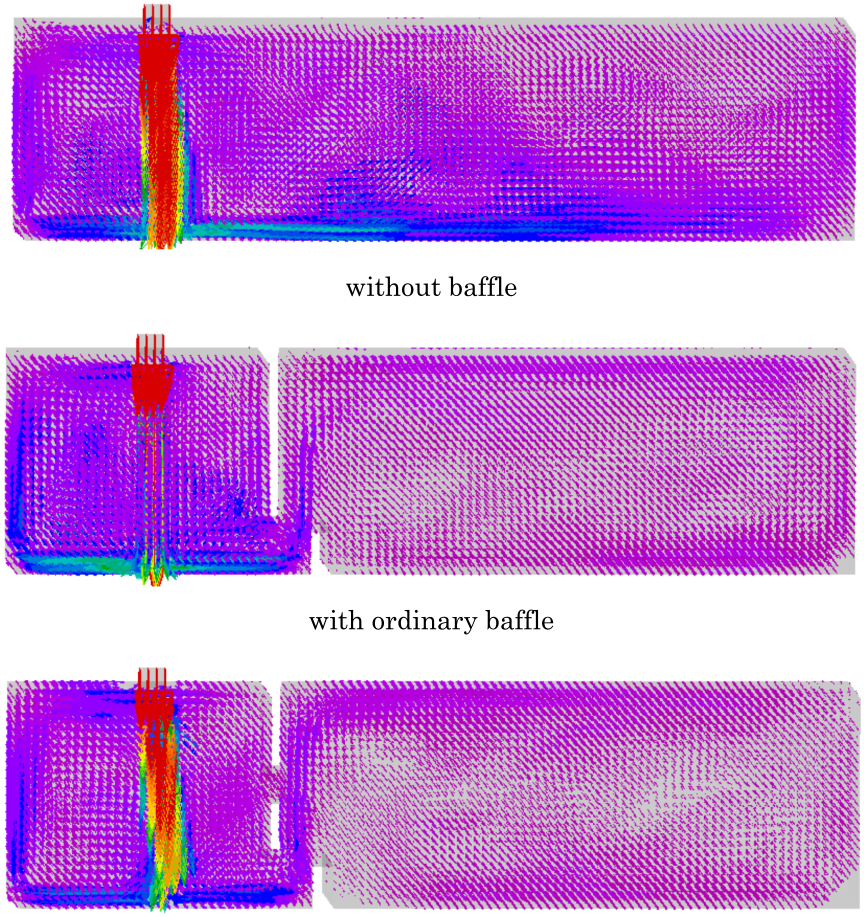


Figure 6. Flow field at 900mm liquid level.

The velocity of molten steel is the fastest in the direct impact area of the injection. In addition, due to the viscous force of liquid steel, raceway appears near the injection flow, but the raceway position is different from that at 500mm liquid level situation. According to the measurement, the horizontal distance between the center of the right raceway and the center of the injection is 248.8mm; the position of the left raceway is shifted to the wall due to the influence of the nearby wall, and the horizontal distance from the injection center is 273.2mm. Moreover, the raceway center is located deeper below the free surface than that at 500mm liquid level situation, and the distance is about 667.1mm.

4.2. Comparative analysis of flow field in different tundish structures

Based on the previous study, the following analysis is the comparison of 900mm liquid level results. Figure 7 shows the comparison of overall flow field in tundish.



without baffle

with ordinary baffle

with perforated baffle

Figure 7. Comparison of flow field in tundish with different schemes.

It can be seen from the figure that, on the left side of the baffle plate, the tundish with baffle has more severe disturbance than the molten steel without baffle plate in the casting area of long nozzle. The flow velocity of liquid steel is slowed down in the area with baffle, especially in the area without baffle. On the other hand, in the middle of liquid steel depth, the flow with baffles is more stable than that without baffles. In the upper part, the velocity distribution of molten steel with baffles is more uniform. The kinetic energy transfer distance of molten steel on the bottom surface of tundish with baffle is obviously smaller than that without baffle. The average flow velocity is about 1280m/s when the baffle is immersed in the baffle, and the average velocity is about 0.2m/s when the baffle is immersed in the baffle, and the average velocity is about 0.16m/s when the baffle is submerged through the baffle, and the average velocity is about 0.16m/s when there is a hole in the baffle. That is to say, under the conditions of this paper, the baffle can obviously limit the bottom flow rate and reduce the free surface steel flow rate, but the effect of restricting the flow rate on the free surface with or without holes is not obvious.

5. Conclusion

In the comparison of the results of different liquid levels, the deeper liquid level is beneficial to the stability of the flow field, which is due to the restriction of the viscosity of the liquid steel itself. In addition, the deeper liquid level is beneficial to the operation of tundish metallurgy.

Compared with the tundish with baffle, the disturbance of liquid steel without baffle is stronger than that with baffle at both bottom and free surface of molten steel. This is because the restriction of baffle limits the kinetic energy of liquid steel and hinders the transmission of kinetic energy of liquid steel.

The effect of steady flow effect of lower molten steel by perforated baffle is better than that of ordinary one, but there is no significant difference in the effect of free surface.

References

[1] Dong-Yuan Sheng, Mats Söder, Pär Jönsson and Lage Jonsson, Modeling micro-inclusion growth and separation ingas-stirred ladles, Scandinavian Journal of Metallurgy 31(2) (2002), 134-147.

DOI: https://doi.org/10.1034/j.1600-0692.2002.310208.x

[2] L. T. Wang, Q. Y. Zhang, S. H. Peng and Zheng Bang Li, Mathematical model for growth and removal of inclusion in a multi-tuyere ladle during gas-stirring, ISIJ International 45(3) (2005), 331-337.

DOI: https://doi.org/10.2355/isijinternational.45.331

[3] Bangwen Zhang, Kang Deng, Zuosheng Lei and Zhongming Ren, A mathematical model on coalescence and removal of inclusion particles in continuous casting tundish, Acta Metallurgica Sinica 40(6) (2004), 623-627.

[4] T. Nakaoka, S. Taniguchi, K. Matsumoto and S. T. Johansen, Particle-size-grouping method of inclusion agglomeration and its application to water model experiment, ISIJ International 41(10) (2001), 1103-1111.

DOI: https://doi.org/10.2355/isijinternational.41.1103

[5] Deng-fu Chen, Rui Hu, Qing-Xia Wang, Xing Jin, Xi-Jiu Yan, Jin-Zhu Li and Kai-Cheng Zhou, Physical and mathematical study on weir setting in continuous casting tundish, The Chinese Journal of Process Engineering z1 (2008), 49-53.

DOI: https://doi.org/10.3321/j.issn:1009-606X.2008.z1.010

[6] A. R. Alaei, H. Edris and E. Shirani, Upward molten flow for optimization of fluid flow in continuous casting tundish, Journal of Iron and Steel Research International 17(11) (2010), 29-33.

DOI: https://doi.org/10.1016/S1006-706X(10)60166-5

[7] Peng-long Han and Ruosi Wang, Influence of tundish reform on casting slab quality, Foundry 35(3) (2014), 565-567.

[8] Lifu Zhang, Luyi Wang, Fuxiang Cui, Chunfeng Lv, Hongliang Zhang and Xiaoguang Zhang, Optimization of flow field in tundish in heavy slab continuous caster, Angang Technology 5 (2019), 14-18.

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