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NUMERICAL SIMULATION STUDY ON THE INFLUENCE OF CURRENT STABILIZER ON TUNDISH FLOW FIELD

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The software ProCAST is used to simulate the flow field in the tundish. In the tundish without current regulator, the long nozzle injection impacts the tundish bottom directly, which is easy to cause damage to the refractory. The molten steel flow diffuses far along the bottom, and the disturbance is large near the submerged nozzle. The maximum speed at the bottom can reach 0.8m/s, and the general flow trend is that the injection flow direction is upward from the bottom to both sides, which is not conducive to the upward floating of inclusions. In the tundish with current stabilizer, the velocity of the injection decreases rapidly under the action of the liquid steel contained in the current stabilizer. Due to the attenuation of injection kinetic energy, the scouring effect on the bottom of tundish is obviously smaller and the flow field is more stable.

Key words: steel, continuous casting, tundish, nozzle analysis, numerical simulation

INTRODUCTION

The tundish can hold the liquid steel for a certain time, so that the inclusions can be fully removed[1,2]. And in the tundish, static pressure of liquid steel can be controlled reasonably, the liquid steel flow rate can be controlled through the mechanism[3-5]. Multiple outlets are set to realize multi flow casting at the same time. When the ladle changing, the molten steel retained in the tundish can continue to be poured, which is the key component of continuous pouring[6]. Many metallurgical functions of tundish are related to flow field. The control of flow field is an important means to determine the effect of tundish metallurgical function[7-9]. In this paper, the influence of tundish current stabilizer on the flow field is simulated and analyzed, which has certain guiding significance for production practice.

MODEL ESTABLISHMENT

Geometric model and grid partition

The tundish model is shown in Figure 1. The total length of the tundish is 10 307 / mm, the total width is 2 308 / mm and the total height is 1 630 / mm. The tundish in this paper is an 8-flow tundish, the diameter of the nozzle is 148 / mm and the center distance of the nozzle is 1 247 / mm. The thickness of bottom plate is 300 / mm, the average thickness of wall is 210 / mm.

The structure of the current stabilizer in this paper is shown in Figure 2. The total height of the current regulator is 350 / mm, the diameter of the outer wall is 560 / mm, the diameter of the uppermost opening is 420 / mm, and the diameter of the bottom surface of the inner cavity is 317 / mm.

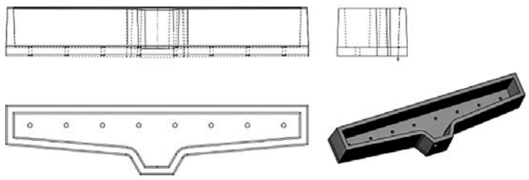

Figure 1 The tundish model

In this simulation, tetrahedral mesh is used to discretize the geometry, in which the number of 2D elements is 117 528 and the number of 3D elements is 1 027 550.

Governing equation and setting of simulation conditions

continuity equation

$$\frac{\partial \rho}{\partial t} + \frac{\partial(\rho u_i)}{\partial x_i} = 0$$

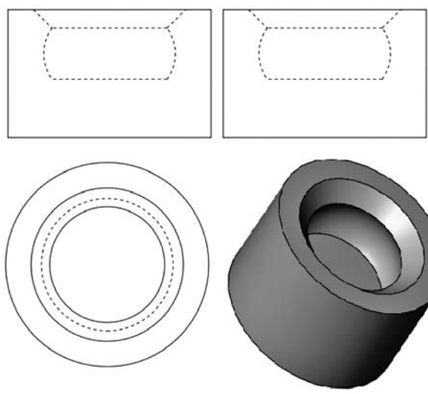

Figure 2 Current stabilizer model

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momentum equation

$$\frac{\partial(\rho u_i u_j)}{\partial t} = -\frac{\partial \rho}{\partial x_i} + \frac{\partial}{\partial x_j}\left[(\mu + \mu_t)\left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i}\right)\right] + \rho g_i$$

k equation

$$\rho u_i \frac{\partial k}{\partial x_i} = \frac{\partial}{\partial x_i}\left(\frac{\mu + \mu_t}{\sigma_k} \times \frac{\partial k}{\partial x_i}\right) + \mu_t \frac{\partial u_i}{\partial x_j}\left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i}\right) - \rho\varepsilon$$

ε equation

$$\rho u_i \frac{\partial \varepsilon}{\partial x_i} = \left(\frac{\mu + \mu_t}{\sigma_\varepsilon} \times \frac{\partial \varepsilon}{\partial x_i}\right) + \frac{c_1 \varepsilon G}{k} - \frac{c_2 \rho \varepsilon^2}{k}$$

Where u_i is the projection component of fluid velocity on the coordinate axis, m/s; ρ is the density of the fluid / kg/m^3; μ is the viscosity coefficient of fluid / kg/m/s; μ_t is additional viscosity coefficient of fluid / kg/m/s; k is turbulent kinetic energy / m^2/s^2; ε is turbulent energy dissipation rate / m^2/s^3.

No slip boundary is set at the contact between molten steel and tundish inner wall and retaining wall, the inflow speed is 2 / m/s in the long nozzle, and the outflow speed is 0,4566 / m/s in submerged nozzle. The pouring temperature of molten steel is 1 530 / °C.

In the simulation, it is assumed that the molten steel flow in the tundish is incompressible, and its physical parameters are only a function of temperature.

SIMULATION RESULTS AND ANALYSIS

Figure 3 shows the flow field in the inner section of the pouring port. In this area, the space is small. In the tunndish without current stabilizer, there is obvious backflow after the injection touches the bottom due to the wall restriction. On the other hand, the flow velocity at the bottom is 0,8 / m/s, which has a certain attenuation compared with 2 / m/s at the injection boundary of the long nozzle, which is caused by the viscous buffer effect of molten steel and can also be considered as the result of the kinetic energy transfer consumption of molten steel.

In the tundish with the current stabilizer, the high-speed injection flow at the bottom disappears. There are two vortices of up gyration and down gyration at a height of about 400mm from the bottom, which are caused by the overflow flow of the current stabilizer driving the molten steel. The velocity of overflow at the edge of the current stabilizer is about 0,7 / m/s. The liquid steel flow at the bottom of the tundish is mainly caused by this overflow, and the maximum velocity on the bottom is about 0,2 / m/s.

Figure 4 shows the flow field in the central area of the pouring. It can be seen from the figure that the flow velocity in the injection area without flow stabilizer is large, the velocity changes from 2 / m/s at the top to 0,99 / m/s at the bottom, and the flow velocity in the injection impact area is basically about 0,99 / m/s. Due to the large impact kinetic energy, the reflux velocity is large relatively, and the upwelling velocity reaches more than 0,4 / m/s. The surface velocity of molten steel is driven by injection flow and reflux vortex, and its average velocity is about 0,35 / m/s. In this region, the injection has a great impact on the bottom of the tundish.

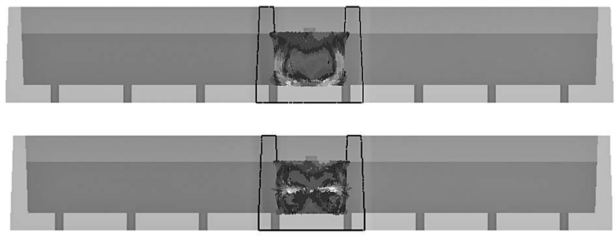

Figure 3 The flow field in the inner section of the pouring port

In tundish with current stabilizer, the flow velocity in the injection area decays rapidly after entering the current stabilizer, and the velocity changes from 2 / m/s to 0,24 / m/s at the bottom of the current stabilizer. The injection has little impact on the bottom. This is because the structure of the current stabilizer causes the kinetic energy of molten steel in it to overflow and diffuse from the edge. The kinetic energy overflow, diffusion molten steel and injection consume each other, resulting in the rapid reduction of injection kinetic energy. Thus the flow speed is already at a low level when reaching the bottom of the current stabilizer. The overflow of the injection at the edge of the current stabilizer forms two downward swirls, while the upper swirling flow is not obvious. The downward flow velocity of the molten steel far away from the injection is only 0,16 / m/s.

Figure 5 shows the flow field of 240 / mm sectional from the injection. In the tundish without current stabilizer, the flow field maintains the flow field characteristics of the injection area because it is close to the injection area. That is, a larger reflux area is formed after the top-down core injection hits the bottom. At the bottom of the profile, the flow rate is almost the same as that at the bottom of the pouring area, about 1 / m/s, which is the extension area of high-speed injection in the pouring area. There is still serious scouring on the bottom of the tundish. In the tundish with current stabilizer, the initial kinetic energy consumption of injection is large, the velocity at bottom is significantly smaller, and the free surface flow velocity of liquid steel is significantly lower than that in the tundish without current stabilizer.

Figure 6 shows the flow field in the inner section of the submerged nozzle. On the inner side of the submerged nozzle, the diffusion range of its core kinetic

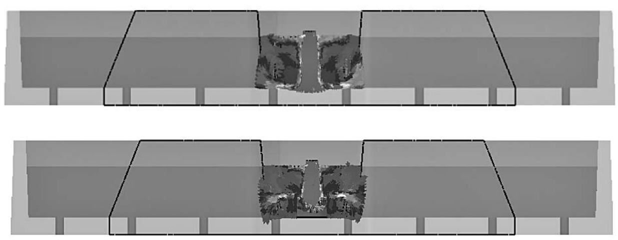

Figure 4 The flow field in the central area of the pouring

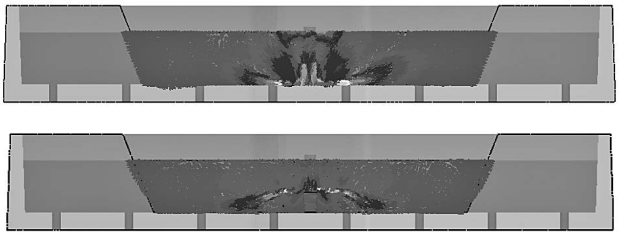

Figure 5 The flow field of 240mm sectional from the injection

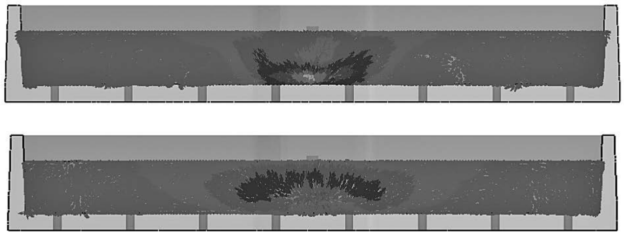

Figure 8 The flow field outside the submerged nozzle

energy is large since the tundish without flow stabilizer has no restriction on the injection flow of the long nozzle. The molten steel mixing disturbance to the central area of the section is more serious because of the combined action of high-speed horizontal diffusion flow at the bottom, central injection drive and reflux vortex.

In the tundish with current stabilizer, due to the lifting effect of current stabilizer on the position high-speed area, the high-speed area is far away from the bottom of the tundish, and its average speed is much lower than that of tundish without current stabilizer.

Figure 7 shows the flow field in the central section of the submerged nozzle. In the central area of the section without the flow stabilizer tundish, the flow field presents reflux characteristics obviously. the characteristics of direct injection impact are obvious far from the central area. In the tundish with the current stabilizer, the effect of long nozzle injection on the flow field near the submerged nozzle is weak.

Figure 8 shows the flow field outside the submerged nozzle. Outside the submerged nozzle, the kinetic energy of molten steel in tundish without current stabilizer is further diluted and weakened. In the central area, the main flow is the upward reflux after the bottom of the long nozzle injection, and the high-speed core area is at the bottom of the tundish. In the tundish with current stabilizer, the average velocity of liquid steel bottom contact reflux is less than that without current stabilizer,

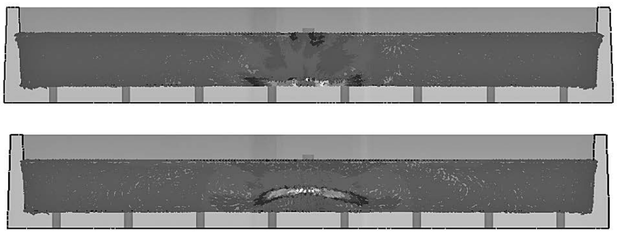

Figure 6 The flow field in the inner section of the submerged nozzle

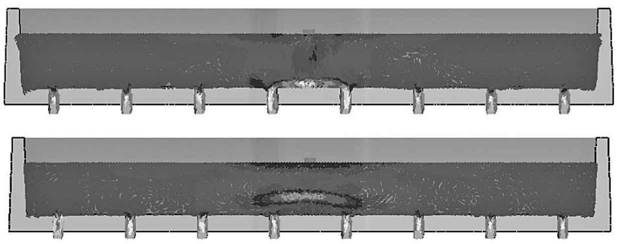

Figure 7 The flow field in the central section of the submerged nozzle

and the reflux diffusion range is large, and the flow field is generally stable.

CONCLUSIONS

In the tundish without current stabilizer, the long nozzle injection directly impacts the tundish bottom lining, the liquid steel flow diffuses along the bottom face, and the disturbance is large near the submerged nozzle.

The flow stabilizer can significantly slow down the impact of liquid steel flow on the bottom, change the injection flow direction, consume the downward kinetic energy of liquid steel injection greatly, and make the tundish flow field more stable.

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Z. S. Zhang is the corresponding author.

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