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STUDY ON FLOW AND TEMPERATURE DROP BEHAVIOR OF SIX-STREAM TUNDISH WITH LESS-FLOW CASTING

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In this paper, numerical simulation method was used to study the influence of closing different nozzles on the flow state and temperature distribution of molten steel in the six-stream tundish, which provides a theoretical basis for ensuring the temperature uniformity of molten steel in the tundish and the subsequent stable continuous casting production during the less-flow casting. The results show that: (a) In the case of closing one nozzle, when the No. 3 nozzle is closed, the overall temperature is relatively uniform. (b) In the case of closing two nozzles, when the No. 2 and No. 3 nozzles are closed, the overall temperature is more uniform.

Keywords: steel, six-stream tundish, less-flow casting, numerical simulation, temperature field, velocity field

INTRODUCTION

In the actual continuous casting process of multi-flow tundish, due to the production rhythm or steel leakage [1,2], a certain number of water outlets need to be closed, that is, to perform pouring with less-flow[3-5]. At present, there are few reports about the multi-stream tundish with less-flow casting, and the influence of closing different nozzles on the flow and temperature of molten steel in the multi-stream tundish is not clear. Therefore, a in-depth research on this process needs to be conducted so as to guide the actual production. Which is of great significance to ensure the quality of continuous casting billet, stable continuous casting production and effective utilization of tundish.

Based on the six-stream continuous casting tundish of a steel plant, this paper used numerical simulation method to study the influence of closing different nozzles on the flow state and temperature distribution of molten steel in the tundish. Which provides a reference for accurately grasping the selection of closing nozzles in the actual production with less-flow casting and ensuring the stability of continuous casting.

MATHEMATICAL MODEL DESCRIPTION

A geometric model was established according to the “T” type symmetrical tundish structure of six-stream billet in a steel mill. As the structure of six-stream tundish is symmetrical, only half of the model needs to be built, as shown in Figure 1. The No 1, No2 and No3 in the figure represent three outlets with different positions. The specific parameters in the model are: 385mm molten steel depth of the tundish, 10mm insertion depth of the long nozzle, 50mm diameter of the tundish nozzle, 30mm inner diameter of the tundish outlet.

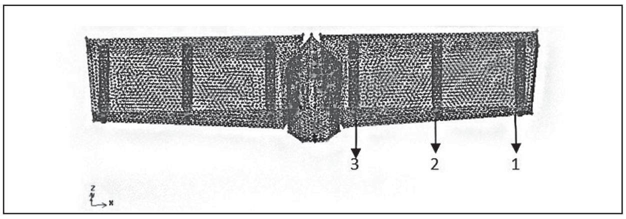

Figure 1 Geometric model and grid plot

Boundary conditions and governing equations

The influence of slag layer on flow is ignored, and the steel level is considered as free slip interface. At the entrance of tundish, it is assumed that the velocity is evenly distributed on the whole entrance surface, and the inlet velocity is calculated according to the casting speed and the size of casting billet. At the inlet boundary, the magnitude of the normal velocity of the liquid phase is given. Casting speed is 2 m/min and slab section is 50 mm × 150 mm. In this paper, FLUENT›s k-ε turbulence model was used for simulation[6]. The continuity equation, momentum equation, and k-ε double equation were used to establish a six-stream tundish three-dimensional mathematical model for flow field and temperature field calculation.

Parameters of numerical simulation

The boundary conditions required for numerical simulation are shown in Table 1.

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Table 1 **Parameters of numerical simulation**

Description	setting
Turbulence model	Standard k-ε
Reference density	7 026,8 kg/m^3
Thermal conductivity	52,535 W/m·K
Viscosity	0,0053 kg/m·s
Specific heat	822 J/kg
Inlet inner diameter	Φ 100 mm
Inlet external diameter	Φ 200 mm

Numerical simulation schemes

Because the six-stream tundish is a center-symmetric structure, the repeatability can be reduced when the scheme is formulated. The numerical simulation schemes are shown in Table 2.

Table 2 **Numerical simulation schemes**

Schemes	1	2	3	4	5	6
Closed nozzles	3	2	1	3,2	3,1	2,1

RESULTS AND DISCUSSION

Analysis of velocity field and temperature field when a nozzle is closed

Figure 2 shows the distribution of tundish velocity field when a nozzle is closed. From Figure 2, it can be seen that when the No. 3 nozzle is closed which is closest to the injection zone (scheme 1), the raceway of tundish formed on the left side of the pouring zone is larger and lower than the other two schemes. As a result, the velocity of liquid steel passing through the raceway decreases and flows slowly to No.1 and No.2 nozzles, thus prolonging the flow path of liquid steel in tundish. Which is beneficial for increasing the residence time of liquid steel, the homogeneity of liquid steel and the uniformity of each flow, and the removal of inclusions. When the No. 1 nozzle is closed (scheme 3), a raceway area is formed at the upper part of the distal end of the tundish and the position is relatively high, which is not easy to generate a dead zone.

Figure 3 shows the distribution of the temperature field of scheme 1, scheme 2 and scheme 3, and table 3 shows the specific temperature comparison of scheme 1, scheme 2 and scheme 3. From Figure 3 and Table 3, it can be seen that the temperature difference of each flow is at the middle level, which is 1.91 K. The overall temperature difference in the tundish is the smallest, which is 16.5 K. And the overall temperature is relatively uniform. In scheme 3, there is a minimum temperature difference of each flow, and the temperature consistency of each flow is the best.

Analysis of velocity field and temperature field when two nozzles are closed

Figure 4 shows the distribution of tundish velocity field when two nozzles are closed. It can be seen from Figure 4 that both scheme 5 and scheme 6 form a raceway zone in the upper area of No. 1 nozzle of the tundish, but the position is not high, which leads to the formation of a dead zone at the corner of the tundish. In scheme 4, only the no. 1 nozzle farthest from injection zone is opened, which extends the flow path of molten steel in the tundish and increases the residence time of molten steel. Which is conducive to improving the uniformity of molten steel and the removal of inclusions.

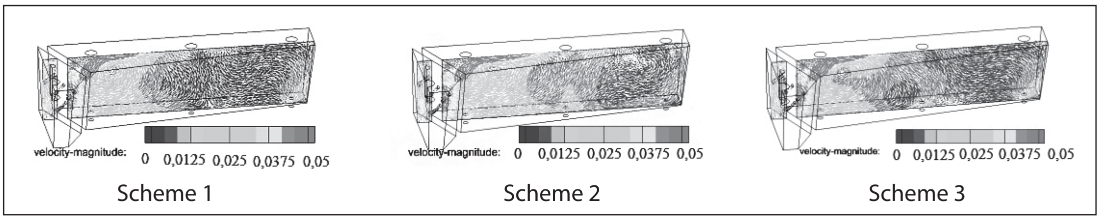

Figure 2 Velocity field distribution of scheme 1, scheme 2 and scheme 3

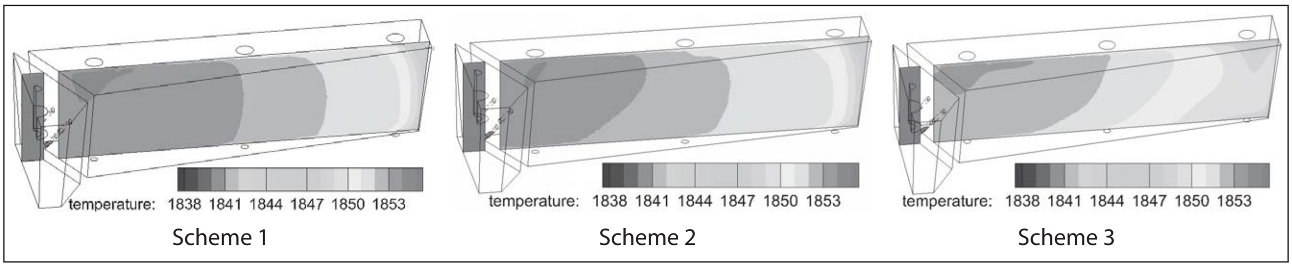

Figure 3 The temperature field distribution of scheme 1, scheme 2 and scheme

Table 3 **Temperature comparison of scheme 1, scheme 2 and scheme 3**

	Inlet temperature / K	Minimum temperature in Tundish / K	Temperature difference / K	No1 outlet / K	No 2 outlet / K	No 3 outlet / K	Temperature difference of each flow / K
1	1 856,15	1 839,65	16,50	1 849,31	1 851,22		1,91
2	1 856,15	1 837,44	18,71	1 850,34		1 853,05	2,71
3	1 856,15	1 838,65	17,50		1 851,22	1 852,19	0,97

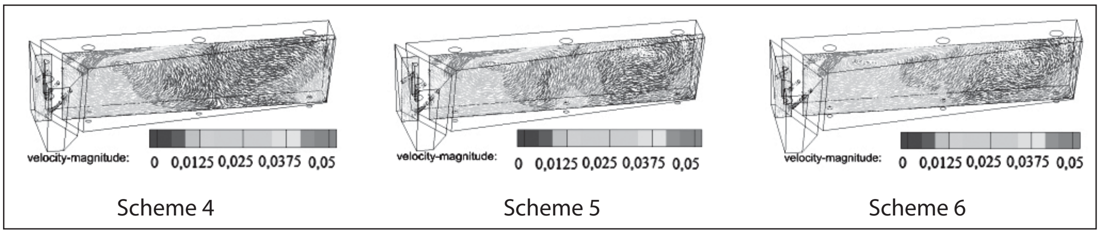

Figure 4 Velocity field distribution of scheme 4, scheme 5, and scheme 6

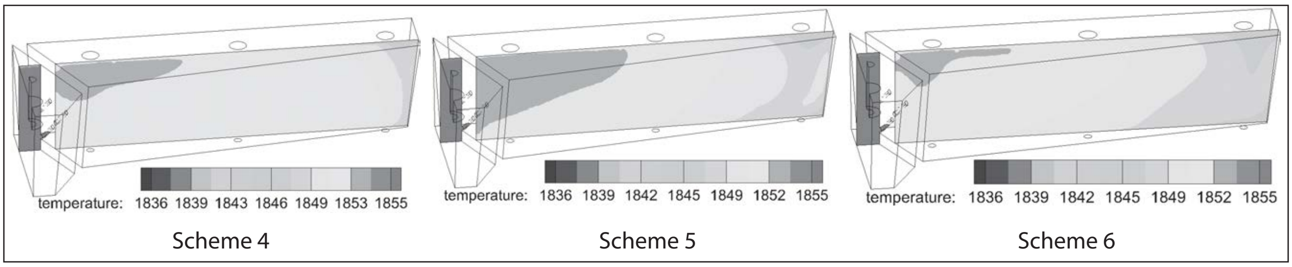

Figure 5 The temperature field distribution of scheme 4, scheme 5, and scheme 6

Table 4 **Temperature comparison of scheme 4, scheme 5 and scheme 6**

Schemes	Inlet temperature / K	Minimum temperature in Tundish / K	Temperature difference / K	No1 outlet / K	No 2 outlet / K	No 3 outlet / K	Temperature difference / K
4	1 856,15	1 839,53	16,62	1 850,64			5,51
5	1 856,15	1 835,57	20,58		1 850,69		5,46
6	1 856,15	1 835,60	20,55			1 850,66	5,49

Figure 5 shows the distribution of the temperature field of schemes 4, scheme5 and scheme 6, and Table 4 shows the specific temperature comparison of schemes 4, scheme 5 and scheme 6. It can be seen from Figure 5 and Table 4 that the temperature drop of the three schemes at the water outlet is about 5,5 K, with a little difference. The scheme of the minimum temperature difference of molten steel in tundish is scheme 4, which is 16,62 K, and the overall temperature is relatively uniform. The lowest temperature in the three schemes is all located at the corner of the upper surface of the tundish, but the volume of the lowest temperature in the tundish of scheme 4 is the smallest. In scheme 5, there is a minimum temperature drop of 5,46 K at the nozzle of molten steel in tundish, but the overall temperature difference in tundish is the largest, which is 20,58 K, and the overall uniformity is poor.

CONCLUSIONS

When only one nozzle is closed for pouring, closing No. 3 nozzle is beneficial to increase the residence time of molten steel, make the molten steel mix more fully and facilitate the inclusion floating up. When No. 3 nozzle is closed, the temperature difference between the streams is 1,91 K, but the overall temperature difference in the tundish is the smallest, which is 16,50 K. Which is 5,7 % lower than that the temperature difference in the tundish of molten steel of scheme 3 with No 1 nozzle closed and 11,8 % lower than that of scheme 2 with No 2 nozzle closed. The overall temperature is more uniform.

When the two nozzles are closed for pouring, closing No. 3 and No. 2 nozzles can extend the flow path of the molten steel in the tundish, increase the residence time of the molten steel, and facilitate the uniformity of the molten steel. The temperature drop of the molten steel at the outlets of scheme 4, scheme 5 and scheme 6 are both about 5,5 K. However, the scheme 4, with the No. 3 nozzle and the No. 2 nozzle closed for pouring, the minimum temperature difference in the tundish is 16,62 K, and the overall temperature is relatively uniform.

Acknowledgments

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Note: X Qinghe is responsible for English language, Liaoning, China