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STUDY ON THE INFLUENCE OF NOZZLE BRICK STRUCTURE ON THE TAIL COIL OF MOLDED STEEL INGOT

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Mold casting has unique advantages in the production of complex shape, large single weight and small batch steel ingot. In the field of special steel, continuous casting still can not be replaced, but the quality problem of steel ingot is still the key bottleneck problem restricting the high-end of its products. At present, the industrial production often focuses on how to control the loose hole defects inside the ingot, generally ignoring the ingot surface and subcutaneous slag rolling problem. In view of this, with the study of 2,8 t octagonal ingot on the edge of arc, the influence of the nozzle brick structure in the average diameter of the nozzle is 40 mm and the cone of the nozzle is above 0,20.

Keywords: 42CrMo4, molded, nozzle brick, structure

INTRODUCTION

The ingot is a metal billet produced by the die casting process, which is often used in the manufacture of large mechanical equipment and special industrial components [1]. In-depth study of steel ingot quality is a necessary prerequisite to obtain high-end steel. At present, there is still a lack of experience in the formation mechanism of steel ingot surface and subsurface defects.

After investigation, a steel mill is now through the injection method of steel ingot production of serious tail slag rolling defects. The tail slag is often on the ingot surface or secondary surface, the size is larger, seriously affecting the ingot material rate, which is extremely unfavorable to the production of enterprises [2]. As early as 1992, Yu et al. [3] found that the outlet section of the dilated steel ingot mold water inlet brick was large, and the flow rate of the steel liquid into the ingot mold was small. Later, Fan et al. [4] found under the cold test that the trumpet mouth brick effectively reduced the number of large inclusions. Zhang Wen et al. [5] used the simulation software ProCAST to study the influence of Shuikou brick aperture on the pouring process of 25t large steel ingot, and the increase of Shuikou brick aperture was beneficial to prevent slag rolling. In 2015, Hu Jiandong and other [6] proposed to improve the pouring system, such as setting up extended pore channels, to help reduce the liquid level fluctuations. Therefore, it is necessary to study the systematic brick structure.

This paper studies the influence of 1.6t the average diameter (30 mm, 40 mm, 50 mm, 60 mm, 70 mm) and the (-0,09, 0,00, 0,09, 0,18, 0,27, 0,36) on the flow behavior and the level fluctuation, discusses the rationality of the nozzle brick structure from the perspective of static pressure, and takes the Weber alignment number as the criterion for whether the slag rolling occurs.

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MATHEMATICAL MODEL

Mathematical model of the solidification process

The main heat transfer methods of the ingot solidification process are heat transfer, conduction heat transfer and radiation heat transfer. The mathematical expressions in this study are as follows:

$$\rho c_p \frac{\partial T}{\partial t} = \frac{1}{r} \cdot \lambda \frac{\partial T}{\partial t} + \frac{\partial}{\partial r}\left(\lambda \frac{\partial}{\partial r}\right) + \frac{r}{r^2} \cdot \frac{\partial}{\partial \theta}\left(\lambda \frac{\partial T}{\partial \theta}\right) + \frac{\partial}{\partial z}\left(\lambda \frac{\partial T}{\partial z}\right) + Q$$

Where cp is the specific heat capacity of the material, J/kg·K; ρ is the density kg/cm^3. Where T is a function of x, y, and z, then T is also a function of γ, θ, and z.

NUMERICAL CALCULATION

Figure 1(a) shows the geometric model of the calculated ingot; Figure 1(b) shows the total number of grids, with about 389 673.

Thermal property parameters:

The steel used in this simulation calculation is 42CrMo4 steel, which has high quenching and high strength. The solid and liquid phase line temperatures of 42CrMo4 steel are 1 425 °C and 1 494 °C respectively, and the chemical scores of 42CrMo4 steel are shown as follows in Table 1.

Table 1 **Chemical composition of steel 42CrMo4 /wt. %**

Element	Content /%
C	0,38~0,45
Si	≤0,40
Mn	0,60~0,90
P	≤0,0035
S	≤0,035
Mo	0,025
Cr	0,90~1,20

Figure 1 (a) The model of the ingot (b) Grid profile

The initial conditions are set as shown in Table 2.

Table 2 **Related parameters needed for slmulation**

initial condition	parameter
Insect mode initial temperature/°C	100
Initial temperature of the insulation plate/°C	100
Casting temperature/°C	1 524

The heat transfer coefficients between steel ingots, steel ingot molds, insulation boards, water outlet bricks, and the surrounding environment are set as shown in Table 3.

Table 3 **Interface heat transfer coeffcident**

Interface	Coefficient /(W/m²k)
Insect die/ adiabatic plate	100
Steel ingot/ adiabatic plate	100
Steel ingot/ ingot mold	300
nozzle brick/ ingot mold	50
nozzle brick	50
Steel ingot environment	0

RESULTS AND DISCUSSION

Effect of the average nozzle diameter

In the case of no taper of the nozzle, the influence of the average diameter of the tail brick was systematically investigated systematically. As can be seen from Figure 2, as the average diameter of the nozzle increases, the surface velocity of the liquid steel changes significantly. The red area represents the instantaneous flow velocity exceeding 0,5 m/s, when the average diameter of the nozzle is 30 mm, the maximum surface velocity is 0,553 m/s, and when the average nozzle diameter increases to 70 mm, the maximum surface velocity decreases to 0,233 m/s. When the average diameter of the nozzle is 30 mm, the internal flow of the steel liquid is relatively strong and chaotic. When the average diameter of the nozzle increases to 40 - 50mm, a relatively stable double circulation is formed inside. With the increase of the average diameter of the nozzle, the internal circulation of the steel liquid gradually weakens.

It can be clearly seen in Figure 3 that the larger the average diameter of the nozzle, the smaller the maximum speed of the liquid steel surface. Figure 4 shows the trend diagram of the maximum Weber number on the steel surface with the average diameter of the nozzle. With

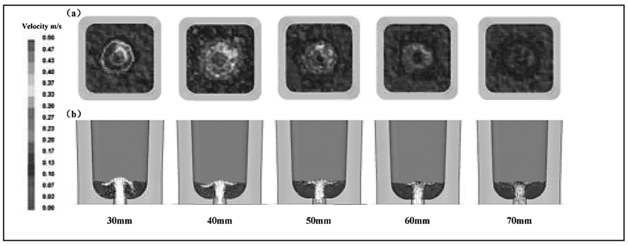

Figure 2 The effect of the average diameter of the nozzle on the internal flow field when the tail of the ingot is filled

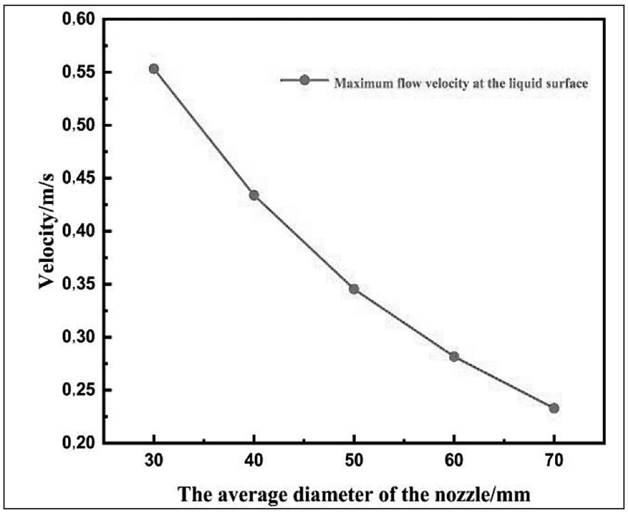

Figure 3 Effect of the average nozzle diameter on the maximum velocity on the molten steel surface

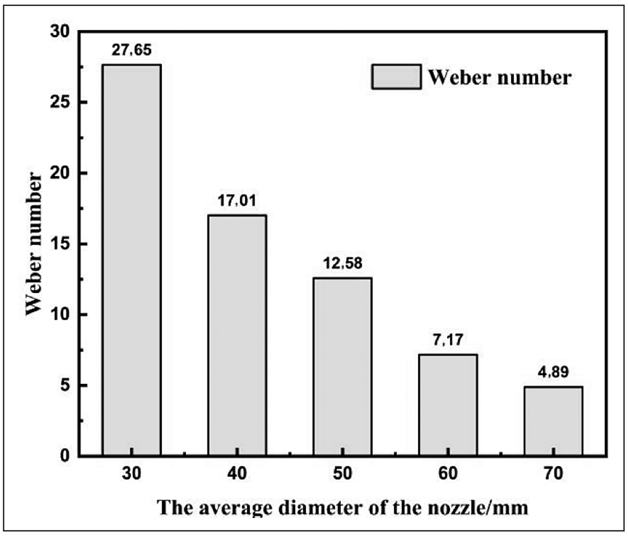

Figure 4 Effect of the average nozzle diameter on the maximum Weber on the molten steel surface

the increase of the average diameter of the nozzle, the Weber quasi number gradually decreases. When the average diameter of the nozzle is 30 mm and 40 mm, the weber number is greater than 12,3. When the average diameter of the nozzle reaches more than 50 mm, the weber number is lower than the slag coil near value. As the average diameter of the nozzle increases to 70 mm, the weber accuracy can even be reduced to below 5,0, which can be considered to be no risk of slag rolling. Therefore, for this ingot type, the average diameter of the nozzle should reach more than 50 mm to reduce the slag rolling defects at the tail of the ingot.

Influence of nozzle taper

The average diameter of the nozzle of 50mm was selected as the research object, and the influence of the nozzle taper on the steel liquid interior and surface flow field when the tail was filled was systematically studied, so as to analyze the possibility of slag rolling. According to Figure 5, when the nozzle taper is-0,09, the maximum surface flow rate reaches 0.46 m/s, and when the nozzle taper increases to 0,27 or above, the maximum surface flow rate decreases to 0,19 m/s. In addition, the proportion of high flow rate area gradually decreases with the increase of nozzle taper. As can be seen from Figure 6, the larger the taper of the nozzle, the smaller the upward impact force of the steel liquid, and the deceleration of the internal flow rate of the steel liquid. It should be pointed out that when the taper of the nozzle is 0,27, the surface of the steel liquid and the internal flow rate of the steel liquid are relatively minimum, but when the taper increases to 0,36, the flow rate increases instead. The analysis reason is that the greater the taper of the nozzle, the smaller the lower size, the greater the upward pressure of the steel liquid, thus causing this phenomenon.

The larger the taper of the nozzle, the smaller the maximum velocity of the liquid steel surface. When the taper of the nozzle increases above 0,27, the taper of the nozzle has less influence on the surface velocity of the liquid steel. As shown in Figure 8, when the nozzle taper is negative and no taper, Weber is above 12,3, especially when the negative taper, the risk of slag rolling is greater. When the nozzle taper increases to 0,09 or above, Weber drops below the slag coil critical value of 12,3, the taper above 0,27 has little impact on the slag coil. Therefore, for the 1,6 t square ingot, the appropriate increase of the nozzle taper is beneficial to inhibit the tail slag rolling defect of the ingot.

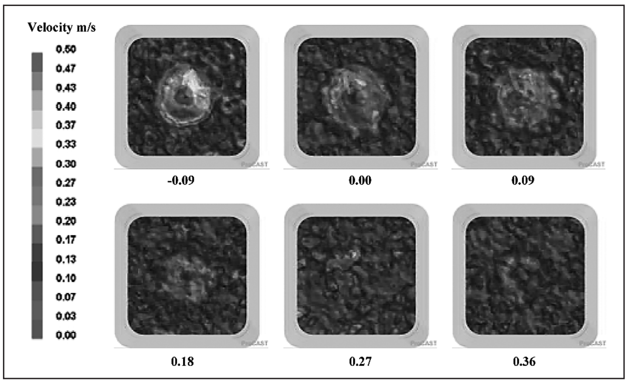

Figure 5 Effect of nozzle taper on surface velocity distribution when ingot tail is filled

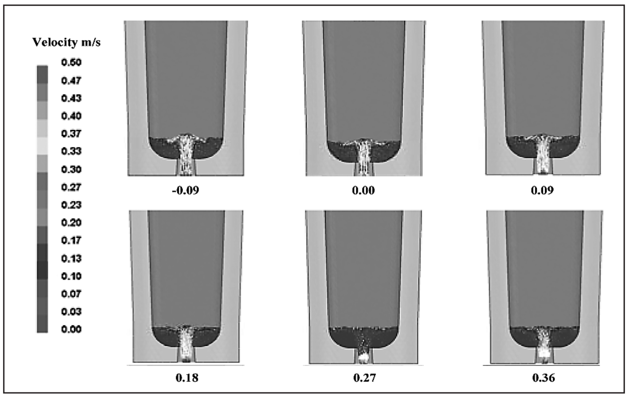

Figure 6 The effect of nozzle taper on the internal flow field when the tail of the ingot is filled

CONCLUSION

For the 1,6-ton square ingot, when the average diameter of the nozzle is more than 50 mm, the risk of tail slag coil is low.

When the average diameter of the nozzle is 50 mm and the taper is-0,09, the maximum flow rate of the liquid steel surface reaches 0,46 m/s. When the taper of the nozzle increases to 0,27 and above, the maximum flow rate of the surface decreases to 0,19 m/s. For this ingot type, the increase of the nozzle taper to 0,09 and above is beneficial to inhibit the occurrence of slag rolling.

In the casting process of the mold casting process, the nozzle brick structure has a great influence on slag rolling. Appropriate increasing the average diameter of nozzle brick and the taper of nozzle can effectively reduce the risk of slag rolling.

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Note: The responsible for English language is lector of University.