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SIMULATION STUDY ON INFLUENCE OF EXOTHERMIC RISER ON INGOT SOLIDIFICATION

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In this paper, the effect of exothermic riser on ingot solidification is studied by numerical simulation. Through the study, it is concluded that the combustion of exothermic risers delayed the solidification of steel in riser, and the solidification time increased significantly, extending about 8 143 / s. In the later stage of solidification, the temperature isotherm of the ingot is smoother than that of the ordinary ingot, making the angle of the solidification front larger, which is conducive to feed. The shrinkage of the ingot with heat riser is better than that of the common ingot. The shrinkage above 10 % of the ingot is almost not found in the ingot with exothermic riser, and the shrinkage of the ingot is mainly concentrated above the riser line. And it obviously improves the internal quality of the ingot.

Key words: Steel, ingot solidification, exothermic riser, feeding, numerical simulation

INTRODUCTION

The exothermic riser is the riser with exothermic compound. The exothermic compound in the riser reacts and releases heat by liquid metal heating [1]. And the heat makes the liquid metal keeping high temperature, and the metal liquid is preserved for a long time in the liquid state [2]. Thus it makes the size of the riser smaller and saving metal, and it has obvious technical benefit [3].

The advantages of exothermic riser[4], include the wide and simple source of material, cheap price, easy to manufacture, greatly reducing the size of the riser, improving the yield of the steel process, effectively reducing the probability of the defect.

In this paper, the effect of exothermic riser on ingot solidification is studied by numerical simulation.

MATHEMATICAL MODEL ESTABLISHMENT

Geometric model and grid partition

In this paper, the process of solidification of 11 tons flat ingot is simulated. The geometric model is shown in Figure 1.

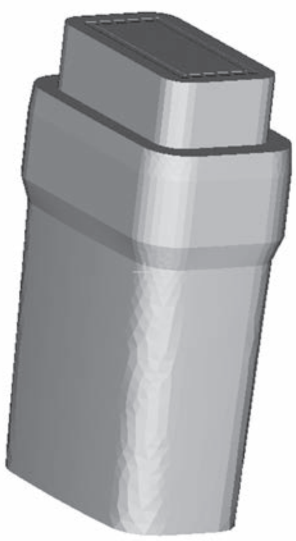

Figure 1 Geometric model

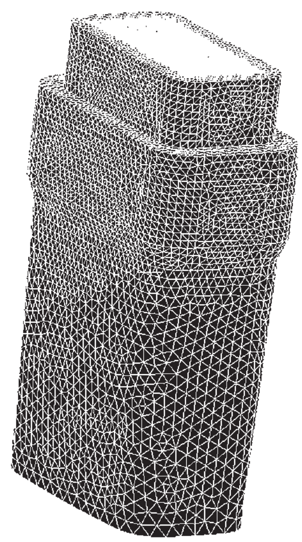

Figure 2 Model grid partition

The model grid partition is shown in Figure 2. The number of grid nodes is 84 842 and the number of tetrahedron elements is 401 458.

Governing equation and setting of simulation conditions

The heat transfer governing equation [5]:

$$\rho c \frac{\partial T}{\partial t} = \frac{\partial}{\partial x}\left(\lambda \frac{\partial T}{\partial x}\right) + \frac{\partial}{\partial y}\left(\lambda \frac{\partial T}{\partial y}\right) + \frac{\partial}{\partial z}\left(\lambda \frac{\partial T}{\partial z}\right) \quad (1)$$

Where T is temperature / °C, ρ is steel density / kg/m^3, λ is thermal conductivity / W/m/°C, c is specific heat / J/kg/K.

Heat flux calculation is:

$$Q = h \times (Tm - Tc) \quad (2)$$

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Where q is heat flux / W/m^2, Tm is mould surface temperature / °C, Tc is environmental temperature / °C, h is comprehensive heat transfer coefficient / W/m^2 /°C.

Initial conditions are:

Liquid steel: T = Tst0, mould: T = Tm0.

Composition of steel: C is 0,17 %, Si is 0,35 %, Mn is 1,4 %, S is 0,03 %, P is 0,03 %.

In the simulation, the thermal conductivity is isotropic, the thermal physical parameters of molten steel is only a function of temperature. The heating time of the exothermic riser is 1 200 / s, the ignition point is 700 / °C, and the heating power is 5 000 / KJ/Kg

THE ANALYSIS OF CALCULATION RESULTS
Contrast results of temperature field

Figure 3 is the result of the temperature field of a wide cross section.

It can be seen from the Figure 3 that the ingot solidifies from outside to inside under the condition of air cooling. The end point of the simulation is set at 1 200 / °C. The end time of the calculation of common ingot is 25 213 / s. According to the temperature field of the ingot with exothermic riser, the ingot solidifies gradually from inside to outside as same as the common one. But under the effect of the heat riser, the time of the solidification of molten steel at the riser is extended, and the end point of the calculation is 33 356 / s. Due to the heating effect of the exothermic riser, the molten steel in the riser is in liquid state for a long time, which makes the isothermal line near riser region in ingot with exothermic riser gentler than that of the common ingot. It shows that the heat dissipation of the liquid steel to the side wall becomes smaller, which makes the angle of the liquid steel solidifying front becomes larger. It is beneficial to the feeding of ingot.

Figure 4 is the result of the temperature field of the narrow section.

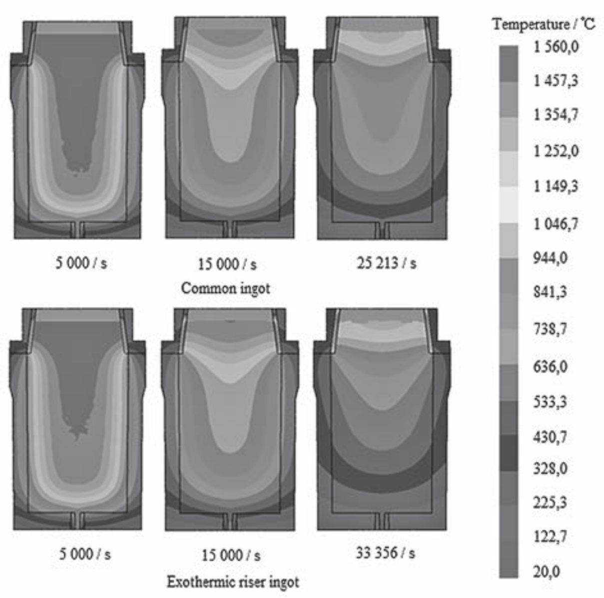

Figure 3 Temperature field of wide section of ingot

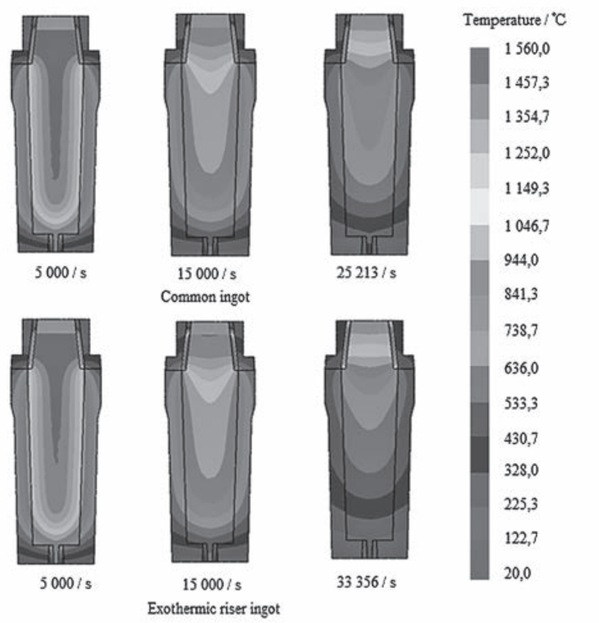

Figure 4 Temperature field of narrow section of ingot

It can be seen from the Figure 4 that, on the narrow surface, because of the smaller geometric size and the narrow space, a slender steel liquid channel is produced during the solidification and cooling, which can easily lead to the obstruction of the reinforcement of the molten steel. The results of the cross section temperature field of the narrow surface of the flat steel ingot show that the temperature distribution in the narrow surface is the same as that of the wide surface, and the isotherm of the upper part of the ingot near the end point of the narrow surface tends to be gentle. In addition, due to the heat release of the exothermic riser, the adiabatic plate is still at a high temperature above 1 450 / °C when the simulation reaches the end point.

Comparison of internal quality between exothermic riser ingot and ordinary ingot

Figure 5 is comparison of internal quality between exothermic riser ingots and common ingots.

It can be seen from the figure that the internal shrinkage of the ingot with the heat riser has been obviously improved. The area of the shrinkage index above 10% is almost not distributed in the ingot body, most of which are concentrated above the riser line, and the ingot is more compact. This is because the exothermic riser burns the molten steel of the riser part and makes it melt for a long time. This improves the heat preservation of the upper part of the ingot and is beneficial to the shrinkage of molten steel.

CONCLUSION

The exothermic riser delayed the steel solidification in riser, which resulted in a significant prolongation of the total coagulation time and a lengthening of about 8 143 / s.

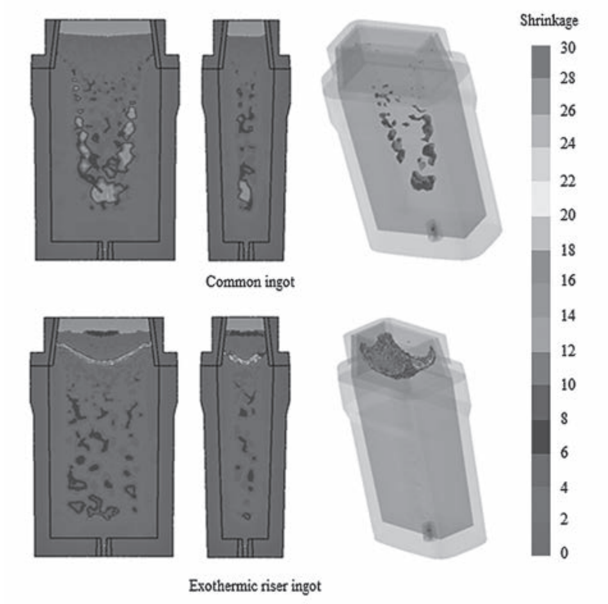

Figure 5 Comparison of internal quality between exothermic riser ingots and common ingots

In the later stage of ingot solidification, the temperature isotherm of the ingot with exothermic riser is smoother than that of the common ingot, which makes the angle of the solidification front larger. And it is beneficial to the feeding of ingot.

The shrinkage of the ingot of the exothermic riser is obviously better than that of the common ingot. The shrinkage above 10 % level is almost no distribution in the ingot part, and it is mainly concentrated above the riser part.

Acknowledgements

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