G. X. LIU, Z. S. ZHANG, Y. HUANG, Y. W. BAI, J. W. ZHANG

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SIMULATION STUDY OF COLD STEEL FEEDING IN STEEL DIE CASTING

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To solve the problem of slow solidification of large ingots and the difficulty of eliminating internal shrinkage, a cold steel bar was fed into the molten steel during the solidification process after the completion of casting to affect the solidification process. Different cooling and solidification schemes for 60-ton 16-angle ingots were simulated by the finite element simulation software PROCAST. The simulation results show that the insertion of cold steel rods can shorten the full solidification time of the ingot. It is beneficial to improve the concentrated shrinkage in the central region under the conventional cooling scheme; in terms of the cold steel addition method, the decentralized addition of cold steel is more effective in improving the internal quality of the ingot.

Key words: steel, die casting, cold steel feeding, solidification, numerical simulation

INTRODUCTION

High quality large forgings are indispensable components in the fields of aviation, electric power, petrochemical, nuclear power, etc. The quality of a forging depends on the quality of the ingot. Although the shrinkage porosity and shrinkage cavities in steel ingots can be improved in subsequent processing, Many of the serious shrinkage porosity and shrinkage cavities are difficult to be eliminated which is becoming a defect of large forgings[1-3]. Researchers have adopted methods to improve the internal shrinkage of steel ingots, such as reducing the height to diameter ratio, increasing the taper of the ingot, increasing the height of the riser, improving the insulation of the riser, optimizing pouring parameters, and improving the heat dissipation of the ingot mold[4-6]. However, for large steel ingots, due to their long solidification time, it is extremely easy to eventually form a situation of synchronous solidification between the upper and lower parts, resulting in a decrease in the angle between the solidification fronts and poor feeding of the upper molten steel. In this paper, the method of inserting a cold steel rod into the molten steel is used to reduce the superheat, provide the solidification nucleation medium, improve the solidification process of the ingot, and thereby improve the internal quality of the ingot.

CALCULATION MODEL ESTABLISHMENT

Geometric model and grid partition

The object to be researched is 60 tons of 16 angle ingot, and there are two ways to feed cold steel: the scheme 1 is to insert one round steel in the center, with a diameter of 200 / mm, and a length of 4 010 / mm; The scheme 2 is to insert four round steels around the center, with a diameter of 100 / mm in diameter, and 3 660 / mm in length.

The ingot system model is meshed and discretized into tetrahedral meshes, as shown in Figure 1. According to the component size and simulation requirements, the elements at the riser was locally densified. The number of traditional ingot surface elements is 67 601, and the number of volume elements is 565 806; In Scheme 1, the number of surface elements is 43 842, and the number of volume elements is 563 387. In Scheme 2, the number of surface elements is 64 270, and the number of volume elements is 1 404 195.

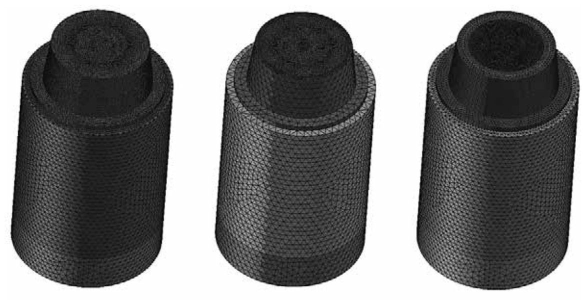

Figure 1 Ingot model grid partition

Governing equation and setting of simulation conditions

The heat transfer governing equation [6]:

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

G. X. Liu, Z. S. Zhang(lnaszzs@163.com), Y. Huang, Y. W. Bai, J. W. Zhang, School of Mechanical Engineering and Automation, University of Science and Technology Liaoning.

Where T is temperature / °C, ρ is steel density / kg/m3, λ is thermal conductivity / W/m/°C, c is specific heat / J/kg/K.

Heat flux calculation is:

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

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 0,23 %, Si is 0,11 %, Mn is 0,63 %, Ni is 0,07 %, S is 0,034 %, P is 0,034 %.

Composition of mould: C is 3,44 %, Si is 1,63 %, Mn is 0,8 %, S is 0,008 %, P is 0,017 %.

In the simulation, the thermal conductivity is isotropic, the thermal physical parameters of molten steel is only a function of temperature. The initial temperature of molten steel is set as 1 550 / °C, and the mold temperature is 100 / °C. The boundary condition is set as that the top of the ingot is the covering agent, and its equivalent convective heat transfer coefficient is 0,5 / W/m^2/K. The equivalent convective heat transfer coefficient of the ingot mold bottom is 300 / W/m^2/K. The outer wall of the ingot mold is air-cooled, with a emissivity of 0,8 and a heat transfer coefficient of 10 / W/m^2/K.

SIMULATION RESULTS AND ANALYSIS

Conventional ingot solidification results

Figure 2 shows the results of the shrinkage and porosity.

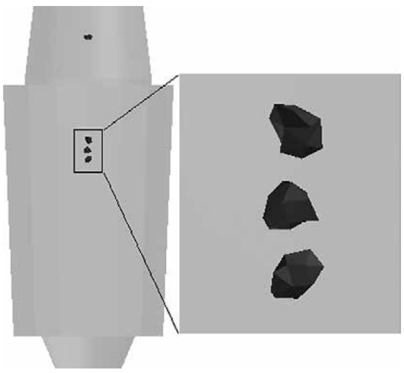

Figure 2 The shrinkage and porosity of the ingot

It can be seen from the Figure that there is a significant concentration of shrinkage and porosity in the center of the ingot body. The main reason is that the molten steel in the central area of the ingot solidifies slowly in the later stage of solidification which results in a "solidified metal bridge" situation. It makes the upper molten steel cannot feed downward effectively. The calculation results show that the volume of central shrinkage porosity is 0,0339 / m^3.

Comparison of solidfication results of steel ingots with different schemes

Figure 3 shows the comparison of ingot solidification process with different schemes

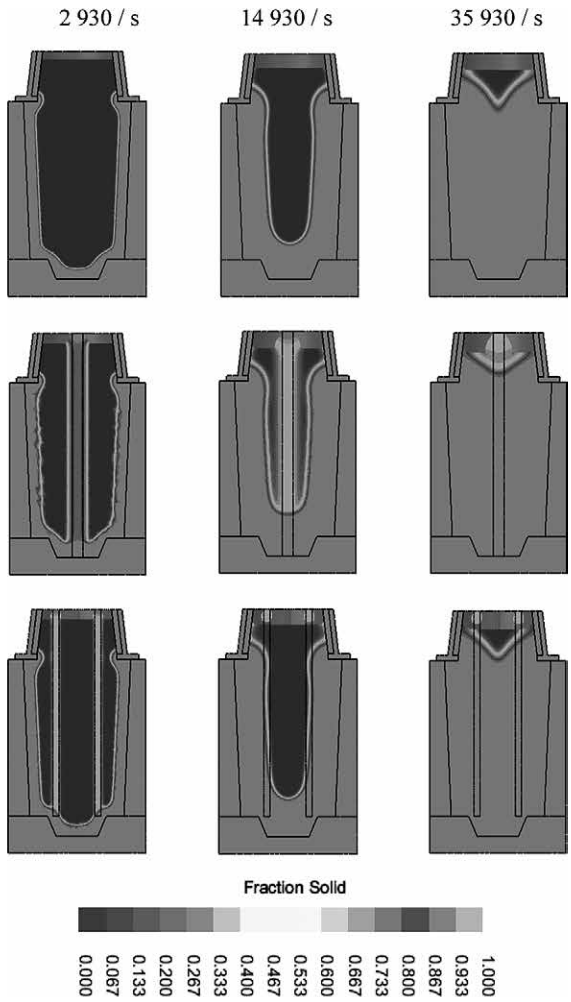

Figure 3 Comparison of ingot solidification process with different schemes

It can be seen from the figure that liquid steel solidifies from the bottom to top, from outside to inside. According to the simulation data, the solidification time of the traditional ingot body is 38 256 s.

In the scheme 1, due to the feeding of cold steel in the center of the ingot, the solidification sequence starts simultaneously inside and outside. Due to the low temperature of the fed steel, the liquid surrounding the steel solidifies first, and then melts due to the sensible heat effect of the molten steel. In scheme 1, due to the large diameter of the central steel bar, there is a situation where there is an unmelted steel in the center of the ingot at solidification end. The solidification time of the ingot body is 32640s.

In the scheme 2, the diameter of the steel bar is small. The influence range of unmelted steel bar is significantly smaller than that of scheme 1. However, the steel bars are fully melted which can exert its cooling effect and reduce the superheat in the central area of the ingot. The solidification time of the ingot body is 35 454 s.

Comparison of shrinkage and porosity results

Figure 4 shows the comparison of distribution of shrinkage porosity in ingots

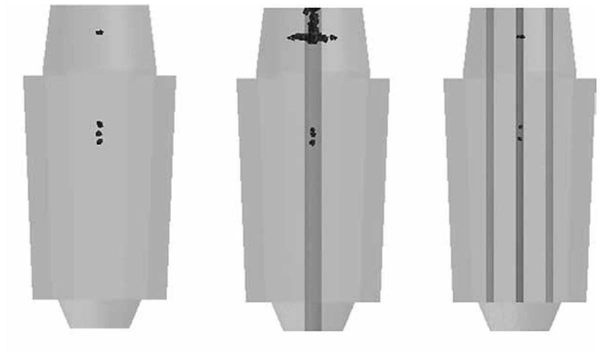

Figure 4 Comparison of shrinkage and porosity results

It can be seen from the Figure that the shrinkage and porosity positions of steel ingots are mainly concentrated in the upper center area. The distribution of shrinkage and porosity areas in the ingot body of scheme 1 is more concentrated than that of traditional ingots, and the riser shrinkage and porosity are more obvious. The shrinkage and porosity areas in scheme 2 are significantly reduced.

According to the simulation results, the volume of shrinkage porosity of traditional steel ingots is 0,0339 m^3, 0,0225 m^3 for scheme 1, and 0,0075 m^3 for Scheme 2. It can be seen that Scheme 2 (adding cold steel bars more dispersedly) is more advantageous for improving the central shrinkage porosity of large ingots. In this process, Scheme 2 can reduce the volume of the shrinkage region in the traditional process to 22 % of the original.

CONCLUSIONS

Cold steel feeding can effectively reduce the solidification time of the ingot and improve the production efficiency.

Cold steel feeding can improve the central porosity and concentration of large ingots.

Dispersed addition of cold steel has a good effect on improving the internal quality of steel ingots.

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Note: The responsible translator for English is Yan Wu, University of Science and Technology Liaoning, Anshan, China