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Numerical Simulation of Solidification Process of Small Die Steel Ingot

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Abstract

The three-dimensional modeling software Pro.E was used to complete the modeling of small P20 ingot, and then the filling and solidification process of the small die steel ingot was simulated in the ProCAST software. The temperature field results of the small die steel ingot were analyzed, and it was predicted that the loose defect would occur right below the primary shrinkage hole at the ingot rise.

Keywords

Steel ingot; Numerical simulation; Solidification; Porosity shrinkage.

1. INTRODUCTION

With the proposal of "Made in China 2025", China's equipment manufacturing industry is also developing towards the direction of intelligence and precision. At the same time, steel ingot, as the main raw material of national defense, Marine engineering, petrochemical and other important fields, has higher and higher quality requirements. Besides, the casting of steel ingot is almost an indispensable and vital key technology and production link in all steel processing processes except casting. It is an indispensable steel production process in the national economy, and its importance is self-evident. In the past, due to the limitation of research technology, it is very difficult to study the solidification process of ingot. But with the rapid development of computer technology and software, more and more researchers can use numerical simulation method to study the solidification process of ingot, so as to provide some guidance for the actual casting process[1-3].

This paper mainly studies the variation law of temperature field in the filling and solidification process of small P20 die steel ingot, and predicts the possible position of loose defects through simulation, hoping to provide certain reference value for the production of small die steel ingot.

2. MATERIALS AND METHODS

The ingot material studied in this paper is P20, a typical Inconel prehardened plastic die steel. Its main characteristics are: uniform hardness, good polishing performance and photo-etching performance, excellent processing performance, pure steel, good dimensional stability, suitable for the production of polishing or etching processing of plastic molds. In this study, the internal control components of P20 raw material are shown in Table 1:

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Table 1. Internal control components of raw materials

Element	C	Si	Mn	S	P	Cr	Ni	Mo
Standard (%)	0.32	0.30	0.90	/	/	1.90	0.20	0.50

In this paper, the ingot of small die steel with a weight of 50KG is studied. The model is established by three-dimensional software Peo.E, as shown in Figure 1:

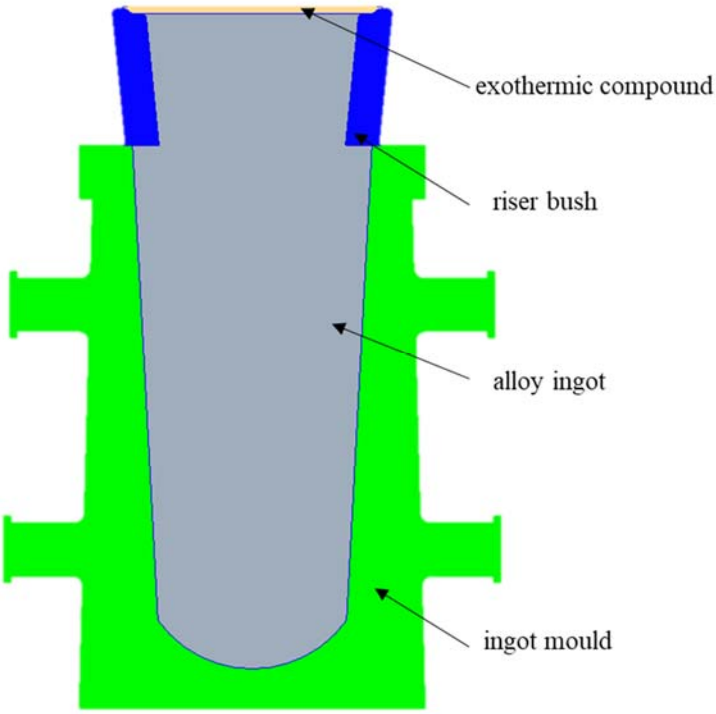

Figure 1. Structure diagram of ingot mold

Then ProCAST software was used to divide the imported 3D model into grids, and the total 3D Elements was 0.246million.

Based on the actual production process, the pouring temperature of the molten steel was set at 1750℃, and the pouring speed was set at 6.57kg/sec. Then the temperature field and stress field during the solidification process of the ingot were simulated, and the relevant results were obtained.

3. RESULTS AND DISCUSSION

3.1. Simulation analysis of filling and solidification

The simulation results of steel ingot solidification are shown in FIG. 2:

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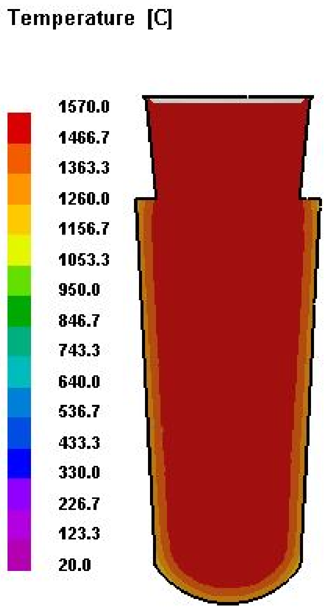
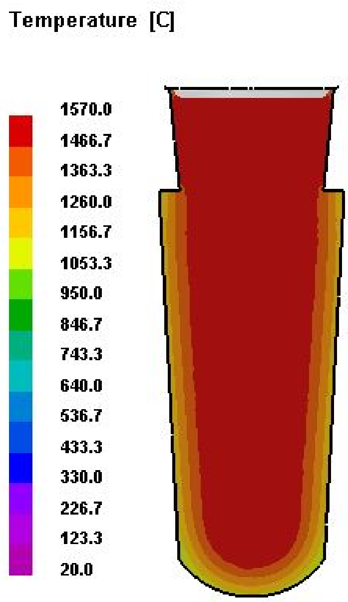
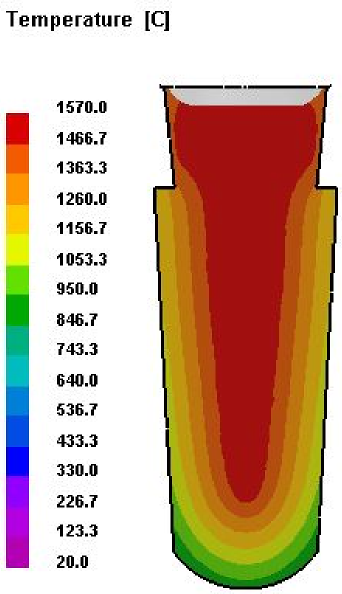


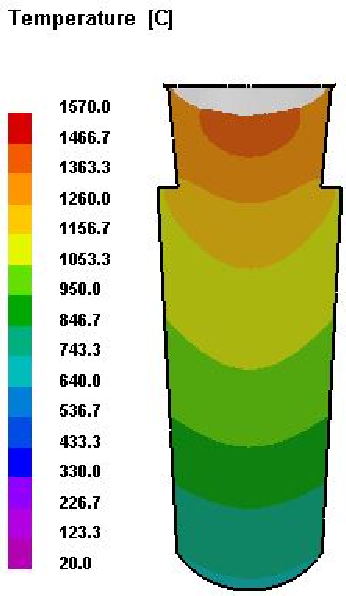
Naturally cooled 61sec
(solid phase ratio 29%)



Naturally cooled 121sec
(solid phase ratio 47.8%)



Naturally cooled301sec
(solid phase ratio 80%)



Naturally cooled 941sec
(solid phase ratio100%)

Figure 2. Temperature field of ingot

By analyzing the temperature field during the solidification process of the ingot, it can be seen that under the condition of natural air cooling after pouring, a stable solidified billet shell gradually forms on the surface of the ingot after 61sec, and the overall solidification rate is 29%. With the passage of pouring time, after 121sec of air cooling, the solidification rate of the ingot reached 47.8%. At this time, the internal temperature of the ingot became uniform, and the temperature of the cap mouth remained consistent with the internal temperature of the liquid steel. The temperature of the ingot head was the highest, and the solidification of the ingot was a process from bottom to top and from outside to inside. After the casting of 301, it can be observed that the temperature in the riser is still high, indicating that the cap has good insulation capacity and strong feeding capacity. At this time, the ingot gradually solidified completely, the solidification trend is "T" shaped, and the final solidification area of the body is

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approximately located in the upper part of the center; After natural air cooling 941 ingot solidification rate of 100%, as the steel ingot solidification completely, and can be observed that the final solidification region at the top of the cap mouth, mouth cap internal steel drawdown is not much, and the top cap mouth been bowl, shows the mouth of the cap in the design of the heat preservation and the feeding capacity are fully play, to improve the final quality of ingot.

3.2. Analysis of shrinkage simulation results

The results of steel ingot shrinkage cavity and porosity obtained by simulation are shown in Figure 3:

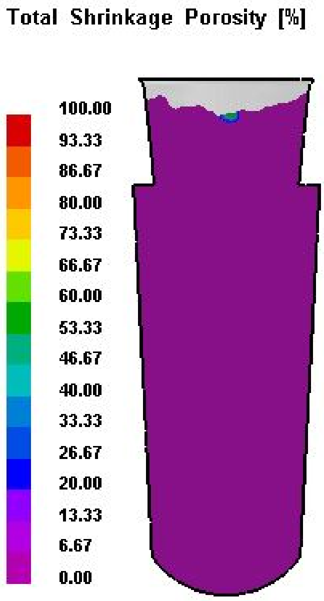

Figure 3. Total Shrinkage Porosity

From figure 3, small ingot ingot and compact structure, no loose phenomenon, only a small percentage of osteoporosis is concentrated in the riser end a shrinkage cavity directly, this is because in the process of steel ingot production, when the liquid steel ingot model cavity after, under the chilling effect of ingot mould, molten steel temperature is lower and in contact with the inner wall of the ingot mould surface layer of the shell. Subsequently, the temperature of the molten steel decreases further and the liquid shrinkage of the molten steel and the solid shrinkage of the solidified layer continuously occur. The level of the molten steel at the head of the ingot decreases continuously under the action of gravity, and finally a shallow disk or tubular shrinkage hole is formed at the head of the ingot. If there is an unsolidified liquid phase under the shrinkage cavity at this time, the liquid phase region will be separated from the upper solidified shell due to further contraction under the action of gravity, and a secondary shrinkage cavity will eventually be formed. At the late solidification stage of the ingot, there are many liquid steels isolated or not completely isolated by grains in the final solidification area, which can not be supplemented during solidification and form dispersed and tiny loose.

4. CONCLUSIONS

a.The solidification of steel ingot is a process from bottom to top and from outside to inside. In this study, the thermal insulation and feeding capacity of the cap mouth is given full play, which is conducive to improving the final quality of steel ingot.

b. In this study, it is predicted that the ingot body structure is relatively dense, and the only loose defect is located directly below the primary shrinkage hole at the riser.

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