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STUDY ON UNIDIRECTIONAL SOLIDIFICATION INGOT WITH HOLLOW LATERAL WALL INSULATION

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Hollow side wall insulation mathematical model of unidirectional solidification temperature field was carried out. With the aid of finite element analysis software ProCAST, directionally solidified ingot temperature field with hollow lateral wall insulation during the process of unidirectional solidification was simulated. The results show that the numerical simulation results are in good agreement with experimental results. The hollow side wall significantly improves the thermal insulation effect, inhibits heat transfer directionally solidified casting side wall, and reduces the lateral heat of the ingot. As the hollow side wall was used in nuclear power, large-scale steel and other special steel ingot improve the yield and quality, provide the basis of theory and application.

Key words: steel, solidification, hollow air gap, temperature field, numerical simulation

INTRODUCTION

The processing of materials with unique electronic, mechanical, optical and thermal properties plays an important role in modern technology. The quality of these materials depends heavily on the morphology and microstructures during processing, e.g. directional solidification. directional solidification refers to the technology that establishes specific direction along the temperature gradient between the solidification metals, and the non-solidification melt using the mandatory ways in the solidification process so that the melt solidification along with the heat flow in the opposite direction. The technology can better control the grain-oriented of the solidification organizations to eliminate the horizontal grain boundary, get a column or single organization and improve the longitudinal mechanical properties of the materials [1]. By using directional solidification technology, Shrinkage, porosity, segregation, inclusions and other casting defects exist only in the upper part of the ingot, while the lower part of the ingot was manifested as clean and compact. [2]

The smaller the depth of the upper casting defects, the longer was the clean compact segment of the lower, and the higher was the ingot quality rate and rate of material too. Moreover, the upper and lower part of the exact split, which preserves the lower part of the clean compact segment, is also very important. Its premise is to predict the upper ingot casting defect depth. Consequently, to accurately predict large-scale ingot casting defects within the act, the numerical simulation of steel ingot solidification process, the production of large castings and forgings and internal quality assurance, energy and materials are of great significance [3,4].

Side wall insulation is the key technique of the directional solidified ingot. The inhibition of side wall heat transfer is the main symbol of directional solidified ingot which is different from the ordinary ingot, and it significantly reduces the segregation generation. The side wall of the common directional solidification device is generally close to the ingot side for heat resistant material with high strength, high insulation material for the heat outside, it cannot meet the side wall of the good insulating effect in the production process of the directionally solidified ingot. It will affect the growth of columnar crystals during the process of ingot solidification and produce the equiaxed grains. The equal axis grains would undermine the longitudinal mechanical properties of ingot, reduce the quality of ingot [5]. However, few studies have been focused on insulation in the hollow side wall.

Using the adiabatic property of gas can significantly improve the thermal insulation performance of the side wall. We aim to test the feasibility of unidirectional solidification with hollow side wall insulation for the production of large steel ingot with thermal modelling experiments and mathematical simulation. The research results show that the unidirectional solidification method of large steel ingot production with hollow side wall insulation can extend the full coagulation time, make the steel ingot solidification uniform in the longitudinal direction, and improve the quality of steel ingot.

A numerical simulation following the finite element method is widely used today [6].

By using FEM software ProCAST, simulation on temperature field of 45 t ingot during the directional solidification process was calculated, and simulated results were verified on the basis of thermal modelling

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experiments, consequently ensure the accuracy of the numerical simulation calculation. Traditional unidirectional solidification and hollow side wall insulation during unidirectional solidification process under the two conditions of steel ingot solidification through the numerical simulation was compared. The simulation results showed the rational design of unidirectional solidification with hollow sidewall insulation; the use of hollow sidewall insulation during unidirectional solidification can restrain the side wall heat loss, prolong the whole coagulation time, enhance the internal quality of ingots, and thus improve the quality of heavy plate steel ingot.

EXPERIMENTAL WORK

In order to verify and modify the mathematical model, this paper uses the self-made device in the laboratory to carry out the thermal simulation experiment of the insulating properties of the side wall. The device comprises a resistance furnace, corundum brick, insulating layer, hollow air gap, asbestos felt and thermocouples. The Schematic of the experiment is shown in Figure 1.

According to the actual requirement of ingot process and safety requirements of test equipment, providing high temperature environment was needed by the simulation experiment of high temperature resistance furnace, using corundum brick as inner and outer wall of mold in simulation, with a certain gap left between the inner wall and the outer one, which is full of air, sealing air gap with asbestos brick, the inner wall and the outer wall temperature were real-time monitored by thermocouple. Thus provide experimental data for mathematical models, and through the test and measurement of the temperature data hollow side wall insulation directionally solidified ingot mathematical model is further verified and modified, and the hollow side wall insulation directionally solidified ingot process parameters are optimized. The geometric model in which the steel ingot with the length of 4 000 mm, height of 800 mm and width of 2 500 mm is shown in Figure 2. And the diagram of mesh generation is shown in Figure 3.

This paper chooses Q235B steel as simulation object, with chemical composition given in Table 1. Thermal physical parameters of Q235B are automatically calculated by ProCAST.

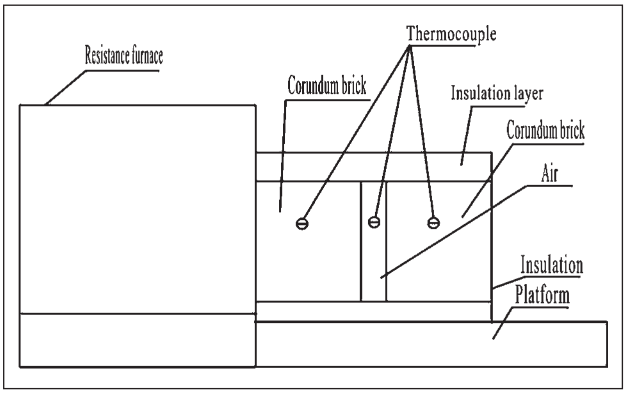

Figure 1 Schematic of experiment

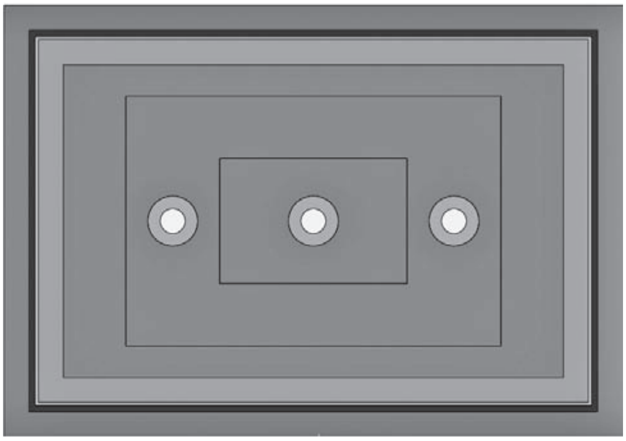

Figure 2 The diagram of geometric model

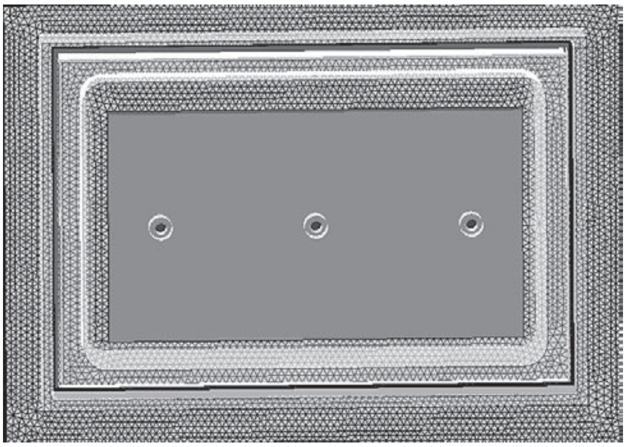

Figure 3 Mesh generation diagram

Table 1 **Chemical composition /wt. %**

C	Si	mn	P	S
0,06	0,3	1,6	0,01	0,003
Mo	Ni	Ti	Cu	
0,025	0,4	0,017	0,15	

NUMERICAL SIMULATION RESULTS AND DISCUSSION

Ingot solidification temperature field curve of side wall under different air gap

By using the air gap during unidirectional solidification with hollow side walls, thermal resistance of the gap is very large, the insulation effect of refractory brick is obviously improved, greatly extends the complete solidification time of liquid steel, and even the side wall temperature curve of steel ingot is changed. The temperature of an ingot mold increased significantly during the solidification process, but because the side wall insulation played a role in thermal resistance, most of the heat was conducted through the chassis, the temperature rose limitedly.

Taking 1/2 side wall position of directionally solidified ingot as measurement points under different air gap, through the observation of the inner surface temperature curve can be found: the inner surface temperature curve is coincident basically, which accords with the heat transfer law with the same resistance furnace and the same inner wall. Therefore, under the same condition of inner wall temperature, outer wall temperature curve can fully react hollow thermal insulation effect of air gap.

Figure 4 shows outer side wall temperature field distribution of solidified ingot as air gap is 0, 5, 10, 25, 30, 40 respectively. It can be seen from Figure 6, due to the role of insulation hollow side wall, without an air gap, the temperature of the traditional outer wall was significantly higher than that of hollow air gap, and heat insulation effect with an air gap is obvious. When air gap is 25 mm, the side wall heat preservation effect is the best, and agrees well with the experimental results.

Figure 5 is the comparison of simulated and experimental temperature curves with 25 mm hollow lateral wall. It is shown in Figure 5 that the numerical simulation results are in general agreement with the experimental results. Numerical simulation of unidirectional solidification process with hollow sidewall insulation is feasible and has high accuracy.

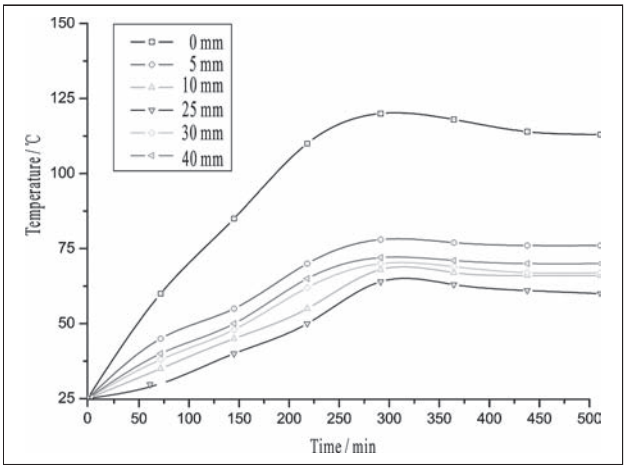

Figure 4 Side wall temperature field distribution of solidified ingot with different air gap

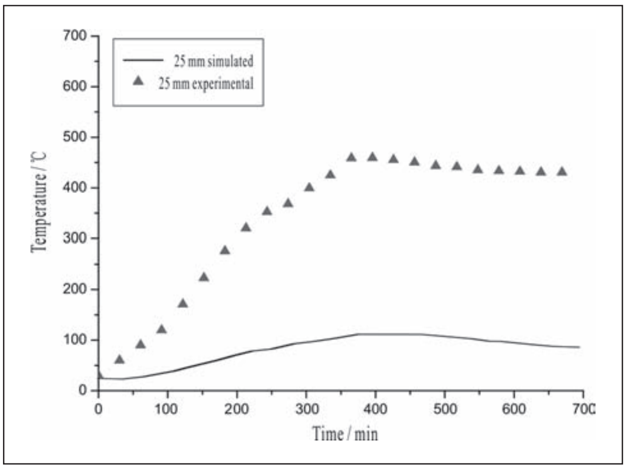

Figure 5 Comparison of simulated and experimental temperature curves with 25 mm hollow lateral wall

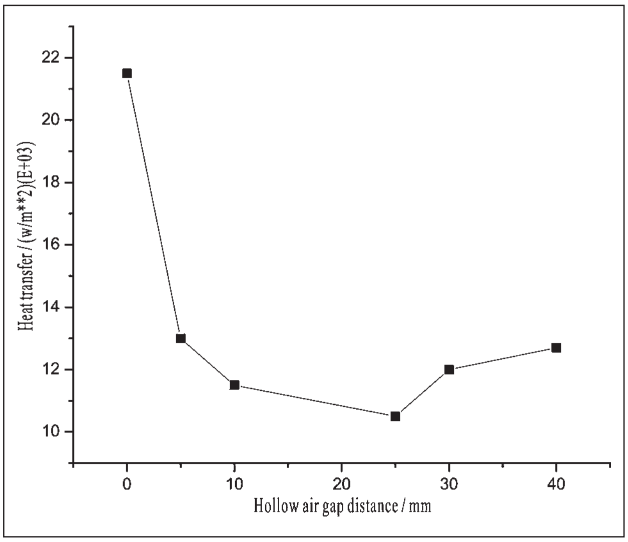

Figure 6 Variation curves of heat transfer under different air gap

In this experiment, along with the increment of die wall temperature of inside and outside, especially after the temperature stability, due to the fact that the hollow air gap spacing is small, the heat transfer is mainly by radiation. Ignore corundum brick and cover plate heat storage capacity and identify heat transfer as steady-state in the air gap. According to the experimental data, the heat transfer in the air gap distance is shown in figure 6. Heat transfer of corundum brick in the air gap is very large without air gap distance, reaching 21,545 W/m^2. When there is a gap in the air, the heat transfer is significantly reduced, but there is little difference between them in different air gap. The minimum heat transfer is 10,598 W/m^2 with 25 mm air gap and when the air gap distance increases to 30 mm, the heat transfer quantity is 12,234 W/m^2, and the air gap distance increases up to 40 mm, the heat transfer quantity increases up to 12,758 W/m^2. This is because when the air gap distance increases, the air flow in the air gap is increased, the heat convection heat transfer increases, and the insulation effect is reduced [7].

CONCLUSIONS

Analysis of experimental research on the characteristics of hollow side wall heat preservation through the self-designed device, the insulation effect with hollow air gap is obvious than conventional one.

For the hollow side wall heat transfer, the larger the medial and lateral space is, the thicker between the air layer is, so does the heat resistance, but the space is too large to cause air flow to accelerate, thereby reducing the thermal resistance, which is not conducive to the preservation.

Through different gap wall temperature change curve and the internal and external wall temperature change curve analysis, compared to other air gap, 25 mm has the advantages of good thermal insulation, thermal insulation effect is obvious.

To confirm the results of insulation, a more complete analysis with different parameters and heat insulation board inserting in the hollow side wall is suggested for further studies.

Acknowledgements

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