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ISSN 0543-5846
METABK 58(1-2) 47-50 (2019)
UDC – UDK 669.18.015:66.065:536.45:518.1=111

STUDY ON THE INFLUENCE OF NEW RISER STRUCTURE ON THE QUALITY OF STEEL INGOT

Received – Primljeno: 2018-07-02
Accepted – Prihvaćeno: 2018-10-10
Original Scientific Paper – Izvorni znanstveni rad

A new type of optimized riser structure was proposed, in which a low-emissivity board was inserted into the hollow interlayer of the material to increase the yield of the steel ingot. The insulation effect of different riser heights on the solidification process of steel ingot is numerical simulated. The results show that when the riser height can be reduced from 350 mm to 300 mm, the ingot yield can be increased by 1,92 %. As the number of low-emissivity boards is increases, the riser insulation performance is also increased.

Key words: Steel ingot, air cavity, temperature feild, hollow structure

INTRODUCTION

At present, the production mode of special steel mainly depends on continuous casting and die casting. Although die casting is not the same as continuous casting in mass production, the demand for steel in die casting is not completely replaced by continuous casting. Mainly in: (1) the diversity and flexibility of steel production; (2) high-performance special steel, super large steel ingots.

At present, there are still quality defects to be solved in die-cast products. For example, thick steel plate as a special steel product to improve equipment performance has an urgent need and development space in the thickness, weight and quality of a single product. Because ordinary large steel ingots are two-dimensionally solidified, defects such as looseness, shrinkage, and macrosegregation are easily generated in the axial portion of the ingot. In addition, macroscopic defects such as V-shaped segregation, inverted V-shaped segregation and negative segregation have not been effectively improved and are ubiquitous in large steel ingots, so it is necessary to solve the above problems to improve the quality of extra-thick plates.

As a die-casting accessory, the riser can add more space for filling to store molten metal. It is an important technological measure to improve casting defects and obtain high-quality products. Through the analysis of the castings produced by the riser, it is found that the temperature gradient value in the solidification direction of the casting can directly reflect the feeding effect of the steel ingot. The higher the temperature gradient toward the riser, the larger the expansion angle, ensuring the smoothness of the filler channel during solidification of the ingot, which is beneficial to the sequence of the casting during solidification. That is, the heat transfer of the riser itself has a direct impact on the feeding effect of the casting [1].

This paper presents a novel riser structure, after conventional riser structure is adjusted so that the interlayer material to increase the width of air cavity, and wherein the low emissivity board inserted, effectively suppressing radiative heat transfer at a high temperature, purpose In improving the heat transfer resistance of the material. When the ingot is solidified, the feeding condition is improved, thereby improving the quality of the ingot.

HEAT TRANSFER MECHANISM

The molten steel is mainly an exothermic process from liquid to solid during solidification. The quality of the ingot is affected by the solidification process. In the study of heat transfer in the air cavity, the heat preservation effect is related to the surface temperature, blackness and air cavity distance of the inner wall of the air cavity. The larger the air cavity is, the thicker the inner gas layer is, so the thermal resistance increases, but the excessive spacing causes a relatively “strong” convection effect in the air cavity, which causes the air cavity thermal resistance to be lost, but loses the purpose of heat preservation.

According to the heat transfer mechanism, When the low emissivity board is not inserted into the hollow in-

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Table 1 **The relationship of air cavity insulation riser on heat transfer**

medium	Heat transfer method
air	Thermal convection-thermal radiation
Insulation Materials	Heat Conduction
air cavity	Heat conduction- heat radiation
Riser material	Heat Conduction
Liquid steel	Thermal convection - heat conduction

sulation riser, the air layer can calculate the radiation heat transfer according to the two infinite large parallel gray surface black body, the angular coefficient is approximately 1, When the number of boards is n , the radiation heat can be expressed as [2] :

$$Q_{1,2}^{n}=\frac{\sigma(T_h^4-T_l^4)}{(n+1)\left(\frac{2}{\varepsilon}-1\right)}=\frac{1}{(n+1)}Q_{1,2} \quad (1)$$

Where: Q is the radiation heat transfer, W / m$^{2;}$ ε is the emissivity, taken according to the test material taken ε = 0,75;

σ represents Stefan-Boltzmann radiation σ=5,67× 10^{-8} W / (m^2·K^4); T_h is the inner surface temperature of the middle air cavity, K; T_l is the temperature of the outer surface of the hollow structure.

According to the radiation shielding mechanism [3], insert a low emissivity board into the air cavity as shown in Figure 1, this time by the radiation heat transfer surface is added two to three. For the convenience of analysis, both the radiant wall and the low emissivity board are assumed to be gray, and $\alpha_1 = \alpha_2 = \alpha_3 = \varepsilon$, as in Formulas 2 to 5:

$$q_{1,3}=\varepsilon_S\,(E_{b1}-E_{b3}) \quad (2)$$

$$q_{3,2}=\varepsilon_S\,(E_{b3}-E_{b2}) \quad (3)$$

The emissivity after inserting the board is the same,

$$\varepsilon_s=\frac{1}{\frac{1}{\varepsilon}+\frac{1}{\varepsilon}-1} \quad (4)$$

Under steady state conditions:

$q_{1,3} = q_{3,2} = q_{1,2}$, formula (2) + (3), get:

$$q_{1,2}=\frac{1}{2}\varepsilon_s(E_{b1}-E_{b2}) \quad (5)$$

The radiant heat is reduced by approximately 50 % compared to the air cavity insulation riser in the no-insert board . For the multi-layer plate radiation after the board is inserted, there is Equation 6 :

$$\varepsilon_t=\frac{1}{\varepsilon_1}+\frac{1}{\varepsilon_2}+\Lambda+\frac{1}{\varepsilon_n}-1 \quad (6)$$

when $\varepsilon_1 = \varepsilon_2 = \Lambda = \varepsilon_n$, then $\varepsilon_t = \frac{n}{\varepsilon}-1$, Make ε_t Increase, you can increase the number of boards, or reduce the emissivity.

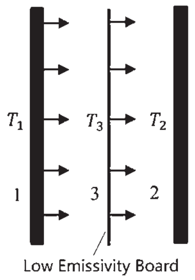

Figure 1 Insert low emissivity board

NUMERICAL SIMULATION WORK

For further analysis of the factors influencing the heat riser of the air cavity, the air cavity in 25 mm, a thickness of the insertion 1 mm, galvanized iron 0,23 emissivity as the low emissivity board material for use ProCAST own database Steel_Low- Carbon , and using finite element analysis software for numerical simulation calculation and analysis [4]. The influence of the number of low emissivity board on the insulation performance of the air cavity riser was analyzed by experiments.

According to the calculation results, it can be concluded from the temperature field cloud map that the total heat resistance of the riser increases with the increase of the number of low emissivity board inserted. That is, the heat insulation effect of the riser on the head of the steel ingot after the insert is increased. Figure 2 , Figure 3 , Figure 4.

Through calculation and analysis, it can be concluded that the average heat flux density of the medium air

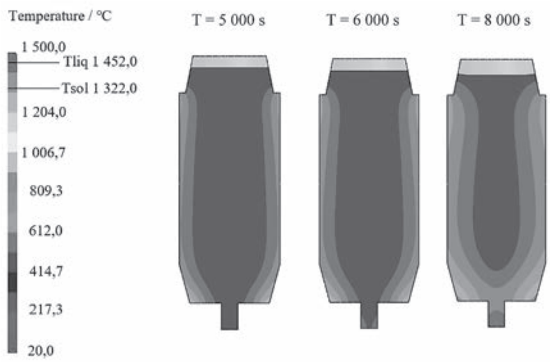

Figure 2 Steel ingot solidification process at different times under the temperature field cloud (insert number: 1)

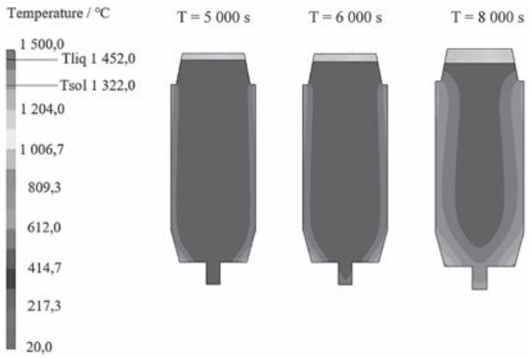

Figure 3 Steel ingot solidification process at different times under the temperature field cloud (insert number: 2)

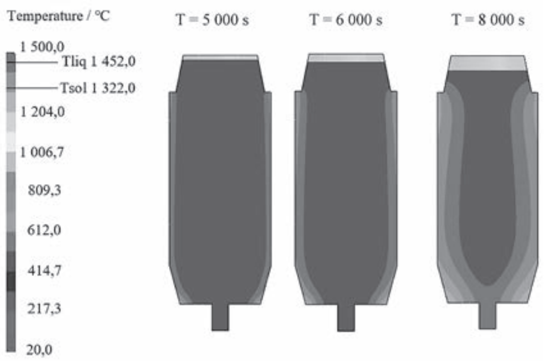

Figure 4 Temperature field cloud diagram of steel ingot solidification process at different times (number of inserts: 3)

cavity insulation riser under different number of inserts is shown in Table 2.

Table 2 **The average heat flux of the air cavity thermal riser at different board numbers**

Number of boards (sheet)	0	1	2	3
Average heat flux (W / m^2)	1 770	1 343	997	661

According to the comparison between the middle air cavity insulation riser and the uninserted medium air cavity insulation riser data, it is found that inserting a low emissivity board into the riser air cavity will significantly improve the thermal resistance effect and reduce the radiant heat. The average heat flux density is significantly reduced. Thereby, the radiant heat transfer between the inner and outer walls of the middle air cavity heat insulation riser is reduced, and thus the heat insulation effect is obviously improved. As the number of low-emissivity board inserted into the riser increases, the radiant heat transfer decreases as it passes through the wall of each air cavity, and the heat-insulating effect of the air cavity insulation riser also increases.

RESULTS AND DISCUSSION

Figure 5 is a comparison of the effect of the conventional heat preservation riser, the middle air cavity heat preservation riser and the air cavity heat insulation riser inserted into a low emissivity board on the solidification and shrinkage of the steel ingot. It can be seen from the feeding effect of different risers in the figure that the feeding effect of the insert riser is obviously superior to other risers.

Using the air cavity riser by the inserting board, the feeder size can be optimized to ensure the yield of the ingot is further improved on the basis of the feeding effect. Figure 6 show s the effect of the air cavity insert riser on the solidification and feeding process of the ingot during the different rise heights of the solidification process.

By comparing the calculated cloud maps, the hollow air inlet riser with the low emissivity board is compared with the traditional insulated riser, and the hollow insert riser has better feeding effect and smaller under the same

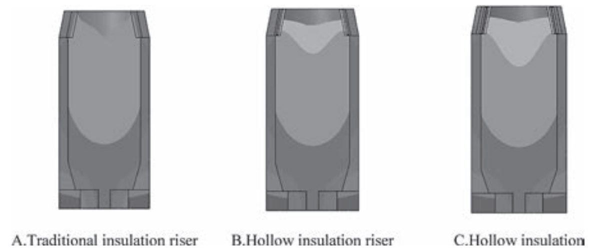

Figure 5 Comparison of the hollow structure insulation riser and the traditional insulation riser (the riser height is 350 mm)

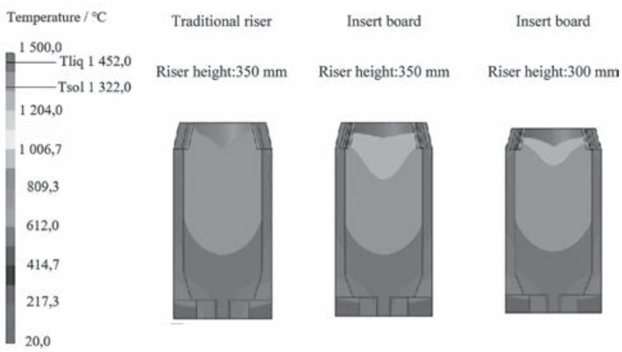

Figure 6 Comparison of the feeding process of traditional risers and hollow inserts at different heights (t = 23 000 s)

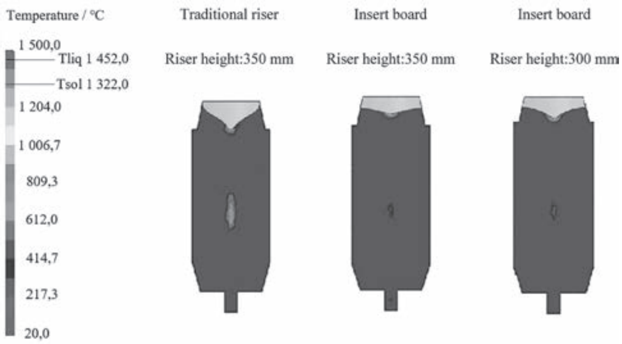

Figure 7 Comparison of the degree of shrinkage within the ingot

riser height. Internal shrinkage. Comparative same structure but different riser heights hollow insulated riser card draw, with reduced height, crater depth ingot also will deepen, but still provides a good feeding performance and quality, through Figure 7 in comparison, it is found that the internal shrinkage of the three different riser heights (350 mm, 330 mm, 300 mm) is not much different, so the riser height can be reduced from 350 mm to 300 mm , and the steel ingot yield is increased by 1,92 %.

CONCLUSION

A mathematical model for heat transfer in the hollow structure insulation riser was established, and the solidification process of the 11 t steel ingot using the medium hollow structure insulation riser was calculated. The results show that:

(1) The insulation performance of the hollow structure riser is better than that of the traditional heat insula-

tion riser. Through the simulation calculation, the thermal insulation performance and heat flux density of the steel ingot are compared during the solidification process at the width of air cavity is 0 mm, 10 mm, 25 mm, 30 mm and 40 mm. The change of the width shows that the hollow structure insulation riser has the best thermal insulation effect when the width of air cavity is 25 mm.

(2) Insert a different number of low emissivity boards into the hollow structure of the original single layer to form a double-layer or multi-layer air cavity, and use 25 mm as the unit width of each air cavity to calculate the unplugged riser in the hollow riser. Compared with the three hollow structure insulation risers inserted three plates in sequence, the average heat flux decreased from 1 770 W /m^2 to 661 W / m^2, which shows that the hollow structure insulation riser can significantly improve the air cavity riser after inserting the board. Insulation effect, with the increase in the number of low-emissivity boards, the insulation effect is enhanced;

(3) Insert a low-emissivity board with a thickness of 1mm into the double-layer 25 mm air cavity in the hollow structure insulation riser. According to the radiation shielding effect of the low emissivity board, by calculation analysis, the air cavityed riser which inserted in a low emissivity board, the ingot feeding process is superior to the traditional riser insulation condition, and the riser height can be reduced from 350 mm to 300 mm, and the steel ingot yield is increased by 1,9.

Acknowledgements

This work has been supported by 2017 joint fund of State Key Laboratory of metal materials and applications for marine equipment and University of Science and Technology Liaoning. The project number is SKLMEA-USTL-201705.

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