Effect of Thermal Controlled Solidification Process on Microporosity of GH3230 Alloy Thin-wall plate

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Abstract: Aiming at the problems such as the shrinkage porosities existing in the large superalloy complex thin-wall castings under the conditions of traditional investment casting conditions, the influence of Thermal Controlled Solidification (TCS) process on the microporosity of thin-wall plate of GH3230 alloy was investigated. The results show that the microporosity of the thin-wall plate can be reduced significantly by TCS process and the reduction degree of microporosity of different height and thickness plates is different. The microporosity content below the upper-middle part of the plate is controlled below 0.5%, and the microporosity content in the lower part and middle part is controlled below 0.25%. The microporosity content in the upper part of 3mm and 5mm plates are higher, which is 1.65% and 1.44%, respectively, the microporosity content in the 7mm plate is only 0.49%.

Keywords: TCS; GH3230 alloy; microporosity

1 Introduction

With the rapid development of high-end equipment, the demand for weight reduction, high performance and high reliability of high-end equipment structures has promoted the development of superalloy structural parts in the direction of thin-wall lightweight, structural complexity, low defects and high dimensional accuracy [1]. The use of integral casting technology to form large complex thin-wall castings instead of welding by multiple parts is one of the current development directions. However, the problems of uneven grain distribution, misrun, cold shut and porosities of large and complex thin wall castings formed by traditional investment casting process are easy to occur.

In order to solve these problems of mold filling and solidification defects of large and complex thin-walled castings under the condition of traditional investment casting process, Precision Castparts Corp of the USA proposed a new equiaxed crystal casting process, which is developed from the directional solidification technology. By controlling the temperature gradient *G* and solidification rate *R* at the front edge of the solidification interface, the shape and refinement of the solidification structure are controlled [2]. TCS technology can be used to create strong sequential solidification conditions, which has obvious advantages for improving the mold filling ability of complex thin-walled castings. In this project, taking GH3230 alloy thin-wall plates as example, the influence of TCS process on the microporosity of the thin-wall plates with different height and thickness was investigated.

2 Experimental procedure

GH3230 alloy bars were selected as raw materials in the experiments. The main chemical composition of GH3230 alloy bar was 0.10C, 21.84Cr, 1.97Mo, 2.10Fe, 13.84W, 2.96Co, 0.46Al, 0.55Si, 0.76Mn and Ni others. In order to study the effect of TCS process on the microporosity of large size thin-walled castings, thin-wall plates with a height of 300mm, a width of 50mm and the thicknesses of 3mm, 5mm and 7mm were designed, as shown in Fig 1.In the TCS experiment, ZGD-25BYF directional solidification furnace was used to melt and cast the alloy, and the main process parameters were shown in Tab 1.

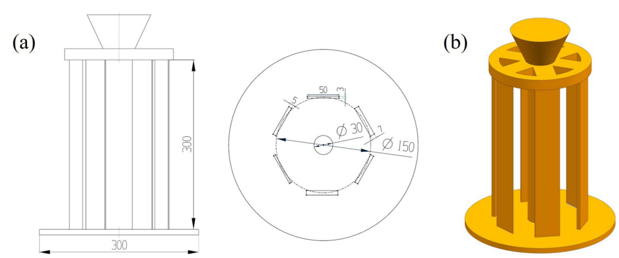

Fig. 1 Schematic diagram of GH3230 thin-wall plates: (a) schematic diagram of size; (b) schematic diagram of three-dimensional model.

Tab.1 Parameters of the main process

Upper mold temperature /℃	Lower mold temperature /℃	Refining temperature /℃
1400	1350	1550
Refining time /s	pouring temperature /℃	withdrawal rate （μm/s）
600	1400	500

3 Result and discussion

Fig 2 and Fig3 show the diagram of GH3230 plate microporosity and the content of microporosity with different thickness and height. As can be seen from the shrinkage diagram in Fig 2 and Fig 3, the shrinkage of 3mm, 5mm and 7mm plates below the upper-middle parts is less than 0.5%, and the shrinkage of the lower and middle parts is less than 0.25%, while the shrinkage of the upper parts of 3mm and 5mm plates is higher, which is 1.65% and 1.44%.

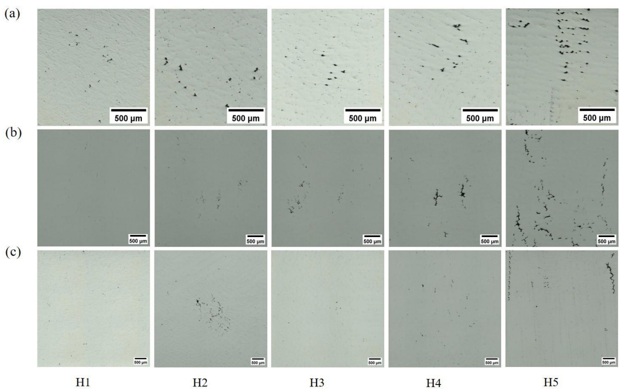

Fig. 2 Schematic diagram of the plate microporosities with different thickness and height: (a) 3mm plate, (b) 5mm plate, (c) 7mm plate; H1: lower, H2: lower-middle, H3: middle, H4: upper-middle, H5: upper.

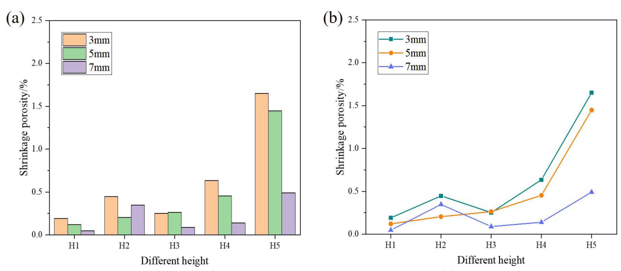

Fig. 3 The contents of microporosities with different thicknesses and heights of the plates.

In the TCS process, the heat transportation models of the plates during solidification process mainly include the heat conduction between the plates and the bottom water-cooled copper plate, the heat conduction between the plates and the shell wall, and the heat radiation between the shell and the furnace body. Among them, the heat conduction between the plates and the water-cooled copper plate accounts for the main part, which is also the premise of ensuring the sequential solidification. In the early stage of the plate solidification process, heat dissipation is mainly through the heat conduction between the bottom of the plates and the water-cooled copper plate, and the heat conduction between the plates and the shell wall and the heat radiation between the shell and the furnace body can be ignored. As the solidification process proceeding, the distance between the water-cooled copper plates and the solidification interface increases, the longitudinal heat conduction efficiency decreases, while the heat radiation from the shell to the furnace body does not decrease obviously. At this time, the transverse heat transfer between the shell and the furnace body cannot be ignored, and the conditions for sequential solidification are limited, and the solidification pattern turns to intermediate solidification dominated by dendrite growth. This increases the possibility of the formation of isolated liquid phase in the late solidification period, which increase the possibility of the formation of shrinkage porosity defects.

When the plates are extracted from the holding furnace, the thin-wall plates solidify quickly due to its rapid cooling and the micro-molten pools formed between the dendrites have solidified before the upper liquid can be supplemented. Therefore, the microporosity content of thin-wall plate is relatively high. However, the solidification of thick plates is relatively slow, and the micro-molten pools formed between dendrites can obtain the feeding of the upper liquid, therefore, there is little increase in microporosities. The above test result is also according with the Niyama criterion proposed by Niyama et al. That is, reducing the temperature gradient or increasing the cooling rate will increase the microporosity.

4 Conclusion

In this paper, the effect of TCS process on the micro-porosity of GH3230 alloy thin-wall plate was studied. The results show that the microporosity of the thin-wall plate can be significantly reduce by the TCS process, but for 3mm and 5mm plates, the upper part of the microporosities is higher. The main reason is that the longitudinal temperature gradient of the upper part of the plate is not enough, and the transverse cooling rate is increased, leading to the increase tendency of microporosity formation.

References

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