Study on Microstructural Uniformity Control of Support Plate Castings of ZTC4 Alloy During Investment Casting and Heat Treatment

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Abstract: The structure of support plate castings of ZTC4 titanium alloy is complex. And the wall thickness varies greatly from 3.4 mm to 22.8 mm. Therefore, the mircostructure of the casting is ununiform. In order to realize microstructure homogeneity of support plate castings during the whole processes of investment casting and heat treatment, the solidification nucleation model and grain growth model of ZTC4 alloy were established based on the cooling curves and solidification microstructure at different positions of the step casting and reasonable nucleation hypothesis. The simulation results are in agreement with the experimental results. The numerical simulation analysis of support plate castings under different casting processes were carried out using this model. The results show that when the conditions of preheating temperature of shell is 200 ℃, the rotating speed is 150 r/min and the heat treatment temperature is 730 ℃, the microstructure of support plate castings is more uniform.

Keywords: Support plate, Titanium alloys, Investment casting and heat treatment, Modeling, Microstructural uniformity

1 Introduction

The final mechanical properties of titanium alloy castings are determined by their microstructure, which is affected by solidification and heat treatment conditions [1,2]. At present, most of the research work [3,4] is limited to the casting process or heat treatment process, without considering the correlation and inheritance between the processes.

In this paper, numerical simulation technology was used to predict the microstructure of the whole process of solidification and heat treatment of titanium alloy castings, and the influence of different casting processes and heat treatment processes on the microstructure of support plates was analyzed. And the optimal processes to realize the uniform control of microstructure were finally obtained.

2 Experimental procedure

In order to obtain different solidification conditions of ZTC4 alloy, the molten metal was poured into a cavity with a step shape. A thermocouple was placed in the center of each step to record the solidification process of different steps (as shown in Figure 1), and the cooling curve of each temperature measurement point was finally obtained. In order to analyze the grain morphology and size under different solidification conditions, samples of the same size at each temperature measuring point were made.

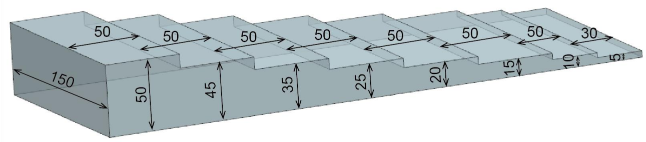

Figure 1 The size of step casting

Numerical simulation procedure

Grain Nucleation model

The continuous nucleation model proposed by Rappaz and Gandin et al. [5] is used to describe the grain nucleation. The total grain density n(ΔT) is calculated by:

$$n(\Delta T)=\int_0^{\Delta T}\frac{dn}{d\Delta T'}d(\Delta T') \quad (1)$$

Where ΔT is the undercooling. The continuous nucleation distribution dn/dΔT′ is given by:

$$\frac{dn}{d\Delta T'}=\frac{n_{\max}}{\sqrt{2\pi}\Delta T_\sigma}\exp\left[-\frac{1}{2}\left(\frac{\Delta T-\Delta T_N}{\Delta T_\sigma}\right)\right] \quad (2)$$

where n_{max} is the total density of grains, ΔT_σ is the standard deviation of undercooling, and ΔT_N is the mean undercooling in nucleation, respectively.

Grain growth model

The expression of mesoscopic grain growth rate is obtained by linear polynomial fitting of the relationship curve between tip growth rate V and subcooling degree:

$$V(\Delta T)=a_1(\Delta T)^2+a_2(\Delta T)^3 \quad (3)$$

where a_1 and a_2 correspond to the fitting coefficients of the polynomial curves respectively.

3 Result and discussion

Simulation and experimental verification of equiaxed dendrite structure of cast titanium alloys

The final microstructure of step castings under different solidification conditions obtained by experiment and numerical simulation was compared. It can be seen that with the increase of cooling rate, the number of nucleation increases, the grain size decreases. The simulation results are in agreement with the experimental results.

Effects of preheating temperatures of shell on grain sizes

The numerical simulation analysis of support plate castings under different casting processes were carried out using the established model. The results show that the preheating temperature of mold shell has little effect on the microstructure of casting. While when the conditions of preheating temperature of shell is 200 ℃, the microstructure of support plate castings is more uniform.

Effects of rotating speeds on grain size

The numerical simulation analysis of support plate castings under different rotating speeds were carried out using the established model. The results show that the microstructure of support plate castings is more uniform under the rotating speed of 150 r/min.

Effects of heat treatment temperatures on grain size

The numerical simulation analysis of support plate castings under different rotating speeds were carried out using the established model. The results show that the microstructure of support plate castings is more uniform under the heat treatment temperature of 730 ℃.

4 Conclusion

The model established in this paper is in good agreement with the experimental results, and it is proved that it can accurately simulate the microstructure evolution during whole process of investment casting and heat treatment of support plate. When the conditions of preheating temperature of shell is 200 ℃, the rotating speed is 150 r/min and the heat treatment temperature is 730 ℃, the microstructure of support plate castings is more uniform.

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