Surface Quality Control of Wax Pattern for Ring Plate Structure

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Abstract: The thermal properties, rheological properties and melt compressible PVT characteristics of KC-2656L wax were investigated. Numerical simulation of the wax pattern process of rotary body structure was carried out based on Moldflow software. The calculation results show that the melt confluence exhibited by the wax pattern filling process matches with the location of fusion marks appearing in the actual injected wax pattern with the same process parameters, which verifies the accuracy of the numerical simulation results. After increasing the wax injection rate, reducing the wax pattern filling time, lowering the temperature difference between the flow front of the wax mold and the freezing layer factor at the end of filling, the wax melt flow resistance was effectively reduced. Correspondingly, the surface flow state and melt marks of the wax pattern were minimized, and the surface quality was improved.

Keywords: Investment casting; Numerical simulation; Mold filling process; Rheology of wax

1 Introduction

Investment casting is a recent near-net forming production process, suitable for difficult to machine parts and large complex thin-walled parts of precision molding, widely used in aerospace, military equipment and other fields [1]. The castings made by investment casting do not require much processing, and the castings are characterized by low surface roughness and high dimensional accuracy. As the first production process, the surface quality and dimensional characteristics of the wax pattern will be transferred to the ceramic shell, which will ultimately affect the surface quality and dimensions of the castings [2].

Problems such as surface quality and dimensional accuracy of the wax pattern produced during the wax pattern pressing process will directly affect the wax pattern repair workload of the subsequent workers, which will waste massive manpower and material resources. The traditional trial and error method is used to redesign the wax pressing process to try to adjust the quality of the wax pattern molding. With the continuous development of the numerical simulation technology in recent years, it has provided a useful reference to improve the quality of the wax pattern molding. Cui et al [3] simulated the wax injection molding process of a large aircraft magazine wax pattern, and found that the numerical simulation and the actual wax pattern in the same location are underfilled holes, which verifies the accuracy of the numerical simulation. This research utilized Moldflow simulation software to numerically simulate the wax pattern forming process and addressed surface flow marks and weld lines issues by optimizing the wax injection parameter.

2 Experimental procedure

The experiment utilized a capillary viscometer to measure the viscosity of wax at different temperatures and shear rates. Additionally, the wax volume change was examined using the PVT module. The specific heat capacity of the wax was tested with a differential scanning calorimeter, while the thermal conductivity was evaluated using the plane heat source method. Parameters were obtained through multi-variable nonlinear regression fitting using the Cross-WLF equation and Tait equation, and then were imported into Moldflow software for numerical simulation. In the simulation, the wax injection rate ranged from 100 to 220 cm^3/s, the injection temperature varied from 62 to 68°C, and the holding pressure was set at 4 MPa. The wax injection experiments were conducted under the same process parameters for comparison.

3 Result and discussion

Figures 1 presented the PVT characteristics curve, rheological curve, specific heat capacity curve, and thermal conductivity curve of the wax.

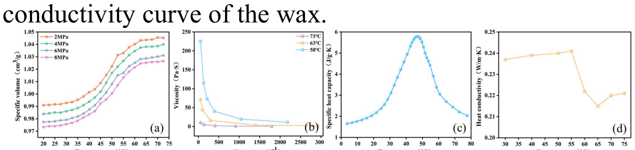

Fig.1 (a)PVT characteristic curve (b)rheological curve (c)specific heat capacity curve (d)thermal conductivity

Figures 2 depicted the schematic of the filling process, temperature field, and solidification field under the condition of a wax injection rate of 100 cm^3/s and an injection temperature of 65°C through numerical simulation. As illustrated, with the increase in filling time, the temperature at the leading edge of the wax pattern decreased, the solidification layer factor at the filling end decreased, and the flow resistance of the wax melt decreased. Figure 3 presented the physical wax pattern obtained under the same process parameters, where the weld marks on the opposite side of the wax mold injection port matched with the convergence point of the wax melt during the numerical simulation filling process, validating the accuracy of the numerical simulation results. Additionally, a large number of flow lines were observed on the surface of the wax pattern, which affected the surface quality of the wax pattern.

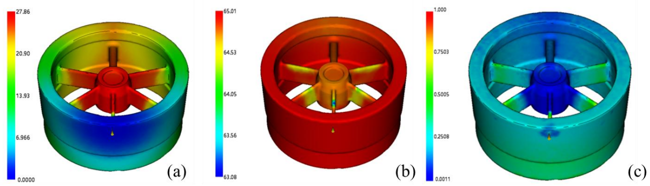

Fig.2 (a)Schematic diagram of filling process (b)Schematic diagram of temperature field distribution (c)Distribution of solidification field

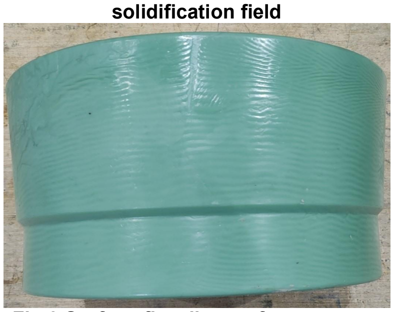

Fig.3 Surface flow lines of wax pattern

This study optimized the surface quality of the wax pattern by increasing the wax injection rate. Figures 4 depicted the schematic of wax pattern filling, temperature field, and solidification field under the condition of a wax injection rate of 220 cm^3/s. The filling time was reduced from 27.86s to 12.67s. The temperature difference at the leading edge of the flow decreased from 1.93°C to 0.54°C. The solidification layer factor at the filling end also decreased correspondingly. Increasing the wax injection rate reduced the filling time and heat loss during the filling process, optimized the uniformity of the melt temperature during wax mold filling, and reduced the flow resistance of the wax melt. Figure 5 presented the actual wax pattern after optimization, showing almost no flow lines on the surface and significantly reduced weld marks.

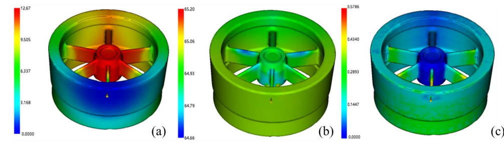

Fig.4 (a)Schematic diagram of filling process (b)Schematic diagram of temperature field distribution (c)Distribution of solidification field

Fig.5 The optimized wax pattern

4 Conclusion

By elevating the wax injection rate, the filling time of the wax pattern was decreased, as well as the temperature differential at the leading edge of the flow and the solidification layer factor at the filling end. The temperature distribution of the melt during the filling process became more uniform, resulting in a reduction of the flow resistance of the wax melt during filling and an optimization of the flow lines and weld marks on the surface of the wax pattern.

Acknowledgments

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