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Design of gating system for radiator die castings based on FLOW-3D software

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Design of gating system for radiator die castings based on FLOW-3D software

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Abstract: According to the structural characteristics of the radiator, two different gate structures were designed. The filling process of metal liquid in different gate structures was simulated by using the simulation software FLOW-3D, the size and location of possible defects in die casting were predicted, and the best design scheme of gate and overflow trough was put forward. The results show that under the conditions of pouring temperature of 680℃, preheating temperature of mold of 220℃ and pouring speed of 60m/s, the most reasonable design scheme is that the whole casting can be filled with molten metal evenly and the concentration of surface defects is low.

1. Introduction

Heat sink is one of the most important components of LED lamp, which can dissipate the heat generated by the chip into the air when LED works. Especially for high-power LED, more than 85% of its power will be converted into heat. If the heat dissipation is poor, it will not only accelerate the aging of packaging materials and phosphors, but also lead to the melting of solder on the chip, making the chip invalid, which greatly hinders the further development and application of high-power LED.

High pressure casting is the most important forming method of magnesium alloy products, which has the advantages of high production efficiency and good forming precision. However, when liquid metal is filled at high pressure and high speed, it is easy to produce defects such as flow marks, insufficient pouring, air holes. At the same time, it is easy to cause erosion, thermal fatigue cracks and shorten the service life of the mold [1-3]. Therefore, designing a reasonable gating system, deeply understanding the filling and solidification process and realizing the reasonable filling of the cavity can reduce the rejection rate of die castings, improve the quality of die castings and prolong the service life of dies.

In this paper, the newly developed Mg-6Al-1Sm-xBi rare earth magnesium alloy is used as radiator material, and the mold filling and solidification process of four gate structures is simulated by the simulation software FLOW-3D, and the influence of gating system on surface oxidation and slag inclusion of radiator is studied. The purpose is to simulate and observe the flow pattern of molten metal entering the cavity, predict the location and area of defects, compare and analyze the influence of four gating system designs on the forming process of die casting, and obtain a more reasonable scheme to optimize the die casting process.

2.Theoretical analysis and entity model

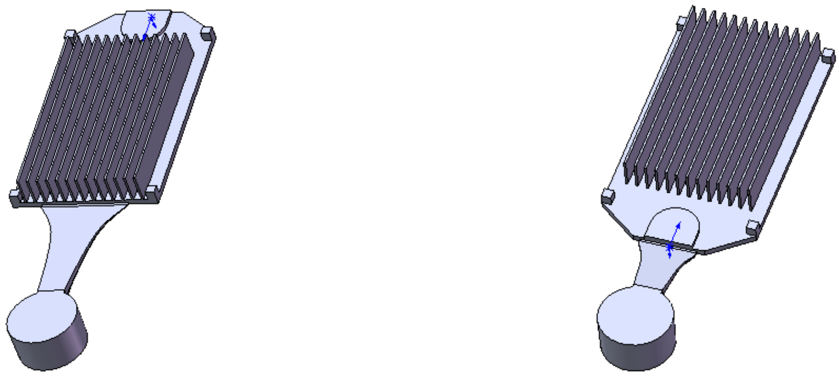
The physical properties of molten metal Mg-6Al-1Sm-xBi are similar to AE42 and belong to rare earth magnesium alloy series. The physical parameters of AE42 are imported from FLOW-3d material library as parameters of Mg-6Al-1Sm-xBi for simulation, and their values are shown in Table 1.

Tab.1 Mg-6Al-1Sm-xBi physical parameters

Density (g·cm^{-3})	Thermal conductivity (w·m^{-1}·k^{-1})	Latent heat of melting (kJ·kg^{-1})	Specific heat (kJ·kg^{-1}·k^{-1})
1.702	84	341.6	1.42

The metal melt in the simulation process is assumed as follows: the metal melt is an incompressible Newtonian fluid with constant physical properties and a free surface, and the metal melt flow is considered as an underdeveloped turbulent flow [4-5]. In the mold cavity, only one fluid of metal melt is considered, and the influence of air fluid is ignored.

In this paper, three-dimensional software Solidworks is used to model as shown in Figure 1, which corresponds to two different pouring schemes of radiator. Scheme 1 and Scheme 2 adopt horn runner as shown in Figures (a) and (b), and these two schemes are converted into acceptable STL format of FLOW-3D and exported.



（a） （b）

Fig.1 Different types of gating system

3. Pretreatment of numerical simulation

In the filling process of die casting, besides the commonly used die casting process parameters such as pouring temperature, die temperature and injection speed, the characteristics of runner and melt have an important influence on the filling behavior of liquid. In this paper, four kinds of gating systems are designed and the flow process of molten metal in the mold cavity is simulated [6-7]. As shown in Figure 1, the STL file is exported after the model is built by Solidworks, and then the STL file is imported into the pre-processing module of FLOW-3D simulation software, and a uniform grid with a size of 0.15mm is selected for grid division. Selected casting material is Mg-6Al-1Sm-xBi, and die material is H13. After many times of analysis, it is set that the speed of molten metal passing through the inner runner is 60m/s, and the pouring temperature and mold temperature are 680℃ and 220℃ respectively. Table 2 shows the setting of boundary conditions.

Tab.2 Boundary conditions

Main boundary direction	Types of boundary conditions	Runner speed/（m • s-1）	Mold temperature/℃
X_{max}	specific speed	specific speed	680
X_{min}	Wall surface	—	220
Y_{max}	Wall surface	—	220
Y_{max}	Wall surface	—	220
Z_{max}	Wall surface	—	220
Z_{max}	Wall surface	—	220

4.Results and Analysis of FLOW-3D Filling Process

4.1 Defect simulation and analysis of different runner design schemes

Using FLOW-3D simulation software, the filling process of die castings with two different gating systems was simulated, and the position distribution of oxidation and inclusions was predicted. As shown in Figure 2, the red area belongs to the defect concentrated distribution zone, followed by the yellow area, and the blue area basically belongs to the defect-free zone. Figures(a) and (b) respectively use fan-shaped runner to fill the cavity from different end faces of the casting. Figure (a) shows that the surface defects are mainly concentrated at the left and right ends of the casting near the gate. Because it is easy to design the overflow groove here, the defects such as gas collection and oxidation slag inclusion can be achieved, thus eliminating the defects on the radiator surface, and finally obtaining the casting meeting the service performance.

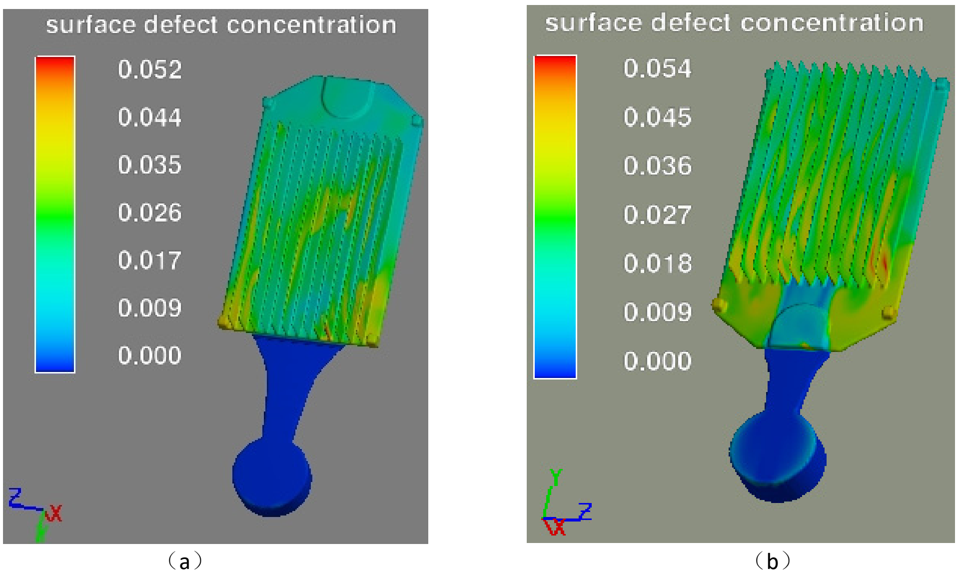
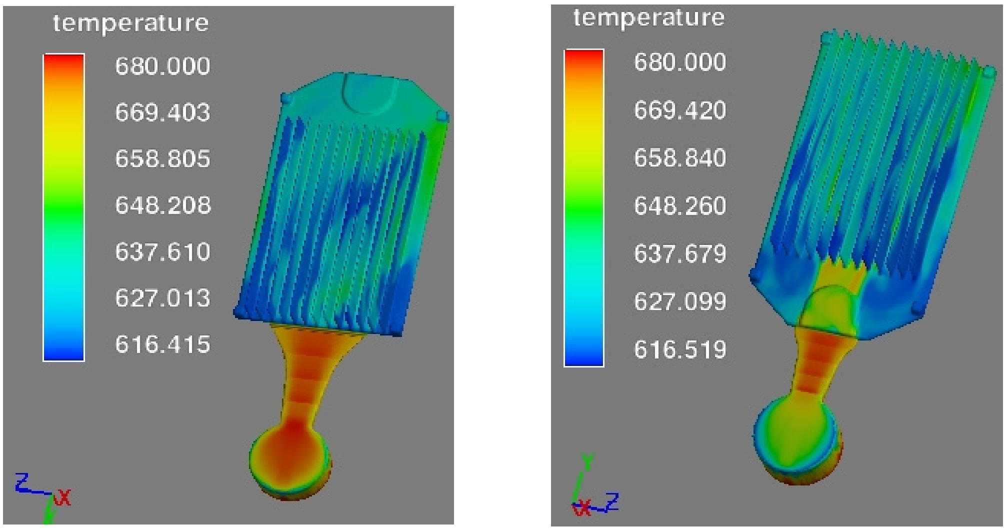


Fig.2 Defects in the radiator

4.2 Defect simulation and analysis of different runner design schemes

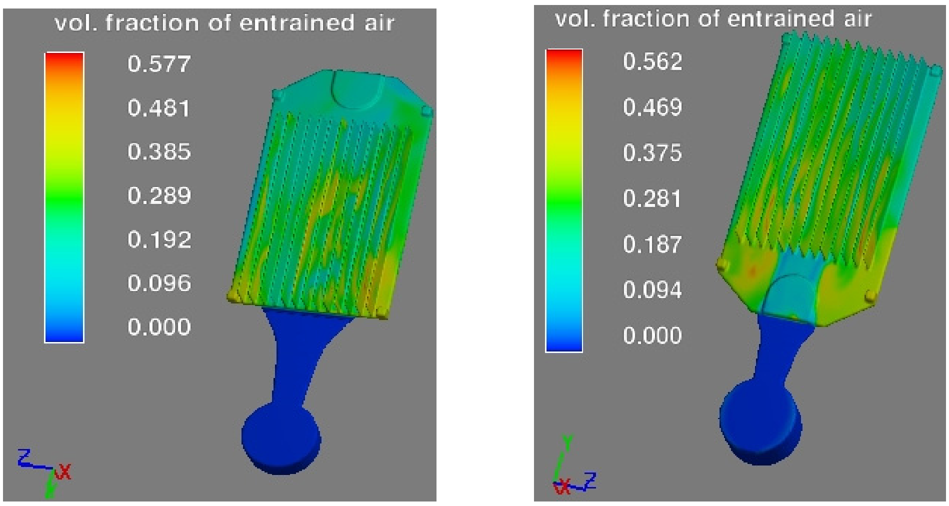
It can be seen from the temperature field of scheme 1 in fig. 3(a) that there is no obvious temperature zone in the whole casting, and the temperature difference between the high temperature zone and the low temperature zone is not big, so it can get good feeding and avoid large cavities in the casting. It can be seen from the temperature field of scheme 2 in figure (b) that the temperature in the area near the inlet gate is relatively high, and defects such as hot joint slag inclusion are easy to occur here after the surrounding heat sink solidifies first, which can also be verified from the surface defect map.



(a) (b)

Fig.3 Temperature fields during filling

It can be seen from figure 4(a) that the maximum air entrainment value of the casting in scheme 1 is 0.577, and a small part is distributed at the edge of the casting, so the air entrainment can be reduced or eliminated by setting an overflow vent groove at the edge. The maximum entrainment value of scheme 2 in figure (b) is 0.562, which is mainly distributed on the heat sink near the middle of the gate. Comparing the entrainment areas in figures (a) and (b), it is found that the yellow area in figure (b) occupies a larger area than that in figure (a).



(a) (b)

Fig.4 Distribution of air entrainment in radiator

To sum up, a more reasonable scheme 1, the horn runner gating system, is finally adopted. A horizontal cold die casting machine with clamping force of 4000KN is used, one cavity per die, the filling time is between 0.04 and 0.06 s, the runner speed of the die casting machine is 60m/s, and r=0.35(r is the ratio of inner gate thickness to casting wall thickness). The inner gate thickness is 1.75mm, and the length is 2 mm. The overflow trough adopts trapezoidal cross section. According to the simulation results of casting, the overflow mouth is set to be 4mm in length, 8mm in width and 0.6mm in thickness, and the overflow trough is 16mm in length and 8mm in depth, as shown in Figure 5.

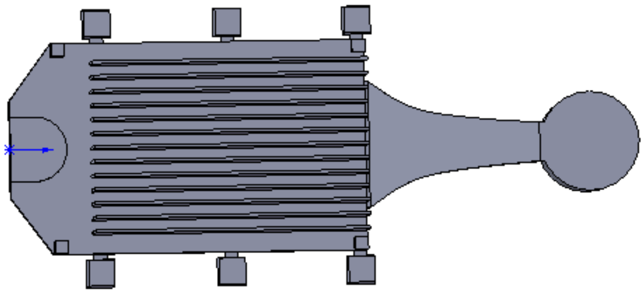


Fig.5 Gating system of horn with overflow

5.Conclusions

(1) Based on FLOW-3D simulation of mold filling of two different gating systems, it is found that the mold filling modes of molten metal in die casting process are basically similar, and the molten metal diffuses to the inner gate by using the runner, then fills the cavity with the thickness of the inner gate until the farthest end of the cavity, and finally flows back. The filling controllability of molten metal after reflow is lower than that before reflow.

(2) The mold cavity can be filled with molten metal evenly, and there is no vortex caused by the confluence of several liquid flows. Scheme1: The gating system of the horn runner is reasonable and feasible, and this gating system can fill the mold to produce die castings with good quality and satisfying service performance.

Acknowledgments

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References

[1] Peng, Y.,Wang,S.C., Zheng,K.H. (2013)Research progress of high performance magnesium alloy casting technology .J. Casting Technology , 34: 203 -204.
[2] Chen,X.H., Geng,Y.X., Liu,J. (2013)Research progress of functional materials of magnesium and magnesium alloys.J. Journal of Materials Science and Engineering, 31: 148-152.
[3] An,S.J.(2015)Mg-Al-Mn alloy by super vacuum die casting.J. Scripta Material, 67: 879-882.
[4] Qi,W.J.,Song,D.F.,Cai,C.(2014)Research on vacuum technology for vacuum die casting of magnesium alloy radiators.J. Casting, 63: 328-329.
[5] Chen,S.T., Qi,W.J., Song,D.F.(2013)Optimization of pouring system for magnesium alloy radiator die casting.J. Special casting and non-ferrous alloys, 33:1134-1136.
[6] Song,D.F., Qi,W.J., Wang,H.Y., et al. (2015)Study on die-casting process of magnesium alloy heat sink for LED.J.Casting, 64: 403-404.
[7] Li,X.B., Cao,W.T., Bai,J.Y.(2010)Study on the heat dissipation performance of AZ91D.J. Journal of Henan University of Technology, 29:685-688.