Numerical simulation and analysis of communication baseplate extrusion casting based on Anycasting

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Abstract. In this paper, the extrusion casting molding process of A356 aluminum alloy communication baseplate was numerically simulated by Anycasting. Through the analysis of the filling and solidification process, the curve of heat conductivity changing with time and the curve of the relationship between filling rate and solidification rate were obtained, and the forming reason of the curve was analyzed. The results show that the solidification rate becomes slower with increasing time. The results show that with the increase of time, the solidification rate becomes slower and slower, while the solidification rate gradually increases with the increase of filling rate. Through the analysis of the combined probability defect parameter distribution diagram and the temperature field during the whole casting process, the possible location of shrinkage cavity and porosity was obtained. By comparing the cloud images of temperature distribution at different time, it was found that this was caused by non-sequential solidification, which was confirmed by pressure test.

1. Introduction
Squeeze casting is a metal forming technology between casting and forging. A certain amount of liquid metal is injected into the mold cavity, and the upper die moves downward to squeeze the liquid metal upward and backward to fill the cavity, so that the liquid metal forms and solidifies under high pressure, so as to obtain high quality castings. The inner structure of the castings obtained by extrusion casting is dense and the mechanical properties are excellent. Therefore, it has been successfully applied in the production of high quality light alloy casting[1-3]. Casting aluminum alloy has high specific strength, good casting performance and corrosion resistance, which is widely used in military, aerospace, aviation, automobile, machinery and other fields. A356 alloy is one of the typical Al-Si-Mg ternary alloys, which is a kind of cast aluminum alloy with excellent comprehensive properties[4,5]. It has good casting properties, such as good fluidity, line shrinkage, no hot cracking tendency, good air tightness. At the same time, it has the characteristics of small specific gravity and good corrosion resistance. High strength, good plasticity and high impact toughness can be achieved by heat treatment. Therefore, it has become the preferred material for casting parts of automobiles and motorcycles[6,7]. Anycasting was used to simulate the extrusion casting of A356 communication baseplate, in order to obtain the general rules of mold filling and solidification in extrusion casting process and reduce the...
2. Establishment of mathematical model of squeeze casting

Anycasting software was used to carry out numerical simulation of the extrusion casting process, including mold filling and solidification. The 3D model of A356 communication baseplate of the casting was shown in Figure 1.

![Fig. 1. Casting model of communication baseplate](image1.jpg)

The communication plate is 359.76mm in length, 94.54mm in width and 32.39mm in thickness. The height of the rib plate is 21.63mm and the thickness is 3.05mm. In order to prevent the phenomenon of air entrapment and insufficient pouring during filling, the sprue is arranged on the side without groove, and the slag ladle and gas chamber are arranged on the side with groove. The chemical composition of casting material A356.2 extruded cast aluminum alloy is shown in Table 1.

![Fig. 2. Model diagram of pouring system](image2.jpg)

| Table 1 Chemical composition of A356.2 aluminum alloy (mass fraction, %) |
|-----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|
| Si   | Fe   | Cu   | Mn   | Mg   | Ni   | Zn   | Ti  | Al  |
| 7    | 0.13 | 0.01 | 0.01 | 0.33 | 0.33 | 0.01 | 0.01 | 92.47 |

3. Meshing and boundary condition setting

The preheating temperature of the mold is set to 180°C, the air temperature is set to 25°C, the mold material is set to STS304 die steel, the gate area is set to 5057mm, the pouring temperature is set to 690°C, and the filling speed is set to 0.1m/s. The heat conduction coefficient between the air and the mold is set to 41.87W/m²*K, while the heat conduction coefficient between the die and the aluminum alloy varies with temperature. The heat conduction coefficient in the solid phase is 3000W/m²*K, and that in the liquid phase is 7000W/m²*K. In the case of solid-liquid coexistence, the heat conduction coefficient is a linear equation increasing with temperature[^8]. The relationship between thermal conductivity and temperature is shown in Figure 3.

![Fig. 3. Thermal conductivity curve with temperature](image3.jpg)

![Fig. 4. Curve of solid fraction with temperature](image4.jpg)
The solidification shrinkage volume change is set to 7.14%, and the output solid fraction changes with temperature. To activate the oxidation/slag inclusion model, the key value is set to 0.001, the dimension is set to (556,0) (616,1), and the iterative method is set to sor iteration. The pouring system was meshing, and the number of grids is 270144.

4. Analysis of simulation results

The simulated extrusion casting lasted a total of 154.6 seconds, and the solidification began when the mold filling was about 50%. When the mold filling rate reached 100%, the solidification rate was 9.3%. According to the simulation results of squeeze casting, the temperature field, filling rate, solidification rate change with time, and the relationship between them in the solid-liquid coexistence state were qualitatively analyzed.

4.1 Curve of solidification rate over time

Fig. 5 shows the curve of solidification rate with time. As can be seen in the figure, the solidification rate becomes slower and slower as time increases.

There may be two reasons. First, for the liquid aluminum at the same position, the liquid aluminum and the mold are in direct contact at the beginning, and the heat transfer efficiency is higher. When the external liquid aluminum starts to solidify, the internal liquid aluminum first conducts heat exchange with the solid liquid aluminum and then with the mold. At this time, the heat transfer efficiency decreases and the solidification rate slows down. The second reason is that the liquid aluminum has a large contact area with the mold at the beginning, resulting in a high heat transfer efficiency. However, when the liquid aluminum at the tail gradually solidifies, the heat transfer area gradually decreases, leading to a decrease in heat transfer rate and a subsequent decrease in solidification rate.
Fig. 7. Cloud diagram of casting temperature distribution during mold filling and solidification.

Fig. 6 shows the change curve of filling rate and solidification rate. As can be seen from the figure, the solidification rate gradually increases with the increase of filling rate. The reason is that the filling rate increases the contact area between liquid aluminum and the mold, and the heat transfer rate increases with the increase of the heat transfer area, and the solidification rate also increases.

Fig. 7 shows the temperature field distribution cloud diagram of 50%, 75%, 100%, 50%, 58% and 70% solidification respectively.

According to the particle velocity flow diagram (FIG. 8), the liquid aluminum is filled from the bottom to the top, and there was no air entrapment. Combined defect parameters and probabilistic defect parameters were used to predict the position of micro porosity. The combined defect parameters are as follows.

\[ P = K(A^a B^b C^c)^d \]  

where, \( K=1, a=1, b=-0.5, c=0 \), \( A \) is the temperature gradient, \( B \) is the cooling rate. The probability distribution of combined defects was obtained as shown in 9. It can be seen that the micro porosity is mainly located at the position of the circular hole thimble, the connection of the casting and the ladle, and the thick wall in the lower left corner. The results are consistent with the prediction of the previous cloud picture, which is due to the porosity of the casting caused by non-sequential solidification[10].
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The wall thickness of the round hole and the lower right corner is larger, and the aluminum in this position can not complete the heat dissipation in time. The joint of the casting and slag ladle is located at a sharp Angle, and the contact area with the mold is very small. Too small contact area will reduce the heat dissipation rate, resulting in slower solidification rate than the surrounding thin-walled position. When the surrounding liquid aluminum solidifies, there is no flowing liquid aluminum available for feeding. Shrinkage cavities are formed.

5. Squeeze casting test
The vertical 350T extrusion casting machine was used for squeeze casting test test. There are two kinds of problems in the test. First, the tonnage of the extrusion casting machine is insufficient. When the extrusion pressure is too large, the clamping force cannot match it, resulting that the pressure release occurs in the pressurization stage, leading to insufficient pouring and shrinkage cavity and porosity, as is shown in figure 10. Second, the cooling system is not perfect. The hysteresis solidification in some thick wall positions leads to shrinkage porosity, as is shown in figure 11.

6. Conclusions
(1) During the period from the beginning of solidification to the completion of filling, the filling rate increases the contact area between the liquid aluminum and the mold. It also increases the heat transfer area and the heat transfer rate, leading to the increasing of solidification rate increases with the increase of filling rate. In the solidification process, because the heat transfer rate at the same position decreases gradually and the overall heat transfer decreases with time, leading to the solidification rate decreases with time.

(2) In the extrusion casting molding process of A356 communication baseplate, the liquid aluminum is filled from the bottom to the top, and there was no air entrapment. Therefore, there is a high probability that pores will not appear after casting molding. During the solidification process, the wall thickness of some positions is too large and the position is at a sharp Angle, which leads to non-sequential solidification and shrinkage cavity and porosity. The simulation results and pressure test results also confirm this.

Acknowledgements
The authors gratefully acknowledge financial support from the Guangdong Science and Technology
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