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NUMERICAL SIMULATION AND OPTIMIZATION OF DIE CASTING FOR AUTOMOTIVE SHIFT TOWER COVER

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The structural characteristics of the car shift tower cover were analyzed, and the pouring system and overflow system were designed according to the empirical formula.The numerical simulation based on Anycasting software shows that the metal liquid flow and solidification rate of the initial process are not smooth.According to the simulation results, the shape of the runner and the number of the gate were modified, and the point cold water pipe was set at the position where the defects might occur to optimize the process.The numerical simulation of the optimized process scheme shows that the filling process is stable and there is no liquid spatter, and good quality die casting is obtained through actual production.

Key words: aluminium alloy,numerical simulation, die casting, process optimization,X-ray inspection

INTRODUCTION

Pressure casting is to fill the molten metal liquid into the die casting cavity under high pressure and high speed. The die casting produced by this process has high dimensional accuracy, low surface roughness value, and can produce parts with complex shapes and thin walls[1]. With the development of automobile industry, automobile lightweight has received more attention.

Because of its low density and high strength, aluminum alloy has become one of the most widely used materials for automobile parts. Research shows that replacing steel with aluminum alloy can reduce the body weight by 30~40 %[2~3].

In this paper, Anycasting mold flow analysis software was adopted to conduct numerical simulation, analyze the flow rule of metal liquid in the mold filling and solidification process of the shift tower cover,and optimize the process, so as to obtain qualified castings through actual production.

STRUCTURAL ANALYSIS OF DIE CASTING

Figure 1 shows the 3D model of the shift tower cover.The casting profile size is 229,5 mm×138,5 mm×95,5 mm, the volume is 483,9 cm^3, the weight is 1306,4 g, the average wall thickness is 5,68 mm, the maximum wall thickness is 20,15 mm, and the diameter of the maximum hole is 5 mm. There are many rib plates and boss on the casting surface, and the structure is complex.

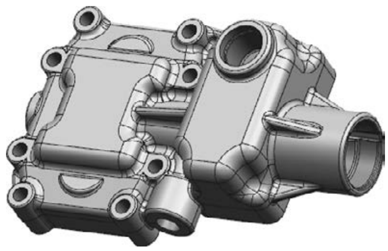

Figure 1 3D drawing of die casting

DIE CASTING PROCESS DESIGN

Parting surface selection should be as simple as possible, easy to process, reasonable parting surface structure can ensure the dimensional accuracy of die casting.As shown in Figure 2, the parting surface of the shift tower cover is selected at the largest section of the outline size of the die casting. Meanwhile, the parting surface coincides with the center line of the side pin hole, which is convenient for the setting of the core pulling mechanism.

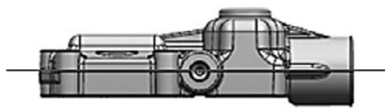

Figure 2 Schematic diagram of the parting face

Gating system design mainly includes the design of sprue, runner and gate. Reasonable gating system can regulate the pressure, speed and temperature, and play an important role in the quality of die casting.According to the structural characteristics of the shift tower cover, the way of side pouring is adopted. The sectional area of the gate can be determined by Formula (1):

$$A_g = \frac{G}{\rho v_g t} \tag{1}$$

X.X. Lu, X.D. Shu, C.Q. Dong, B.S. Sun, G.H. Li, Ningbo University, School of Mechanical Engineering and Mechanics, Ningbo, China; X.D. Shu (Email: shuxuedao @nbu.edu.cn)

Where, A_g is the sectional area of the gate, and G is the mass of the metal liquid passing through the gate, which is 1509 g,ρ is the density of metal liquid, 2,7 g/ cm^3;v_g is the speed of metal liquid passing through the gate, and 22 m/s is taken,t is the filling time, 0,1 s. Through calculation, the sectional area A_r of the gate is 254,04 mm^2, and the thickness of the gate is 3 mm.The sectional area of the transition between runner and sprue can be determined by Formula (2) :

$$A_r = (2\sim4)\ A_g \quad (2)$$

In the formula, A_r is the sectional area of the runner and A_r =2,5A_g=635,1 mm^2. The depth of the runner is determined by Formula (3) :

$$D = (5\sim8)T \quad (3)$$

Where T is the thickness of the gate, through calculation D = 5,5 T = 16,5 mm

According to the geometric characteristics of castings, the pouring system and overflow system as shown in Figure 3 are designed.Car shift tower cover appearance is relatively flat, suitable for the use of side pouring, the use of double gate scheme.A total of 14 overflow grooves are designed and distributed around castings to collect cold contaminated metal liquid. The overflow groove controls the flow state of metal liquid together with the pouring system, which is of great significance for the smooth filling of metal liquid.

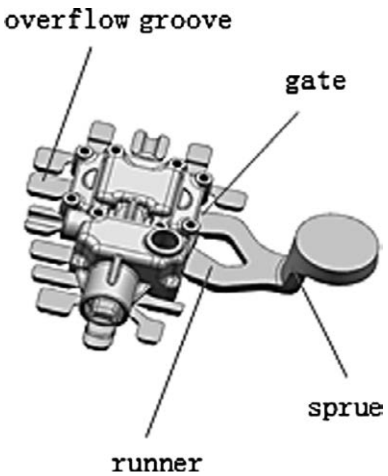

Figure 3 3D modeling drawing of the gating system

INITIAL PROCESS PLAN SIMULATION

The die casting with casting system was imported into Anycasting software in stl format. The die casting material was $AlSi_9Cu_3$ alloy and the die material was H-13.The die casting process parameters were set as follows: pouring temperature 660 °C, slow injection speed 0,15 m/s, fast injection speed 4 m/s, and die preheating temperature 220 °C.

Figure 4 shows the filling sequence simulation results of shift tower cover.At the time t = 0,2508 s, the metal liquid filled the sprue and the runner and began to enter the casting cavity from the gate.When t = 0,2535 s, the liquid metal of the two runner converges in the middle of the cavity and begins to flow to both sides. When t = 0,2730 s, the metal liquid fills the left core-pulling hole. At this time, part of the coiling area in the cavity will entrap gas.When t = 0,27850 s, the filling of casting cavity and overflow groove is completed.Liquid spatter exists in the whole filling process, and sequential filling cannot be completed.

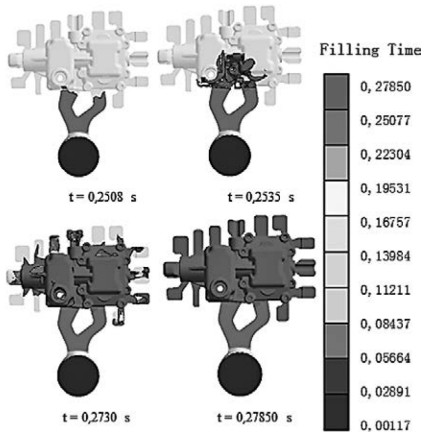

Figure 4 Filling sequence simulation results

Figure 5 shows the simulation results of solidification sequence.It can be seen from the cloud image that the overall solidification time of the die casting is about 5 s, and the solidification time of the central two pin holes is later than that of the other areas. This is because the structure here is complex, the wall thickness is thick, and the heat accumulation leads to insufficient cooling. It is predicted that shrinkage and porosity defects will occur here.

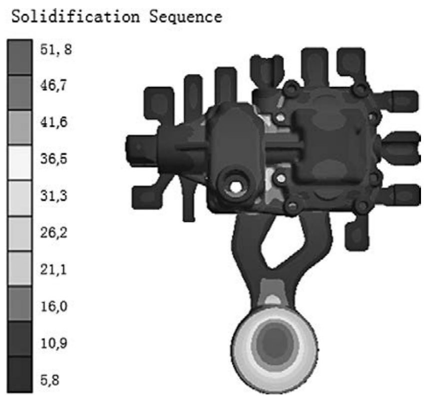

Figure 5 Simulation results of solidification sequence

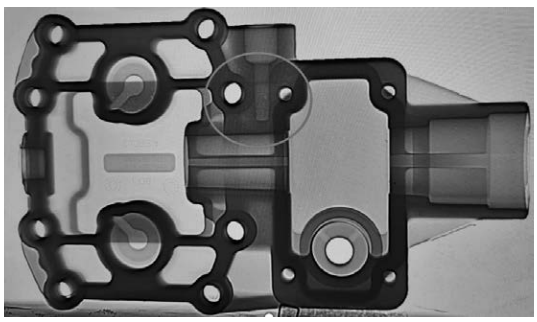

Figure 6 Results of X-ray inspection

According to the simulation results, die casting trial production was carried out, and the non-destructive testing results of the produced die casting X were shown in Figure 6.It can be seen that there are shrinkage cavity defects in the position with thicker wall thickness, which is consistent with the numerical simulation results.

DIE CASTING PROCESS OPTIMIZATION

According to the simulation results of the initial process, in order to solve the problem of complete filling, unstable filling and liquid spatter in the simulation results, the rationality of the runner and the filling process were comprehensively analyzed, and the scheme of changing the shape of the runner and the number of the gate was adopted.The left side was widened by 3 mm to reduce the filling speed of the gate. The right gate was divided into two, and the runner was extended to the right side of the cavity, with a total of five gates.In order to solve the insufficient cooling phenomenon caused by uneven wall thickness during the cooling process, the point cooling process is adopted to adjust the cooling water to the ideal pressure state, so that the flow rate is stable at 5 L/min.The three-dimensional diagram of the optimized pouring system is shown in Figure 7.

Figure 8 shows the simulation results of temperature field after process optimization.When t = 0,2432 s, the metal liquid began to enter the cavity from the gate at the front of the cavity.When t = 0,2486 s, the metal liquid reaches the two sprue on the right.When t = 0,2684 s, the cavity center was basically filled, and the left core hole was filled.When t = 0,2701 s, the metal liquid filling was completed, and there was no liquid spatter in the whole process.

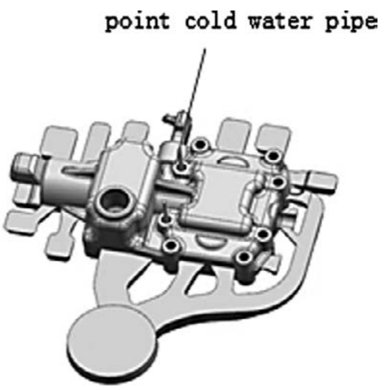

Figure 7 The optimized pouring system

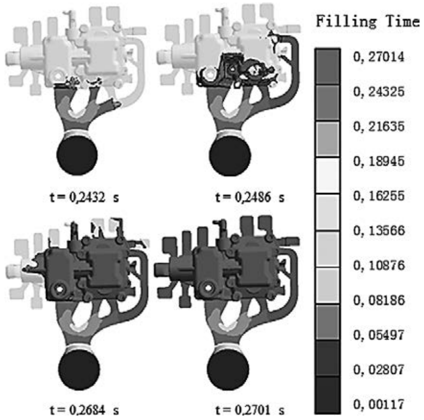

Figure 8 Simulation results of filling sequence after optimization

PRODUCTION VERIFICATION

According to the optimized process, the production was verified, and the surface of the actual production die casting was smooth.The X-Ray nondestructive testing of the die casting is shown in Figure 9. It can be seen that the internal quality of the product is good, without obvious shrinkage holes and cracks.

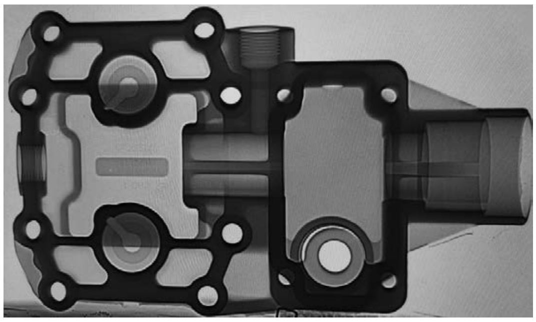

Figure 9 Results of X-ray inspection

CONCLUSION

The die casting process was designed by analyzing the structure of the aluminum alloy shift tower cover and numerical simulation was carried out. According to the numerical simulation results, the original process was improved.The optimized scheme was used to verify the actual production, and the quality of the die casting was qualified.

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Note: The responsible translator for English language is X. X. Lu, Ningbo, China