

Comparative analysis of HPDC process of an auto part with ProCAST and FLOW-3D

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Abstract The high pressure die casting (HPDC) process of an ADC12 aluminum alloy auto part is researched by the software ProCAST and FLOW-3D, respectively. The possible HPDC defects of the auto part are analyzed. The difference of the filling process with the same technological parameter is studied. Compared with the simulation result of ProCAST, FLOW-3D software simulation result is closer to the die casting of the actual production.

1 Introduction

Since die-casting aluminum alloy has been commercialized, it has gotten a rapid progress especially with the development of the car industry and the invention of the cold chamber die casting machines, and has been widely used in aerospace, transportation, light industry, building materials industry, etc. At the same time, the reliability of the castings is demanded more rigor than before. Pressure die-casting condition selection mainly relies on the experience and expertise of individuals working in production industries. In China, the level of the die-casting mould standardization and specialization is relatively low. In actual production process, the trial and error method was used to design and improve gating system by technician. However, this kind of method is high cost, long cycle and may have many casting defects such as bubble models, flow marks and cold shuts. Process simulation software is common in modern industry. Numerical simulation technology can be used to observe the change of flow field and temperature field during the liquid metal filling and solidification process, and it can also be used to analyze various defects which the casting may have under the HPDC progress. It can heighten productivity and make more economical benefits for enterprise. Therefore, it is favorable to ensure the quality of take measures before pouring and can make more economical benefits [1,2].

There are various of professional commercial software being used in die casting at present, and they are used in different areas. In China, there are many applied widely software, such as FLOW-3D, ProCAST, MAGMA and so on. In most cases, they help decision making, where industrial expertise is not enough or the process calibration procedure takes longer than manufacturing process can afford. In this article, two kinds of software, ProCAST and FLOW-3D, are adopted to simulate the HPDC process of the ADC12 aluminum alloy auto part firstly. ProCAST and FLOW-3D are based on different algorithm. The process of simulation may stress different points. Then the filling and the solidification process is analyzed, and it is the main basis of judging the veracity of simulation. Bubble models and shrinkage cavity and shrinkage porosity defects are observed. At last, combining the actual part, observe the accuracy of the simulated results are got.

2 Analysis of the study

2.1 3D modeling

The three-dimensional geometry model of the ADC12 aluminium alloy auto part is shown in Fig.1. The casting belongs to rotary part, and the structure is complex. The net weight of the casting is 0.45 kg. In addition, the biggest diameter is about 68 mm, and average wall thickness is about 3.2 mm. Based on the structure of the casting and the design points of the HPDC gating system, the gating system and the row overflow system of the casting are designed and shown in Fig.2.

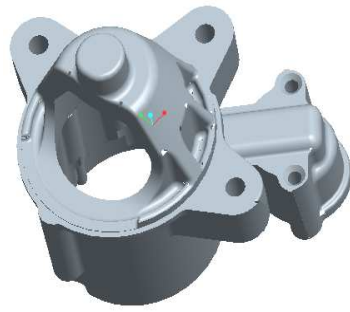


Fig.1 CAD geometry



Fig.2 Gating system

Die-casting material is aluminum alloy ADC12. Its physical properties are shown in Table 1. The physical properties of die material H13 are shown in Table 2[3].

Table 1. Physical properties of ADC12 alloy

Density/ ($\text{g}\cdot\text{cm}^{-3}$)	Liquidu/ $^{\circ}\text{C}$	Solidus/ $^{\circ}\text{C}$	Thermal conductivity $/(\text{W}\cdot\text{m}^{-1}\cdot\text{K}^{-1})$	Specific heat/ $(\text{kJ}\cdot\text{kg}^{-1}\cdot\text{K}^{-1})$	Thermal expansion coefficient/ (10^{-6}K^{-1})	Viscosity / $(\text{Pa}\cdot\text{s})$
2.74	580	515	96.2	0.965	21.0	0.002

Table 2. Physical properties of mould material H13

Density/ ($\text{g}\cdot\text{cm}^{-3}$)	Liquidu/ $^{\circ}\text{C}$	Solidus/ $^{\circ}\text{C}$	Thermal conductivity/ $(\text{W}\cdot\text{m}^{-1}\cdot\text{K}^{-1})$	Specific heat/ $(\text{kJ}\cdot\text{kg}^{-1}\cdot\text{K}^{-1})$
7.367	1491	1331	28.0	0.460

2.2 Set die-casting parameters

At first, it is necessary to ascertain the reasonable die casting time and ingate velocity according to the casting quality, wall thickness and die-casting machine parameters. The ingate velocity is taken as 40 m/s, then the shot velocity is got according to the flow continuum equation. Combined with the casting to select the pouring temperature and mould preheating temperature. The parameters are shown in Table 3.

Table 3. The major parameters of die casting

Pouring temperature/ $^{\circ}\text{C}$	Mould initial temperature/ $^{\circ}\text{C}$	Shot velocity/m/s	Die boundary condition
680	200	2.4	Air cooling

3 Simulations and analysis of two different software

3.1 simulation and analysis base on ProCAST software

ProCAST software which is based on finite element method (FEM) and comprehensive solution, can track the filling of the castings and the solidification process. At the same time, the process of liquid metal into the cavity and the temperature changes can be observed visually. ProCAST software also can be used to predict some defects such as bubble models, shrinkage cavity and shrinkage porosity and observe casting microstructure[4,5].

The 3D geometry model of the casting is output with STP format, and can be preprocessed in GeoMESH firstly, then is reintroduced into ProCAST software. The model can be meshed to surface mesh and volume mesh by MeshCAST system. After meshing, it has 188107 nodal points and 1010920 tetrahedron elements. The result of mesh is shown in Fig.3. In PreCAST module, we set the heat transfer coefficient of interface $h=5000$, input the die-casting parameters in table 3, and select HPDC mode.

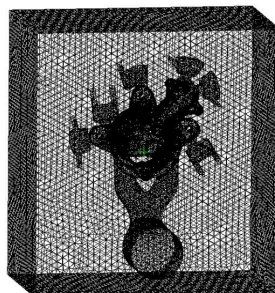


Fig.3 Finite element mesh

The distribution of temperature field is depicted in Fig.4 by the result of ProCAST software simulation.

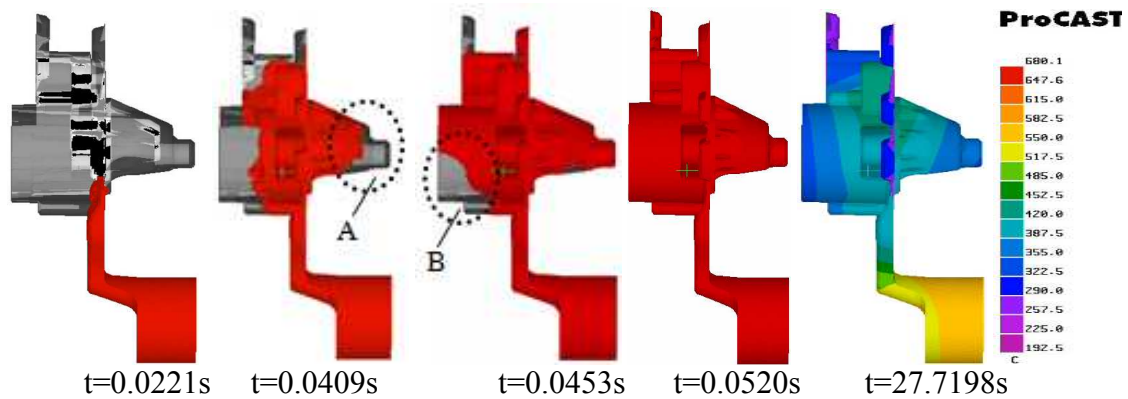


Fig.4 Distribution of temperature field

The time of filling process is 0.052s as the simulation results shown, and more importantly, the liquid metal fill the entire cavity without misrun phenomenon. According to the results shown in fig.4, the liquid metal started filling mould cavity at $t=0.0221s$. Under the high speed and high pressure, the velocity of the liquid is along a straight line direction. Two strands of liquid metal joined together soon. At $t=0.0409s$ and $t=0.0453s$, it is clearly to see that serious bubble models occurred at the area A and B, caused the gas could not be exhausted freely and formed obvious shrinkage cavity and shrinkage porosity. In theory, the bubble models is one of the defects which can not be ignored and the biggish pore could influence the leakproofness of the die-casting parts. Distribution of shrinkage cavity and shrinkage porosity defects is shown in Fig.5. There are obviously shrinkage cavity and shrinkage porosity defects inside the casting, and the total volume is about $0.253cm^3$. Therefore, the simulation results of ProCAST software predict that the actual die-casting part will have obvious porosity defect.

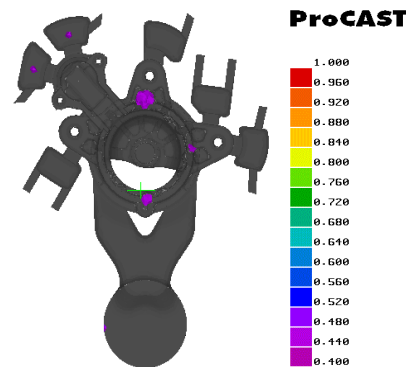


Fig.5 Distribution of shrinkage cavity and shrinkage porosity defects

3.2 simulation and analysis base on FLOW-3D software

FLOW-3D software using the finite difference method (FDM) to simulate calculation, has more advanced liquid-level tracking function that can accurately simulate the free surface liquid flow according to the characteristics of HPDC. It can track the surface defect, find the shrinkage cavity and shrinkage porosity in the solidification process and be also able to forecast thermal stress and cavitation phenomenon [6,7].

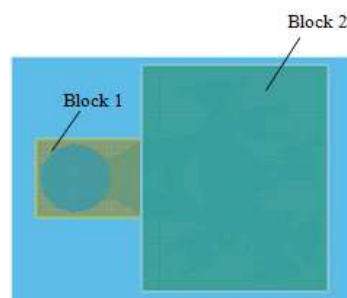


Fig.6 Finite difference mesh

The three-dimensional model can be opened in the FLOW-3D with STL format and be divided into two grid blocks according to the structure of the die casting. The mesh result is shown in Fig.6. In simulation, the parameters of bubble models, bubble and phase change, gravity, defect tracking, heat transfer, viscosity and turbulence model should be chosen. The entrance boundary condition is set to specified velocity. The adjacent grid blocks border is set to I boundary and the remaining boundaries are set to wall.

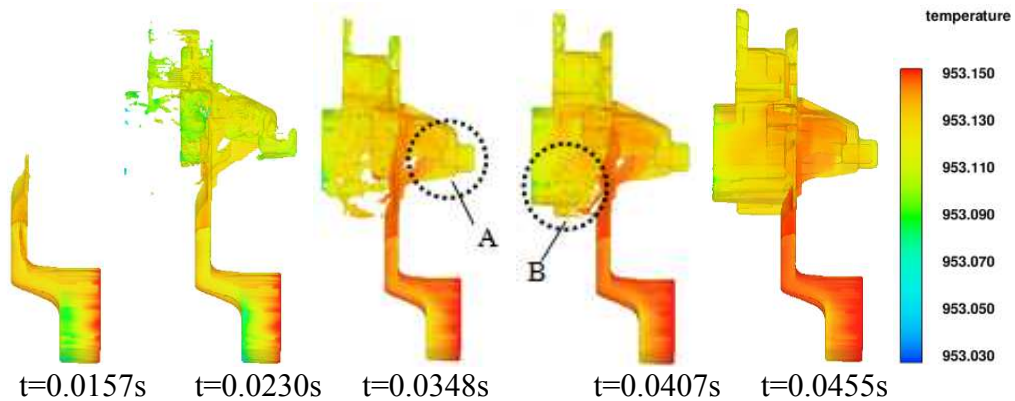


Fig.7 Distribution of temperature field

Fig.7 shows the liquid metal filling states which are simulated by FLOW-3D software in different phase. Obviously, the splash occurred during the filling process when the liquid metal is under high speed and high pressure. In the area A, it can be seen that ,at $t=0.0348s$, the liquid metal rush to the top along the cavity inner wall under high speed and high pressure. That can push the air out from the area A easily, and avoid the bubble models defect. In the area B, liquid metal flows into bottom firstly, and fills full of the mould gradually. The filling process is smooth. There is not bubble models in die casting. The function of overflow in the process which is full of overflow after being full of the production part in the mould can be showed as well. The total filling time is 0.0455s. Fig.8 shows the simulation result of die casting surface defect tracking. There is not obvious surface defect here.

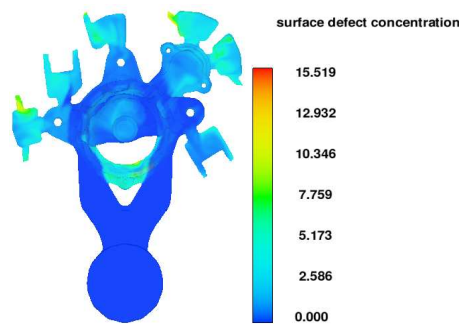


Fig.8 Simulation result of surface defect tracking

3.3 Comparison

It can be seen that the two simulation results are different as the die casting has relatively complex structure. The most obvious difference occurs in area A and area B. Such as the result got by ProCAST software, there would be obvious bubble models in both A and B area, and the defect would be reflected consequentially in the actual die castings. However, because of the great performance of overflow, the path of exhaust is changed in FLOW-3D software. There nearly is not bubble models at A and B in the simulation process, so that the actual die casting will be good. Compare with real production, the FLOW-3D software simulation is more accurate about this kind of die casting (as shown in Fig.9).

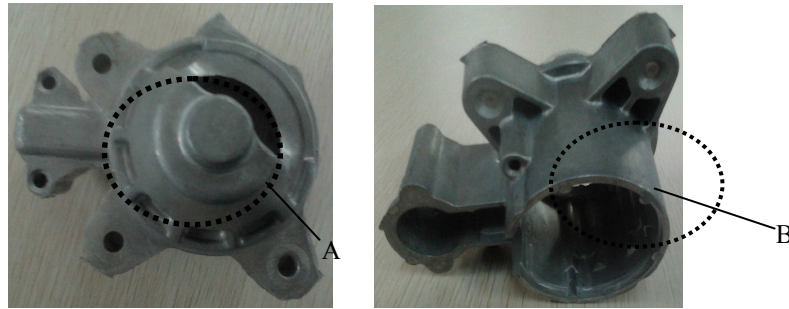


Fig.9 Practical casting

4. Conclusions

The work presented in this paper get some conclusions below:

1. Compare with the simulation result of the two software, the die casting simulation result of is more accurate with FLOW-3D for this kind of ADC12 aluminium alloy auto parts. FLOW-3D software could simulate the filling process effectively to ensure the quality of die castings.

2. Different CAE simulation software, due to differences in the algorithm and target, may lead to the simulate result not entirely consistent. The choice of the simulation software is according to own needs in practical use and the target that making results as accurately as possible.

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