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Research on the Mold Design of Motor Housing using Die Casting Process

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다이캐스팅에 의한 모터 하우징의 금형설계에 관한 연구

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ABSTRACT

In this paper, research on the mold design of motor housing produced by the HPDC process was conducted using computer simulations and experiments. Recently, automobile parts have been required to be light and have high strength. The die casting process was used to manufacture automotive motor housings. In the die casting process, the control of casting defects is very important. However, it has usually depended on the experience of the foundry engineer. For the analysis of the manufacturing process of motor housing, the finite element method is applied. Through the simulations using commercial software, the filling pattern and product defects could be confirmed. The analysis results obtained from the filling behavior of the casting process agreed with the experimental results. The computer simulation results of filling behavior were reflected in the optimal mold design of motor housing.

Key Words : Motor Housing(모터 하우징), Die Casting(다이캐스팅), Mold Design(금형설계), Filling Behavior (충전거동), HPDC(고압주조)

1. Introduction

In recent years, the requirement of light weight and high performance automobiles has been increased. The weight of the automobile is very important from the viewpoint of fuel consumption and traveling performance.

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Consequently, lightweight material such as aluminum, magnesium, and titanium comes to be more important. Optimal design techniques, material techniques, process design for parts and mold design techniques need to be developed for light weight automobile parts. Die casting, melted metal poured into the die cavity in condition of high speed and high pressure, is one of the best methods. Generally the die casting is considered as an appropriate forming process to manufacture the products in which complex shapes or precision surfaces are desired[1-4].

The die casting process is divided into the filling process and the solidification process. The die casting process has a series of complex temperature changes. Incidentally, the research by experiment must have limits because it is proceeded in the die cavity which is shut. But the research which predicts and prevents the defects of products and dies due to the shortage of the precision manufacturing and existing casting technique was possible through the computational analysis[5-6]. Therefore, in this research the filling process was predicted by computer simulation and its results were reflected in the mold design and the process design as a previous step for the development of the precision mold of an automotive motor housing.

2. Theory for Die Casting Simulation

2.1 Analysis Process

Fig. 1 shows the flow chart for die casting analysis using commercial S/W MAGMAsoft™[9].

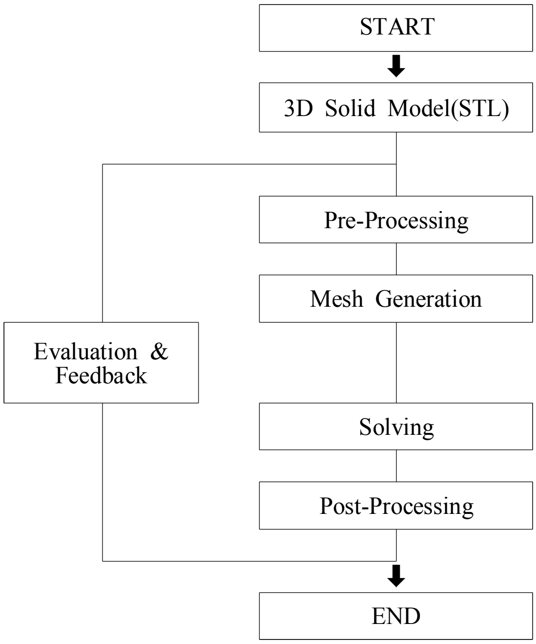

Fig. 1 Flow chart for die casting analysis

2.2 Governing equation

The flow of fluid and the heat transfer phenomenon in the governing equation are represented by the mass, momentum, and the rule of energy conservation. The governing equations used for the flow and the solidification of three dimensional incompressible flow are expressed by Eqs.(1)-(4), continuity equation(1) which states that the mass within a system remains constant with time, Navier-Stokes equation(2) which states that the motion for a real fluid, energy equation(3) which usually referred to as the first law of thermodynamics, and volume of fluid(4). Equation(5) shows the finite differential equation for the filling analysis.

2.2.1 Continuity equation

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}+\frac{\partial w}{\partial z}=0 \tag{1}$$

2.2.2 Navier-stokes equation

$$\begin{aligned}
&\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}+w\frac{\partial u}{\partial z} \\
&=-\frac{1}{\rho}\frac{\partial p}{\partial x}+\nu\overrightarrow{\nabla}^2 u+g_x \\
&\frac{\partial v}{\partial t}+u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}+w\frac{\partial v}{\partial z} \\
&=-\frac{1}{\rho}\frac{\partial p}{\partial y}+\nu\overrightarrow{\nabla}^2 v+g_y \\
&\frac{\partial w}{\partial t}+u\frac{\partial w}{\partial x}+v\frac{\partial w}{\partial y}+w\frac{\partial w}{\partial z} \\
&=-\frac{1}{\rho}\frac{\partial p}{\partial z}+\nu\overrightarrow{\nabla}^2 w+g_z
\end{aligned} \tag{2}$$

2.2.3 Energy equation

$$\rho c\frac{\partial T}{\partial t}=\frac{\partial}{\partial x}(K\frac{\partial T}{\partial x})+\frac{\partial}{\partial y}(K\frac{\partial T}{\partial y})+\frac{\partial}{\partial z}(K\frac{\partial T}{\partial z}) \tag{3}$$

2.2.4 Fluid volume equation

$$\frac{\partial F}{\partial t} = u\frac{\partial F}{\partial x} + v\frac{\partial F}{\partial y} + w\frac{\partial F}{\partial z} \qquad (4)$$

2.2.5 Governing differential equation

$$\frac{\partial}{\partial t}(\rho\phi) + \frac{\partial}{\partial x_j}(\rho u_j \phi) = \frac{\partial}{\partial x_j}(\Gamma_\phi \frac{\partial \phi}{\partial x_j}) + S_\phi \qquad (5)$$

where u, v, w are the direction velocity, ν is the kinematic viscosity, ρ is the fluid viscosity, g is the gravity acceleration, p is the pressure, and F is the volume rate of fluid.

3. Die Casting Process Analysis

3.1 Modeling

Fig. 2 shows the shape model of a motor housing and is expressed using the Unigraphics as the STL file format for recognition in S/W MAGMAsoft™. In the figure A is inlet and has 41181.65㎣ in volume, B is gate and has 179335.9㎣ in volume, C is ingate and has 300.7931㎣, and D is cast and has 105311.3㎣, E and F are the overflow 1 and 2 and have 171.49㎣, 3887.85㎣ in volume respectively.

The motor housing shape model needs the dimensional accuracy of the average thickness 2.5～3.5㎜ within the maximum circularity 0.1 based on an inner diameter Φ100㎜.

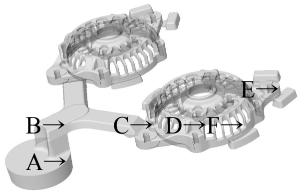

Fig. 2 3D Solid model of motor housing

Table 1 Physical properties of ADC12 alloy

Properties	Unit	Value
Initial Temp.	℃	660
Latent Heat	kJ/kg	514.2
T_{liq}(liquidus Temp.)	℃	614
T_{sol}(solidus Temp.)	℃	555

Table 2 Chemical composition of ADC12 alloy

Cu	Si	Mg	Zn	Fe	Mn	Ni	Sn	Al
3.1	11.5	0.3	0.8	0.9	0.4	0.3	0.2	R

3.2 Input condition for analysis

The motor housing is made using ADC12 known as aluminum die casting material and the physical properties and chemical composition for the analysis are expressed in Tables 1 and 2. The die is made using STD61 known as die steel and water is used in cooling the channel. The melting metal, after the mold is closed, is poured and we add pressure after the filling of melting metal for the strength of casting and the removal of contraction hole during the solidification process. The mold is opened and products are ejected after the completion of the cast solidification, and the mold is shut again after spraying the mold surface for next cycle.

3.3 Structure of the motor housing mold

Fig. 3 shows the basic structure of the motor housing mold. The existing casting technique is problematic for the production of the motor housing products in that it cannot guarantee accuracy within the maximum circularity 0.1 based on an inner diameter Φ100㎜. For this reason, special purpose machines or general purpose lathes are required for machining motor housings. To solve the problem we designed the mold after modifying the machine structure to make possible the ejecting in a fixed part.

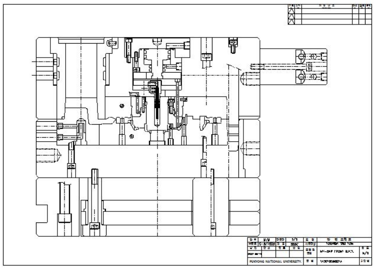

Fig. 3 Assembly drawing of motor housing mold

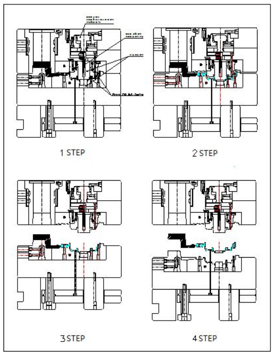

Fig. 4 Sequential steps of die casting process

Fig. 4 expresses the manufacturing process of the motor housing step by step. The overall filling behavior of molten metal is shown in Fig. 5.

4. Results and Discussion

4.1 Filling analysis

Because the motor housing has uniform thickness of 2.5mm to 3.5mm, molten metal fills as a constant filling pattern was considered in the initial form design for filling behavior analysis. Fig. 6 shows a good filling behavior where the temperature doesn't drop below the liquidus(T_{liq}=614℃).

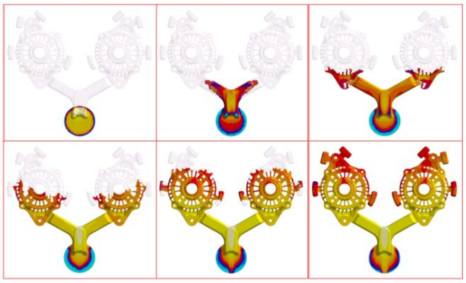

Fig. 5 Overall filling behavior of molten metal

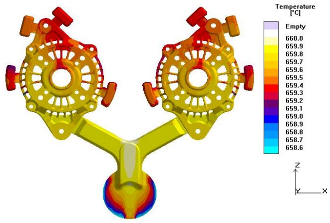

Fig. 6 Temp. distribution of motor housing

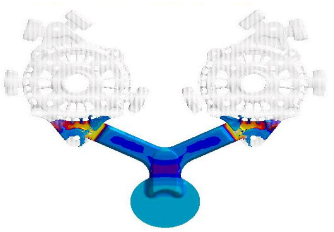

Fig. 7 Filling behavior of motor housing

Fig. 7 and Fig. 8 present the time about 50% of molten metal fills housing mold after the ingate is filled. The melting head collides near mark A, ingate, and it forms a vortex, and because of this, defects occurred in the part. This is considered to be because the flow of molten metal rotates at part A. The injection pressure at the ingate, as a result, is reduced and the cold shut by temperature drop and air porosity are predicted. To avoid this, we moved the parting line of the mold and added the overflow at the A part. By modifying the mold based on the analysis results, we could get better casting product.

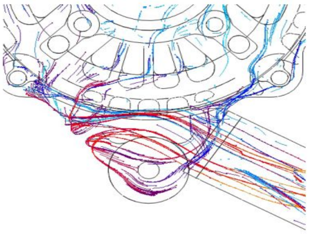

Fig. 8 Enlarged diagram of “A” in Fig. 6

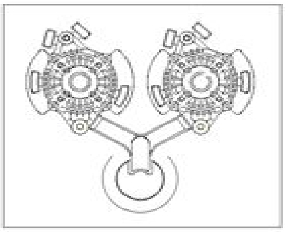

Fig. 9 Modified design of motor housing mold

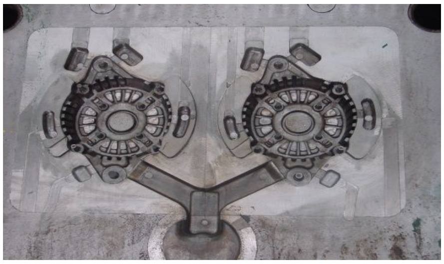

Fig. 10 Photo of motor housing mold

4.2 Final mold design

Fig. 9 shows the mold modified with the overflow to remove the vortex of part A in Fig. 6, in accordance with the simulation results of the first design. Fig. 10 shows the mold made by the second design. Fig. 11 shows the product formed by the second design. The filling behavior agreed with the simulation results and additional machining did not need after ejecting.

5. Conclusion

In this study, the filling pattern and product defects were confirmed, and verified them using the commercial software, MAGMAsoft for the optimal mold design of the motor housing. It is expected the effectiveness of a fixed quantity connected directly with it, will increase, such as the reduction of defects, quality enhancement, and a productivity increase due to this research results.

The conclusions of this research can be summarized as follows, the overall filling pattern expressed constant flow and the filling analysis results are agreed to the filling pattern of product, and then the defects prediction and the analysis of the product and the mold can be obtained using the computer simulation of the first mold design, finally the good casting product with appropriate filling pattern can be manufactured by the application of a new mold design mechanism for the maximum circularity 0.1 of product.

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