https://doi.org/10.21289/KSIC.2018.21.1.001

Design of Shock Absorber Housing Using Aluminum Vacuum Die Casting Technology

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〈Abstract〉

The purpose of this study is to develop a high-strength, high-toughness, thin-walled aluminum shock absorber housing product by applying a high vacuum die casting method to improve internal gas defect and formability. The analysis program dedicated for the casting was used because it was too costly and time-consuming to adopt the gating system design. The final casting plan was designed based on the flow pattern of the material filled into the mold and the result of air pressure and air pocket after the material was completely filled in the mold. Gaty shape was designed as a split type. The runner was designed to have the same shape as the initial inlet curve of the cavity, and the flow of the molten metal was prevented from turbulent flow. The most favorable results were obtained when the injection speed was V_2 = 4.0 m/s. Defects on pores were reduced by applying high vacuum level inside the mold.

Keywords : Vacuum Die Casting, Mold Design, Casting Simulation, Thin-walled part

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1. Introduction

Die casting is a process in which the molten metal is charged into the mold by a plunger operating at a high speed in an extremely short time, and the molten metal is charged in a turbulent state [1,2]. The gating system design part (including the sleeve, the runner, etc.) which was charged, and air and gas which were present in the part and were curled to become bubbles, existed inside the product. Techniques to improve this gas drag have long been studied. The solutions are meant to slow the filling of the molten metal to prevent the turbulence of the molten metal when filling the molten metal by providing a large sprue, to carry out the laminar flow filling die casting and the squeeze casting. In addition, the development of semi-molten and semi-solidification processes, which changes the molten state, is also a way to produce products with good internal quality. However, such low-speed charging tends to make it difficult to form thin and long products, which is one of the advantages of die casting. One of the measures to prevent the gas from being caught inside the die casting product is to exhaust the inside of the cavity with the help of vacuum pump or the like to reduce the amount of entrapment gas. This is called vacuum die casting and is effective in removing defects caused by gas curling [3].

Various methods of vacuum die casting have been developed and put into practical use. Such casting is divided into two types depending on the opening and closing methods of the vacuum valve. The gas free (GF) method is a method in which a valve is closed by inertial force of a molten metal, and the other is a method of closing a valve by a timer or position control, such as a shot-off pin method, which includes an MFT method and a vacuum method.

In the GF method, which uses the inertia of the molten metal, the air in the mold is opened to the atmosphere through the check valve. In this state, the molten plunger advances, and the vacuum valve is switched by switching the electronic valve. In general, the mold has a reduced pressure of 150 to 250 Torr in 0.2 to 0.3 seconds. At this point, the molten metal is filled in the mold at high-speed injection and the valve is driven by the inertia force of the molten metal at a velocity of 15 to 40 m/s, and closing and filling are completed. This method has a disadvantage in that the degree of vacuum is higher than that of the product manufactured by the general die casting method, but the problem of valve clogging occurs [2-4]. The purpose of this study is to develop a high-strength and high-strength thin-walled aluminum shock absorber housing product which can be applied to the running car body by increasing the internal gas defect and formability upon applying the vacuum die casting method described above.

2. Experimental

Figure 1 shows the housing shape for casting simulation. The shape of ingate is designed as a split type so that the shape of the ingate can match the shape of the cavity to make the flow of the molten metal smooth. In this part, ingate, which completely matches the initial cavity part, is designed to reduce the input area of the ingate so that the flow rate of the molten metal could be increased since a large input area of the ingate may cause decrease in the flow rate of the molten metal. In addition, when the ingate part was directly designed in the center part, too fast inflow at the center and the backward flow of the molten metal through the ingate of both sides were observed. Therefore, the ingate was designed to be symmetrical on both sides in the center part design. The runner part was designed to have the same shape as the initial inlet part of the cavity so that the flow of the molten metal can be prevented

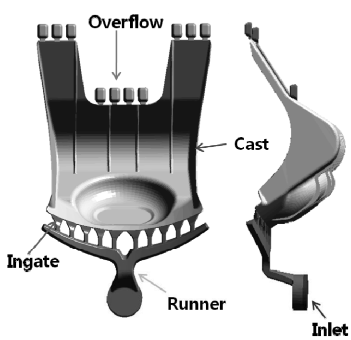


Fig. 1 Design of gate system for Shock Absorber Housing

and molten metal can flow smoothly. Furthermore, an overflow was designed in the final gas outlet by investigating the flow pattern of the melt under the shape of ingate and runner.

In order to investigate the filling pattern and solidification pattern during the die casting process of the shock absorber housing, ADC12 aluminum alloy, which is widely used as a die casting material, was used to simulate casting analysis using MAGMAsoft. Table 1 shows the material data during simulation.

Table 1. Material data

Casting material	ADC12
Initial temperature of cast [℃]	700
Die material	SKD61
Initial temperature of die [℃]	200
Heat transfer coefficient between cast and die [K]	Temperature dependent
Heat transfer coefficient between die and die [K]	1,000
Feeding effectivity [%]	90

Table 2 shows the simulation conditions for casting analysis. The diameter of the plunger was set to 100 mm and the travel distance of the plunger was set to 600 mm. Table 3 shows the injection speed conditions for casting analysis. The analytical work was performed by varying the V_2, which has a direct effect on the molten metal velocity when passing through the ingate, from 2.5 to 4.0 m/s. The ingate feed rate of the molten metal is shown in Table 3.

Table 2. Simulation conditions

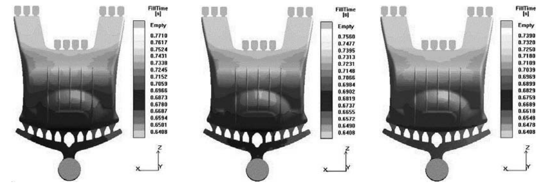
Volume of runner [cm^3]	709.35
Volume of cavity and overfolws[cm^3]	1350.46
Molten metal ladled [cm^3]	2127.91
Ingate area [cm^2]	10.95
Projected area [cm^2]	2291.89
Diameter of plunger [mm]	100
Active length of shot sleeve [mm]	600
Shot sleeve filling [%]	45.15
Area of the plunger [mm^2]	7853.98
Volume of shot sleeve [cm^3]	4712.34

Table 3. Shot velocity conditions

V_1[m/s]	V_2[m/s]	Velocity of Ingate[m/s]	Filling time [ms]
0.5	2.5	17.922	68.778
0.5	3.0	21.506	57.506
0.5	4.0	28.674	42.987

3. Results

Figure 2 shows the comparison of the fill time at each injection speed condition. The fill time was reduced by 0.0320 seconds to 0.739 sec in condition 1-3 with an injection speed of 4.0 m/s compared with condition 1-1 with an injection speed of 2.5 m/s. Since the housing (the product of this analysis) has a thickness of less than 3 mm, it is advantageous to shorten the temperature deviation of the molten metal after filling and to shorten the fill time to improve the fluidity.



V_2 = 2.5 m/s V_2 = 3.0 m/s V_2 = 4.0 m/s

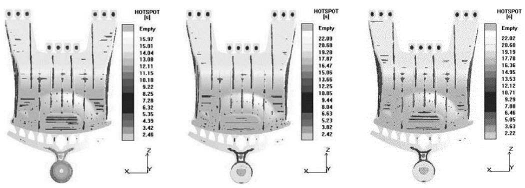
Fig. 2 Filling time in cavity by shot velocities

Figure 3 shows the comparison of the air pressure patterns at the time when the cavity filling of the molten metal is completed under each condition. In general, it is judged that the gas flows out through the air vent at the end of the overflow and a little gas remains in the overflow, which can be addressed by improving the shape of the air vent. It might be advantageous to reduce the filling time to make the flow of the molten metal smooth for a short time.

V_2 = 2.5 m/s V_2 = 3.0 m/s V_2 = 4.0 m/s

Fig. 3 Air pressure in cavity by shot velocities

Figure 4 is a comparison of hot spots in each condition, and a hot spot indicates a region where porosity has possibly appeared due to shrinkage and the like. It is predicted that there will not be a big problem because the distribution time of the overall hot spot is short in the cavity area.



V_2 = 2.5 m/s V_2 = 3.0 m/s V_2 = 4.0 m/s

Fig. 4 Hot spot in cavity by shot velocities

Figures 5 show the filling pattern of each condition. As the ingate shape changes and the fill rate changes according to the injection speed change, the filling is seen to be similar. However, since the number of the ingate shape was eight when the ingate is reduced on the side part of the ingate shape, the molten metal flows along the side surface and has many contact surfaces with the mold, the distance getting longer. It is expected that the temperature of the molten metal will be lowered, and the flow of the molten metal will be influenced in the future. In addition, the temperature gradient between the initially introduced molten metal and the molten metal which is introduced later becomes large, which can lead to forming a contraction line, ultimately may cause shrinkage during the solidification. Since the thickness of the product of the product is as thin as 3 mm and there are many contact interactions of the molten metal, it is considered that a good product can be obtained by increasing the injection speed and reducing the filling time for smooth filling. Based on the analysis results above, the temperature distribution and filling time of the molten metal were found to be the best in the filling aspect analysis with respect to the injection speed, while the hotspot, porosity, and the like were also good. In this respect, the injection speed is considered as the optimal condition V_2 = 4.0 m/s.

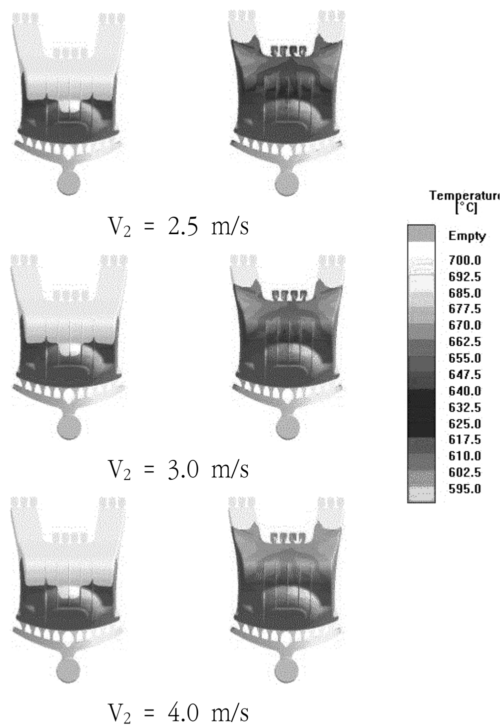


Fig. 5 Filling behavior in cavity by shot velocities

Figure 6 shows the mold temperature distribution from seven to ten cycles with the injection speed of V_2 = 4.0 m/s. After seven cycles, the overall balance became stabilized. However, in the absence of a cooling line, it is seen that the temperature at the interface with the cavity increases about 400 ° C after ten cycles. If the temperature of the mold is too high, there is a possibility of problems such as mold sticking. Therefore, it is considered that the installation of the cooling line is required, and after the 7th cycle when the cooling line is implemented, the temperature is expected to be balanced at a temperature lower than the mold temperature.

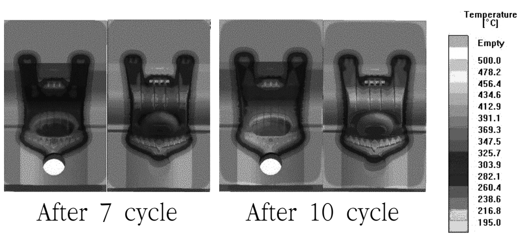


Fig. 6 Temperature in die by V_2 = 4.0 m/s

Figure 7 shows the filling pattern according to the change of the air vent shape. In order to examine the shape of the final gas exhaust, the air vent shape was set as a cavity and the analysis was performed. As a result, it became possible to more visually observe how the gas was discharged according to the change in shape of the air vent.

Figure 8 shows the air pressure pattern according to each air vent shape. The maximum air pressure was 2626 mbar in Vent 1 and 3766 mbar in Vent 2, but there was no overflow and air vent, and the product did not show high air pressure.

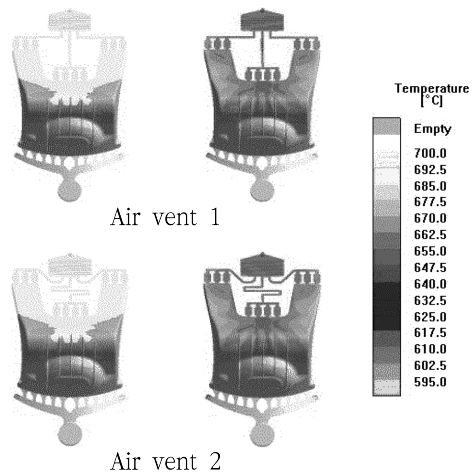


Fig. 7 Filling behavior in cavity according to shape of vent (V_2 = 4.0 m/s)

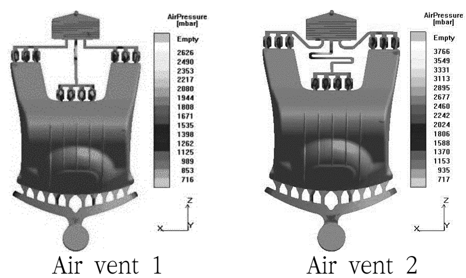
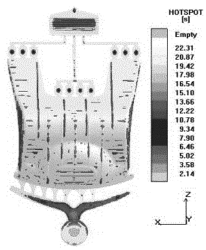
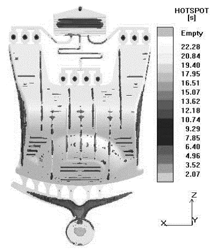


Fig. 8 Air pressure in cavity according to shape of vent (V_2 = 4.0 m/s)

Figure 9 shows the hot spot pattern according to each air vent shape. Vent 1 and Vent 2 show a maximum hot spot duration of 22.31 second and 22.28 second, respectively. However, the hot spot duration was long in the runner region and the inlet region, while the maximum hot spot duration was in the cavity region with 2.14 seconds. It is regarded that it will not be a problem in the production of products because the duration of hot spot of cavity is short,



Air vent 1



Air vent 2

Fig. 9 Hot spot in cavity according to shape of vent (V_2 = 4.0 m/s)

although it is desirable to install a cooling line based on porosity aspect considering product safety.

4. Conclusions

The results of the study on the design of the aluminum shock absorber housing mold of the vacuum die casting method using the casting dedicated software MAGMAsoft are as follows.

1. In order to manufacture a thin-walled housing by high vacuum die casting method, ingate shape was designed as a split type. The runner was designed to have the same shape as the initial inlet curve of the cavity, whereas the flow of the molten metal was prevented from turbulent flow. The defects were controlled by investigating the flow pattern of the molten metal and designing overflow in the final gas discharge area.

2. The charging and solidification analysis was performed for the manufacture of shock absorber housing by vacuum die casting process. The best results were obtained when the injection speed was V_2 = 4.0 m/s.

3. Although high vacuum was applied inside the mold to reduce defects in pores, it was found desirable to install a cooling line based on the porosity pattern for the safety of the product.

Acknowlegement

This work was supported by the National Research Foundation of Korea (NRF) Grant funded by the Korea Government (No.2017-017242).

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(Manuscript received November 24, 2017; revised December 27, 2017; accepted January 8, 2018.)