

Application of High Level Vacuum Die Casting for the Automotive Parts

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ABSTRACT

High level vacuum die casting (HLVD) allows the casting products heat treatable with aid of minimized gas contents (e.g. max 1cc/100gAl), therefore it shows improved mechanical properties. In order to decrease the gas content of castings, vacuum level in cavity should be maintained under 5kPa during mold filling process. For the quality control of mass production, the practical inspection system should be required in the production process. In this study, we have focused on finding the relationship between process parameters and gas porosity, one of the main casting defects. We developed thin walled bracket with HLVD process to achieve weight reduction as well as cost saving. In addition, improved mechanical properties and productivity were acquired.

INTRODUCTION

Recently, rising global warming issue and skyrocketing oil prices require improved fuel economy for the vehicles. According to new CO₂ regulation of EU in 2012 year, we have to achieve 130g/km for the goal by additional 20% improving of current fuel efficiency. Even though much effort has been conducted in various ways to achieve the objective, the weight reduction is still the key issue¹⁾.

Aluminum material has been utilized as one of the optimal materials to reduce car weight, traditionally. However, its intrinsic issues on cost of material and process have limited the expanding its application.

Recently, various type of vacuum die casting^{2)~5)} have been developed to clean process issues, in which still a lots of complexity has been involved.

In this investigation, engine mounting brackets of rear wheel driven near luxury car were developed to utilize enhanced vacuum die casting which was formed on carrying over current die casting, high pressure die casting, facilities with minimum additional modification in terms of sealing system and shot control with vacuum timing. That is, our main process development concept consists of three principle elements; 1) utilizing present conventional die casting machine, 2) developing a unique sealing system, 3) integrating the process control both vacuum and shot system.

MAIN SECTION

1. OPTIMIZATION OF HLVD

1-1 Optimization of equipment

In this research, HLVD equipment has been developed using conventional die casting machine instead of expensive high vacuum die casting machine. The mold and cavity including the sleeve, insert and base plate were sealed using silicon rubber for high level vacuum (see Fig. 1)

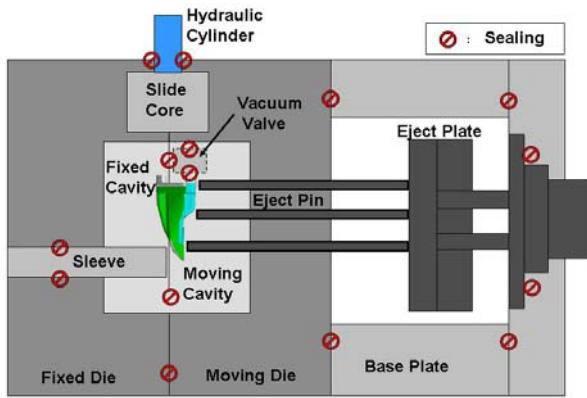


Fig. 1 Sealing of the HLVD die

For the high accuracy in cavity, vacuum level was measured directly in the cavity rather than in the vacuum valve. The vacuum starting time was accurately controlled by interface with plunger movement. Fig. 2 shows the degree of vacuum to cycle time. As a result, vacuum level in cavity could enable us to obtain 3~5kPa. Fig. 3 shows vacuum level to number of shots. (Average vacuum level is 4.27kPa)

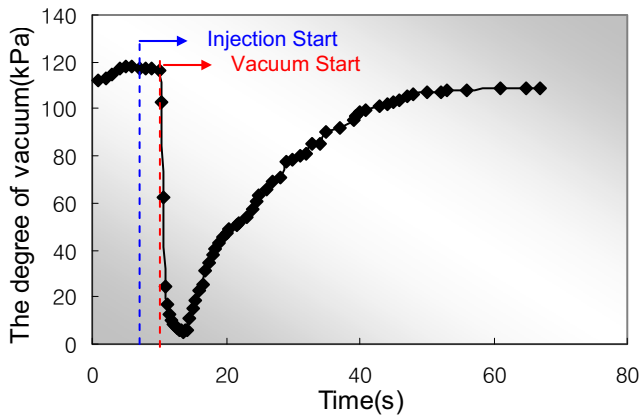


Fig. 2 The degree of vacuum to cycle time

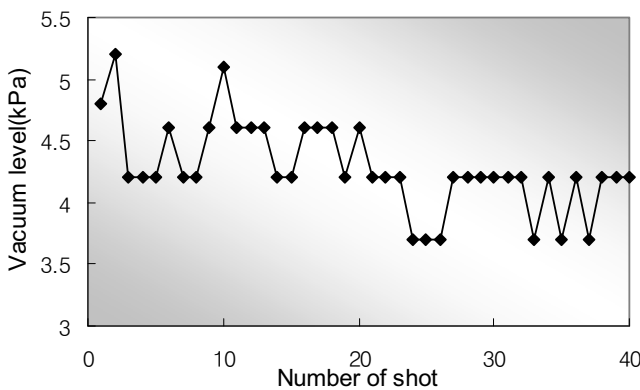


Fig. 3 Vacuum level in the cavity to number of shot

1-2 The gas porosity according to vacuum level

The quality of HLVD castings is significantly influenced greatly effected by vacuum level. Fig. 4 shows the shape

of brackets after T6 heat treatment. Test samples were prepared at 5kPa and 15kPa vacuum levels. 15kPa samples were examined more gas porosities trapped than those of 5kPa. Blisters are formed on the casting surface during T6 heat treatment. For the quantitative evaluation to correlate the vacuum level and gas porosity, we empirically investigated the volume changes on each vacuum level. The 365.0 alloy was selected for prototype of bracket, applied a 660-ton high pressure die casting machine with a developed vacuum devices and highly sophisticated sealing system. Casting conditions are as follows; molten metal temperature of 680℃, casting pressure of 90MPa, and max plunger speed of 3m/s. The vacuum level in cavity could be controlled using vacuum pump. The density was controlled by monitoring specific gravity (1) of the casting before and after heat treatment (T6). Specific gravity can be converted to density⁶⁾. Finally, volume expansion was calculated from density of casting. Fig. 5 shows volume expansion according to vacuum level. When vacuum level in cavity was under 5kPa, volume expansion, the rate of volume before and after heat treatment, was under 1%.



Fig. 4 The castings formed in different vacuum level

$$\text{Specific gravity} = \frac{W_1}{W_1 - (W_2 - W_3)} (s - s_a) + s_a \quad (1)$$

where,

W_1 = overall weight of sample, without wire, in air
 W_2 = overall weight of sample (and of cage) completely immersed and of the wire partially immersed in liquid (water), and
 W_3 = overall weight of totally immersed cage, and partially immersed wire.
 s = specific gravity of liquid (water),
 s_a = specific gravity of air (≈ 0.0012)

The gas porosity (cc/100gAl) was calculated from the theoretical density ρ_t (g/cm³), measured volume V after heat treatment, and measured mass M using equation (2). Instead of theoretical density, this study used the density of a specimen sample which is considered to have a low probability of resulting in blowholes. Fig. 6 shows the relationship of gas porosity and volume expansion. To maintain 1cc/100gAl gas porosity in the casting, the volume expansion must be limited to less than 1% and the vacuum level under 5kPa.