

# Computer Modeling & Simulation

## Calculation of the Die Cast Parameters of the Thin Wall Aluminum Die Cast Part

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Numerical analysis has become an integral part of process development in the die casting industry. With more economical and faster computers, and more efficient and accurate numerical algorithms, engineers can examine more design options and achieve better results in a much shorter time. Efforts to reduce energy consumption and weight, led to die cast parts becoming more complex. Thin wall castings in combination with new materials offer weight reduction with increased strength. These significantly increase the application fit in functional assemblies for pressure die castings.

Secondary operations, including welding, riveting, and heat treatment, have raised quality requirements for these highly engineered castings. In order to achieve the greater structural uniformity, high efficiency vacuum systems are routinely used on die cast dies. We have found that standard vacuum valves provided inadequate venting for the gas in our systems. Rather than adding second and third valves to our die systems, with the associated added operational complexity, we have showed that size of ventilation system could be tripled to meet vacuum requirements of the die cast process in a single valve. Through numerical analysis, utilizing general CFD capabilities of FLOW-3D, a standard vacuum block was modified to achieve a required size of the cross-sectional area of the ventilation channel. Subsequent production runs determined that the numerical calculations were well correlated with the results, generating the predicted improvements.

### Introduction

The automotive industry, from its early beginning to our times, starting with the invention of the steam powered engine in the middle 1600's, and then gasoline, electrical, and hydrogen fuel cells in early to a middle 1800's, searched for the most efficient way to power the engine. Power efficiency is a concern regardless of the type of the energy source used. Unable to develop completely new, revolutionary source of energy which would be as efficient and as cheap as existing ones, the automotive industry researchers tried to solve problem of energy conservation by using lighter, stronger materials. Over time many different materials were used with various degrees of success. In the last decade aluminum alloys have become clearly the material of choice for the structural components. Lightweight, relatively high strength, high corrosion resistance, and high thermal conductivity are the major advantages of these alloys. In order to produce thin wall structural die cast parts, much more stringent requirements have to be applied to the high pressure die cast process. Parts

have to go through several stages of heat treatment process to obtain required strength and elongation under an applied load. Gas entrained during the process has to be minimized, prompting the use of high efficiency vacuum systems that would allow to lower cavity pressure to about 50 – 60 mbars.

### Description of the Problem

In this paper, we describe the process development for a thin wall aluminum die cast part. The part weight is 3.5 kg, with an average wall thickness of 2.5 mm. The manufacturing process includes pressure die casting, heat treatment for 2 hours at 450° C and then an aging treatment at 230° C for 2.25 hours. To enable effective heat treatment, high efficiency vacuum systems are used to aid gas evacuation during the die cast process. There are three sources of trapped gases that contribute to the contaminants that reduce casting properties. Typical atmospheric gases that are displaced by the metal front, hydrogen gas dissolved in the aluminum at the alloy stage that is released at solution temperature during heat treatment, and the lubricant vaporization when the metal front sweeps through the die. All of these gases are required to be at the lowest level to achieve good casting properties. High vacuum in the die during fill accomplishes this goal. Process calculations and subsequent CFD analysis using commercial software FLOW-3D allowed our team to successfully design the process and achieve high quality parts.

### Process Parameters Calculations

High efficiency vacuum die cast process calculations have to start with calculation of the size of the vacuum system. Using the analogy of air flow through a nozzle, critical pressure ratio can be calculated [1]:

$$\left(\frac{P_2}{P_1}\right)_{CR} = \left(\frac{2}{\gamma + 1}\right)^{\frac{\gamma}{\gamma - 1}} = 0.528$$

where,  $P_1$  – air pressure at the nozzle entrance,  $P_2$  – air pressure at the nozzle exit,  $\gamma = 1.4$  for air. At the start of the slow shot stage, when the vacuum valve opens, the vacuum tank is connected to the die cavity of the die cast die. The

