Die Casting Simulation Solves Non-Fill Problem, Saving $50,000-Plus Per Year

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Introduction

The industry in which we operate faces numerous challenges, including skyrocketing prices for energy and raw materials. In response, Citation Corporation has been focusing on its core strengths and pursuing increased operational efficiencies. Cost, quality and delivery are paramount to its competitive position.

Recently, the company experienced difficulties in die casting a thin-wall automotive housing. A scrap rate of about 20%, unacceptable in today's marketplace, resulted from non-fill when casting the part in a six-cavity die. Shutting off two cavities reduced the scrap rate but also cut the production rate by one-third. Using the ProCAST casting process simulation software from ESI Group, Bloomfield Hills, MI, engineers simulated the operation, finding that flow was slowed by an obstruction in the part.

Engineers moved the gate position to avoid the obstruction and reran the simulation. The new simulation showed they had solved the problem. Moving the gates on the actual die virtually eliminated scrap due to non-fill, while making it possible to increase production by using all six cavities of the die. This design change saved a minimum of $50,000 per year for machine time associated with empty cavities and defective parts, cost of re-melting defective parts and inspection and sorting costs.

Non-Filling and Cosmetic Problems Experienced in Die Casting

The part in question is made of aluminum and has a 2 mm wall thickness in many areas. During the casting process, metal is forced into the part at a rate of 1,500 to 2,000 inches per second, filling it in about 20 milliseconds. The casting was run on a machine that provided excellent die temperature control through the use of a hot oil unit, so little improvement could be achieved in this area. The part's strict cosmetic requirements have caused problems in the past, even on parts that filled successfully. Specifically, flow lines appeared on many parts because they filled at too low a temperature, even with the hot oil die control. Considerable additional manpower was required to inspect the parts, and in some cases, inspectors even had to be sent to the customer site.

The engineers originally hoped that reducing the number of cavities in the die would provide more pressure to fill the remaining cavities. This step reduced the scrap rate to 10%, but this was still an unacceptably high number, and reducing the number of cavities substantially increased production costs. So, they decided to simulate the die casting operation. They had previously selected this casting simulation solution because its finite element approach better simulates the part and gating, resulting in more accurate results. The software also has the flexibility to simulate all of our different casting processes, including aluminum die casting, permanent mold and semi-permanent mold, as well as iron lost foam and sand casting. It also simulates investment casting and shell casting.

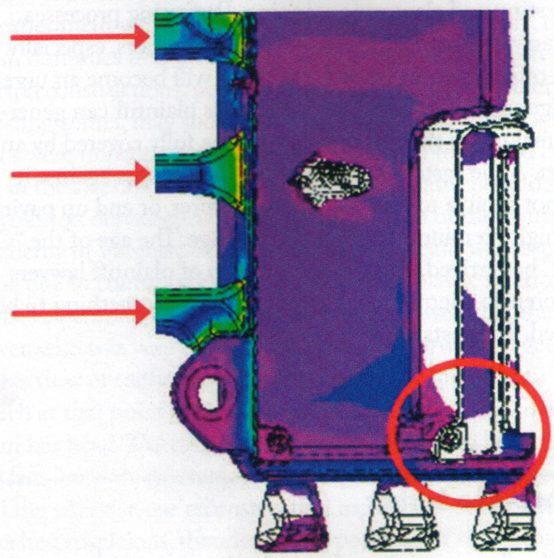


Figure 1 - ProCAST simulation of original gating. Flow interruption results in an isolated gas pocket, which results in non-fills. (Image shows the original gating and flow direction.)

As our engineers have gained more experience in using the software, they have discovered that its advanced capabilities make it possible to simulate every aspect of the metal casting process. The simulation software allows a unique coupling between thermal, flow and stress calculations, which are all performed on the same mesh. This makes it possible to evaluate thermal shock on the tooling during mold filling as well as the influence of gap formation between the casting and the mold upon solidification. Hot tears, plastic deformations, residual stresses and distortions are some of the issues that can easily be investigated. The software also can identify air bubbles or oxide layers trapped in areas where fluid flow is restricted that may locally weaken the component. Air inclusions can be directly monitored, making it possible to optimize the gating system and the positioning of vents and overflows in high pressure die casting. By providing accurate prediction of shrinkage for all types of alloys, the riser positioning and size can easily be modified and validated.

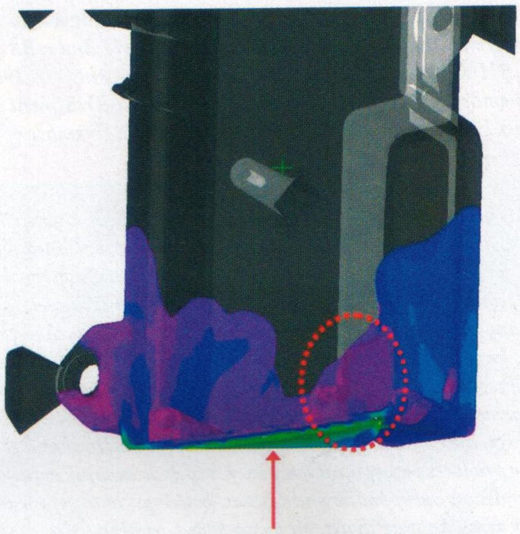
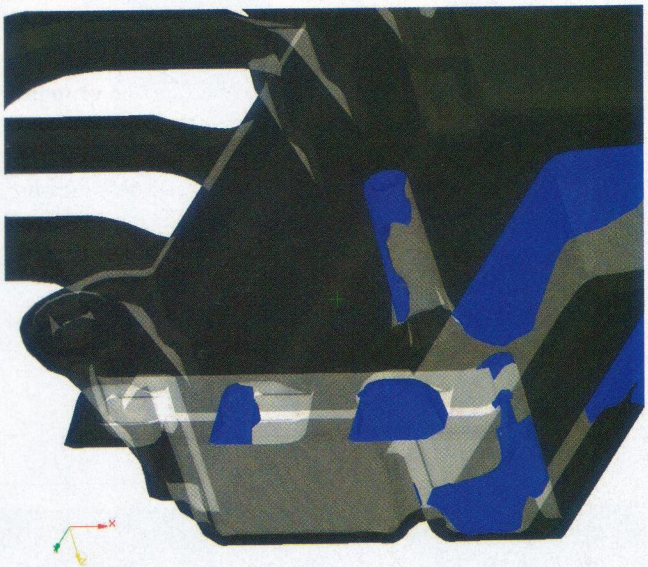


Figure 2 - ProCAST simulation of new gating. No isolated locations to trap gas and create the potential for non-fill at problem location. (Image shows the new gating location and flow direction.)

Simulating the Die Casting Operation

The engineers began the simulation by exporting a surface model in the IGES neutral file format from their CAD system and importing it into the simulation software. They then used the simulation software to automatically mesh the surface model using triangles. Then, a 3-D mesh was generated using tetrahedral elements. Meshing tools integrated in the software are optimized to provide the most efficient solution for geometry representation in shape casting applications, while keeping solution times to minimal levels. The 383 aluminum used in this application was selected from the simulation tool's material database. Engineers ran the flow solver to predict the metal flow inside the mold. Fluid flow calculations were described by full Navier-Stokes equations. The flow solver includes specific models for the analysis of turbulent flows, thixotropic or semi-solid materials and lost foam processes.

Before using the simulation results as a design tool, the engineers first validated the simulation. They produced a series of short shots on the die that showed metal flow through the part. Then, they compared the castings produced by these short shots against software animations that predict the filling of the mold. The results showed that the software had accurately predicted the die filling process. When the engineers viewed animated results from the simulation, they could see an obstruction that forced the molten metal in another direction. This left an air pocket behind the obstruction in exactly the area of the part that was not filling. The metal eventually moved back towards that area, but by that time, the melt temperature had been reduced to the point that filling of the part could not be ensured.



Figures 3 and 4 - Two additional views of the original gating – both the obstruction and the non-fill location are clear.

Optimizing the Gating Position

Company engineers considered various possible solutions to this problem. The part had been designed by the customer and could not be changed. The primary process design variable available was the gating position. Engineers considered various gating positions based on the principle that the flow distance should be reduced to minimal levels. For each gate position that seemed promising, they modified the model and re-ran the simulation to evaluate flow conditions. The gate position that showed the best performance was very close to the area of the part that did not fill. This position allowed molten metal to fill the area in question without ever having to cross the obstruction.

Unfortunately, the die had been constructed in a manner that the gate could be positioned in this location in only three cavities. So, the engineers evaluated other gate positions for the remaining three cavities. They determined that the best gate position was on the side of the part opposite the area that was not being filled. This again provided a direct route for the metal to flow to the critical area without having to cross the obstruction. Flow simulation predicted that both of these gating positions should enable all areas of the part to be filled without any difficulties.

The die was then modified to put the gates in the new positions. The results were that the parts filled completely and cosmetic defects due to flow lines were reduced to negligible levels.

Significant Savings Realized

The new die design generated substantial savings. The $50,000 that had been lost from the high scrap rate was eliminated. The cost of producing the part was also reduced substantially by using all six cavities of the die. In addition, labor savings were realized from reduced inspection needs.

Citation is satisfied with ProCAST software because of its accuracy and speed in simulating metal casting operations. The application described here is one of many for which software simulation has saved the company time and money. This tool allows companies to solve their problems without having to modify and test dies in a production setting. Citation is confident that when its designs will work in ProCAST simulation, they will also work in the plant.

About the Author

Dr. Krishnan Venkatesan is the director of process engineering at Citation Corporation. He has been with Citation since 1997. Previously, he worked for Doehler-Jarvis (Toledo, OH) from 1995-97 and Ohio State University (ERC/NSM) Die Casting Group from 1991-95. Dr. Venkatesan earned his Ph.D. from Ohio State University (Ind. & Man. Eng) in 1995. He also earned an MS degree from Ohio State (Eng. Mechanics) in 1991 and a BS – IT from BHU, Varansi, India (Mechanical Engineering) in 1989. He is a member of NADCA (member of Die Surface Treatment and Process Engineering Sub-Committees) and AFS (member of Casting Modeling Committee).

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