Simulating Thermal Stresses and Cooling Deformations

Amir H. G. Isfahani, Developer
Flow Science, Inc.
Santa Fe, New Mexico

James M. Brethour, Senior Developer
Flow Science, Inc.
Santa Fe, New Mexico

Introduction

In the casting industry, the ability to predict thermal stresses and resulting deformations during solidification and cooling continues to be a challenge. Flow Science has recently developed its fluid-structure interaction (FSI) and thermal stress evolution (TSE) models to provide these kinds of predictions to its customers. With the addition of solid mechanics to its existing fluid focused modeling portfolio, *FLOW-3D** (www.flow3d.com) is now one of the few simulation tools that provide a fully coupled fluid-structure interaction model within one software package. The built-in finite element analysis along with *FLOW-3D*'s proven record in free surface flows makes it an attractive choice to the casting industry.

Many users have been coupling multiple software packages in order to simulate fluid-structure interaction problems including casting processes. The modeler solves the fluid mechanics separately, then imports the surface boundary conditions into a solid mechanics package, obtains the stresses and deformations and then feeds the deformed geometry back into the flow solver and the cycle continues. The manual implementation of this process proves tedious and automating it through scripts and wrappers is challenging. Besides, most of the time, this coupling has to be done on a per case basis. *FLOW-3D* has seamlessly integrated both aspects of this process into one package where both solutions come out as the result of a single simulation.

In this article, a case where the simulation results are compared to deformations from an actual cast part is presented. The part and experimental results were provided by Mark Littler of Littler Diecast Corporation.

The Casting Process

The part is an aluminum (A380) cover and is cast within a steel die. The length and width of the part are 9.45 by 7.01 in, and its overall thickness is 0.51 in. One of the concerns with this part is that during cooling, it bows at the mounting tabs which can prevent clamping and sealing of the lid. Figure 1 shows the top and side views of the cast part with the mounting tabs highlighted.

In order to be cost effective, the casting process should result in a part that is near its final shape requiring only minimal machining. Even with carefully orchestrated runner design, filling patterns, and cooling lines, thermal stresses can cause deformations that lead to deviations from the final geometry.

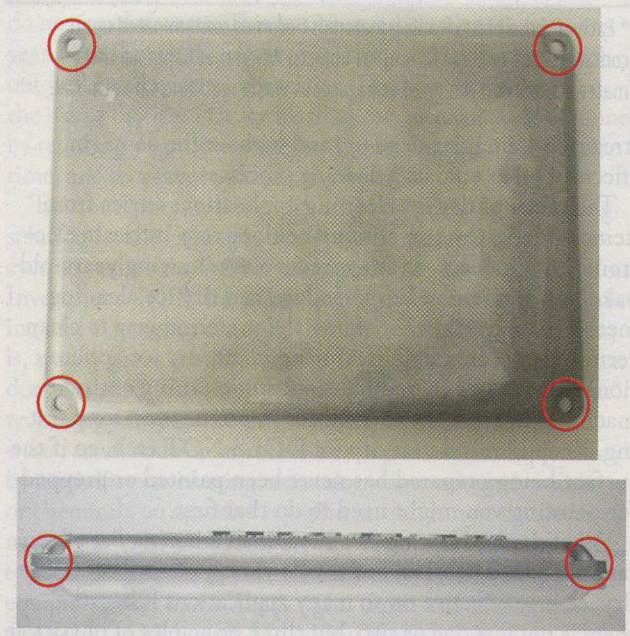

Figure 1 – Top and side view of the cast part (courtesy of Littler Diecast Corporation).

Simulation of Thermal Stress Evolution

The simulations included the following stages of the casting process: after (instant) filling, the part was cooled in the die for 6 seconds (stage 1), then it was removed from the die and air-cooled for 10 seconds (stage 2), and finally, after the runner system was removed, it was cooled for another 10 seconds (stage 3). Figure 2 shows the geometry used for the simulations. Full energy transport, solidification, and thermal stress evolution were the major computational steps throughout the simulation process. A material database pro-

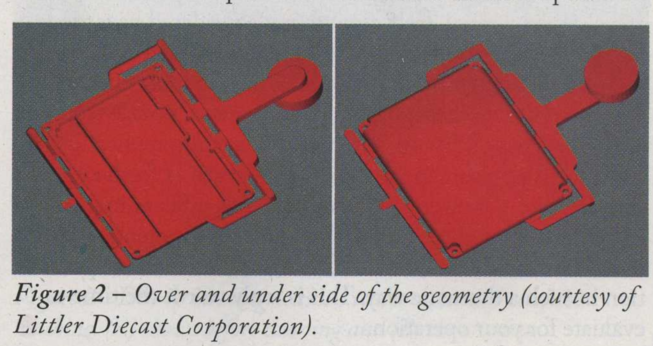

Figure 2 – Over and under side of the geometry (courtesy of Littler Diecast Corporation).