

Using Simulation to Rig Castings and Prevent Defects



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ARTICLE TAKEAWAYS:

- Simulation of unrigged castings drives gating and riser design
- Flow simulation predicts/prevents filling-related defects
- Computational Fluid Dynamics (CFD) improves solidification accuracy

INTRODUCTION

Simulation is the process of predicting, on a computer, what happens when metal is poured into a mold and the metal cools and solidifies. By simulating this process, we hope to predict potential defects in the casting and redesign the process to eliminate these defects, BEFORE making actual castings.

THE DESIGN PROCESS

Typically, the design process begins with receipt of part specifications from the customer. Traditionally this involved a paper drawing, however, nowadays most part geometry is contained a 3D CAD file which facilitates the use of computer simulation.

The first task of the foundry engineer is to decide on a basic process design for the casting, i.e., in what orientation the part will be cast, how it is to be gated and risered, and how many castings are to be placed in a single mold or tree. Simulation can be immediately helpful even at this early stage of design. We have created a design process that starts with running a “naked”

simulation of the part as received from the customer, completely surrounded by mold material and without gates or risers. This unrigged simulation typically runs in just a few minutes and allows the part to be viewed from a thermal standpoint, showing the progression of “natural” solidification and the location of thermal centers in the casting. Figure 1.

In many cases this analysis will determine the orientation of the casting in the mold; contact points for risers become obvious, and the best orientation of the casting to accommodate those contact points can be decided immediately. Gating and Riser Design Wizards are built into

the simulation software, so that location, number and size of risers and suggested size and shape of gating components can be calculated more or less automatically to establish an initial rigging design for the casting, Figure 2.

Once the initial design is developed, it is necessary to prove out and fine-tune the design by running complete flow and solidification analysis. This is because design rules are general in nature and cannot take into account all of the dynamics that will occur within a complex casting/gating system. It is usually necessary to construct a 3D model of the casting with the complete proposed rigging system for simulation.

The simulation process occurs in two phases: Flow of the liquid metal as it enters and fills the mold cavity, and the subsequent cooling and solidification of the metal along with formation of macro- and micro-porosity defects.

FLOW MODELING

Flow modeling is an integral part of the casting simulation process. Flow modeling allows flow-related defects such as misrun and oxide (dross) formation due to excessive velocity to be predicted and reduced or eliminated through design changes, prior to production of the casting. Flow modeling is used to evaluate the gating design to insure the desired delivery of metal in the casting cavity. In addition, flow modeling provides the most accurate initial temperature field for modeling

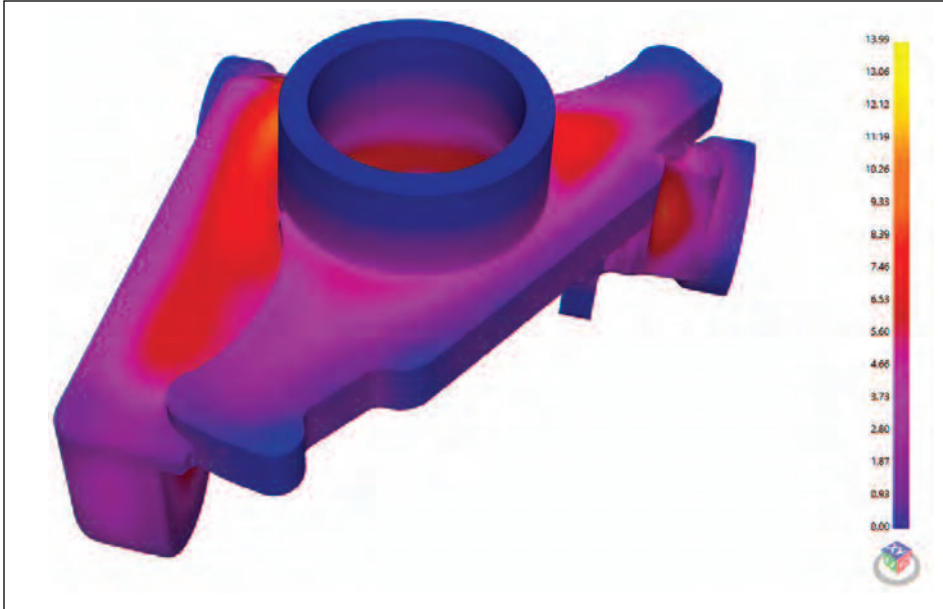


Figure 1. "Naked" simulation of casting plotting solidification time.

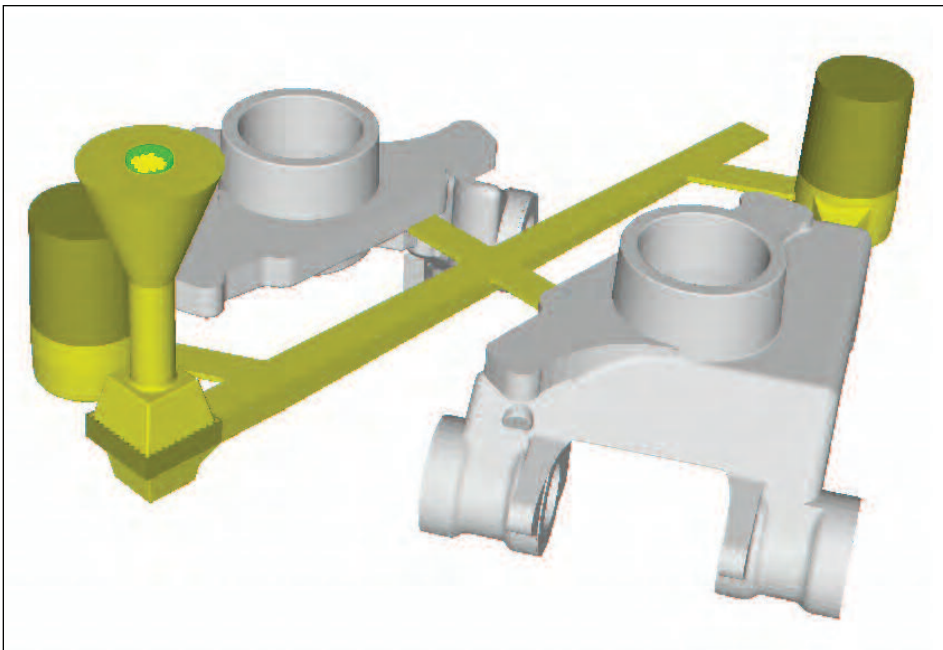


Figure 2. Model of casting with initial rigging design

the subsequent cooling and solidification of the casting along with the gates and risers so that correct feeding of the casting can be obtained.

Flow simulation is accomplished using Computational Fluid Dynamics (CFD), a technique that solves the equations of fluid flow for mold filling. The equations governing the flow of a liquid are the Navier-Stokes equations; these relate the flow of liquid to the principle of conservation of momentum as well as movement in reaction to body forces on the liquid (such as gravity, pressure and friction).

Filling simulation lets the foundry engineer visualise the flow of the liquid metal from the pouring point, through the gating system and into the mold cavity during the entire filling process. This verifies the gating system design. If the gating is not functioning as intended (for example, there is unequal metal flow through various gates), the design can be modified and the new design re-tested. In addition, the fluid flow calculations are coupled with thermal calculations so that the heat transfer from the liquid during filling and the resulting temperature distribution within the liquid metal can be viewed. This allows the prediction of areas in the casting where premature solidification may be occurring during filling, leading to defects such as misruns and folds. Accurate calculation of the temperature distribution of

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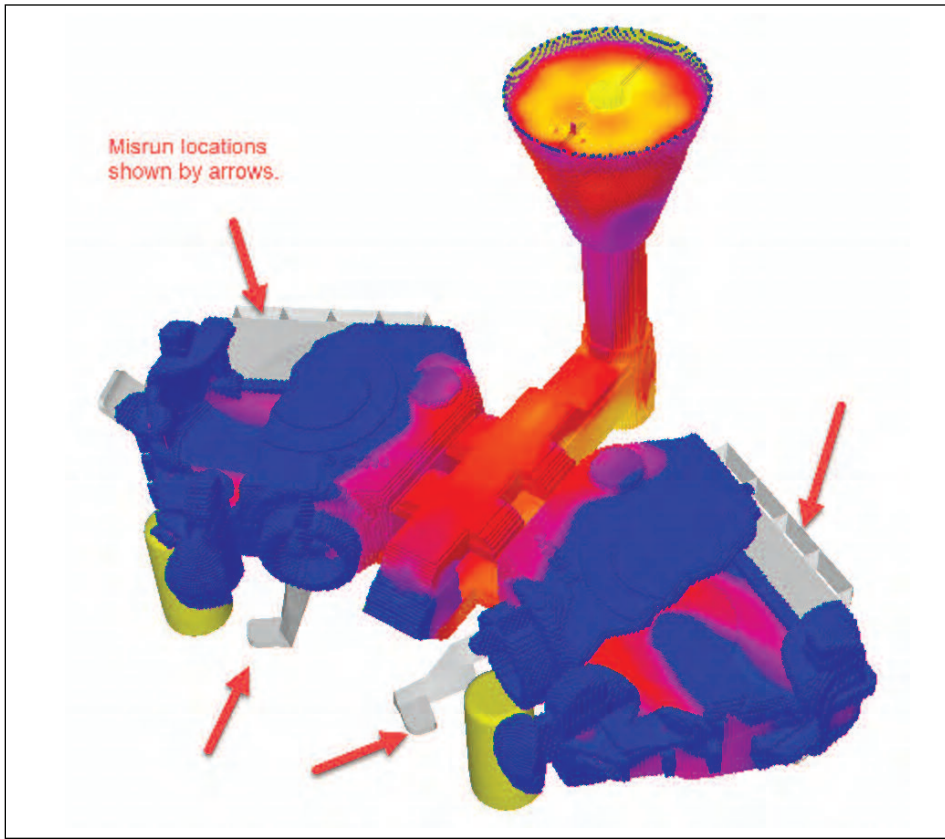


Figure 3. Plot of a misrun predicted by CFD fluid flow simulation.

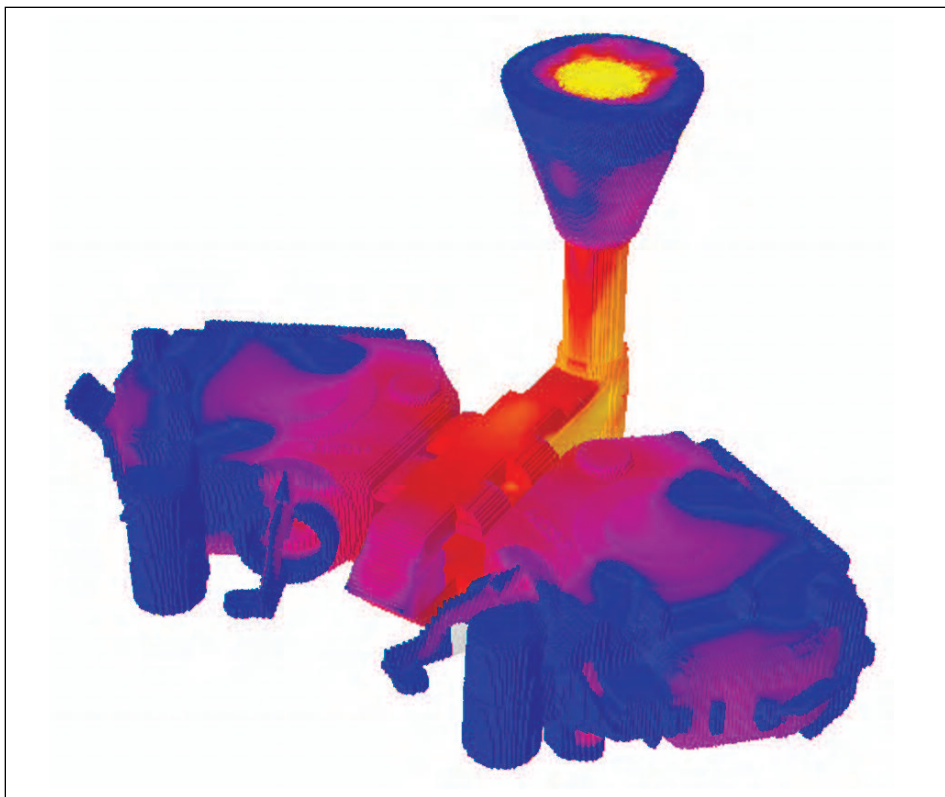


Figure 4. Complete mold filling with an increase in pouring temperature.

the liquid metal in the full mold results in highest accuracy of the subsequent modeling of cooling and solidification of the metal. Figure 3 shows the prediction of a misrun in a copper-base casting that was poured too cold. Figure 4 shows that filling can be completed by increasing the pouring temperature.

Another aspect of filling simulation which is quite useful is prediction of metal velocity during filling. Areas of higher velocity are also areas where excessive turbulence is likely, leading to formation of dross (oxides) as the turbulence entrains oxygen-containing gas into the metal stream. Of course, this effect does depend somewhat on the affinity of the particular alloy for oxygen, so this is more important in alloys such as aluminum which has a great tendency to oxidize as opposed to a carbon steel which has a relatively low affinity for oxygen. Almost all alloys, however, have some tendency to form oxides and using flow simulation to design gating systems which minimise velocity and turbulence of the metal can be quite helpful in reducing flow-related defects in castings.



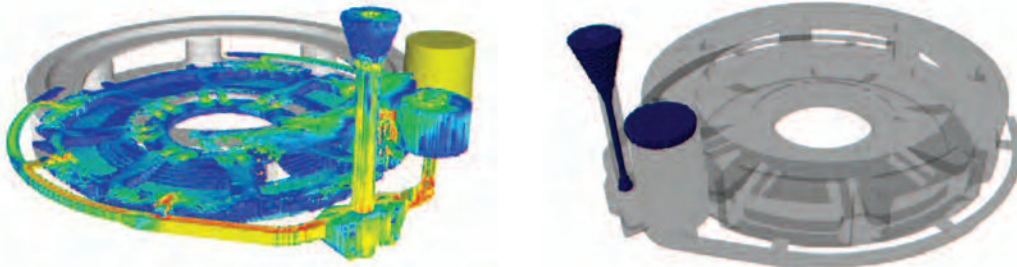
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