COMPUTER MODELING OF THE CASTING PROCESS TO PREVENT DEFECTS

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ARTICLE TAKEAWAYS:

- Simulation of unrigged castings drives gating/risering design
- Flow simulation aids in process visualization
- Computational Fluid Dynamics (CFD) enhances simulation accuracy

Introduction: Computer modeling is the process of simulating what happens when a casting 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 geometries are contained in 3D CAD files, which facilitates the use of computer design and 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, how it is to be risered and how many castings are to be produced in a single mold or tree. Computer simulation can be helpful even at this early stage of design. Many foundry engineers have adopted the practice of running a "naked" simulation of the part as received from the customer, completely surrounded by mold material without gates or risers. This can often be accomplished in just a few minutes with the right software, 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.

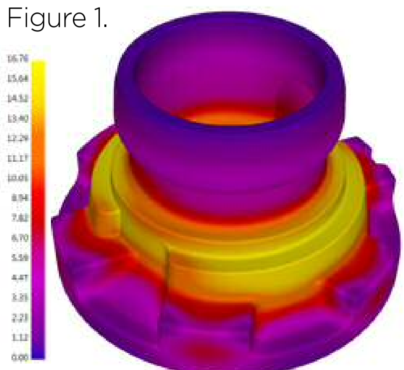

Figure 1
"Naked" simulation of casting plotting solidification time.

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 in order to accommodate those contact points can be decided immediately. It is helpful if the simulation software has built-in design rules for feeding and gating the casting (such as a Gating Design Wizard and a Riser Design Wizard) 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.

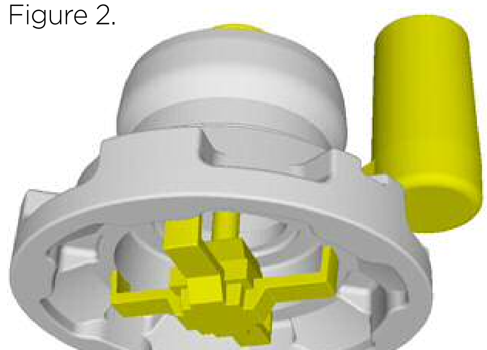

Figure 2
Model of casting with initial rigging design.

Once the initial design is developed, it can be verified and fine-tuned by running complete flow and solidification analysis. This is required, due to the fact that design rules are general in nature and cannot take into account all of the dynamics that will occur within a complex casting/gating system. This means that it is necessary for the foundry to construct a 3D model of the casting with the complete proposed rigging system for computer modeling.

The simulation process occurs in two phases: Simulation of the flow of the liquid metal as it enters and fills the mold cavity, and simulation of 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 simulation process. Flow modeling allows flow-related defects, such as misrun and oxide formation due to excessive velocity, to be predicted and reduced or eliminated through design changes prior to production of the casting. Flow modeling can be used for the evaluation of gating design to ensure the desired delivery of metal in the casting cavity. In addition, flow modeling provides a more accurate initial temperature field for modeling 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 through the use of Computational Fluid Dynamics (CFD), a technique that solves the equations of fluid flow for mold filling. The basic 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 allows the design of the gating system to be verified. If the gating is not functioning as intended (for example, there is unequal metal flow through various gates), the design can be modified and a new design can be 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 within 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 the liquid metal in the full mold results in highest accuracy of the subsequent modeling of cooling and solidification of the metal, Figure 3.

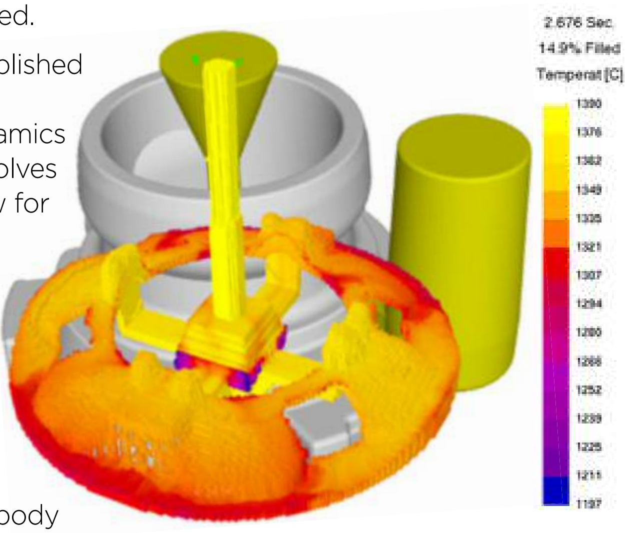

Figure 3
Plot of temperature distribution during mold filling.

Another aspect of filling simulation which is quite useful in improvement of casting quality is prediction of the velocity of the liquid metal during filling, Figure 4. Areas of higher velocity tend to be areas where excessive turbulence is likely, leading to formation of oxides as the turbulence entrains oxygen-containing gas into the metal stream.

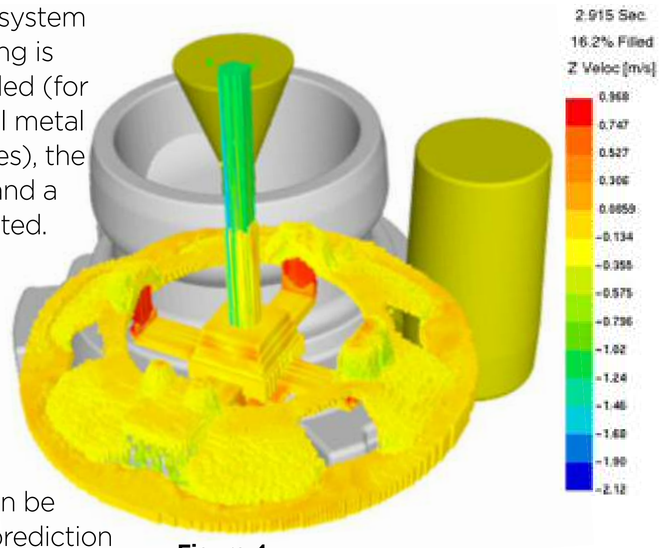

Figure 4
Plot of velocity distribution during mold filling.

Of course, the criticality of this effect does depend somewhat on the affinity of the particular alloy for oxygen (the tendency of the alloy to form oxides), so this is somewhat more important in alloys such as aluminium, which has a great tendency to oxidize as opposed to, say, carbon steel, which has a relatively lower affinity for oxygen. Almost all alloys, however, do have some tendency to form oxides and using flow simulation to design gating systems which minimize velocity and turbulence of the metal can be quite helpful in reducing flow-related defects in castings.

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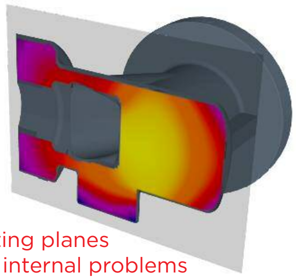
ALL CASTING SIMULATION SOFTWARE IS THE SAME... RIGHT?

WRONG



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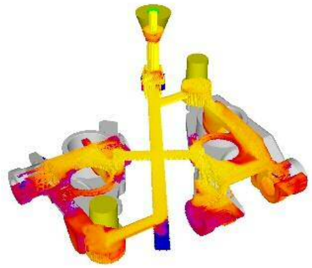
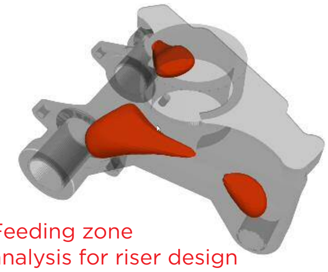


CFD-based fluid flow analysis



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