ADVANCED SIMULATION OF THE PERMANENT MOLD PROCESS

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ARTICLE TAKEAWAYS:

- Permanent Mold Casting is the most complex of the gravity filling processes
- Mold coatings and forced cooling improve simulation realism
- Several speed-up techniques can be used to minimize simulation time, yet provide accurate results

When simulating gravity filling processes, permanent mold is the clear winner for complexity. Some of the reasons for this complexity are:

- The mold is re-used, so you need to get the die up to operating temperatures before you evaluate results. With sand and investment casting, you only need to consider a single filling/cooling cycle.
- The mold is conductive, like the metal poured into it, so interactions at die/metal interfaces are extremely important. Mold coating techniques and air gap formations significantly affect process outcomes. This requires additional data and calculation.
- Complex forced heating and/or cooling schemes can be used on the shop floor and need to be accounted for in simulation. This involves a more detailed model, as well as specifying how the heating or cooling scheme operates.

In spite of these complexities, simulation of the permanent mold process can be straightforward and not too time consuming. Let's see how we can set up a permanent mold simulation that provides realistic result with a minimum amount of calculation time.

MODEL BUILDING CONSIDERATIONS

Ingate filling vs fixed volume filling – The simplest way to model metal entry into the die is by creating an ingate made of "fill material". This creates an interface where hot metal enters the system at a constant filling rate, based on the overall pouring time. For the greatest simulation accuracy in the permanent mold tilt pour process, however, a fixed volume method is used. Here a pouring cup is filled with hot metal, and the metal transfers from the pouring cup to the die as the die is rotated. The filling rate varies during the process, based on the rotation speed and the pull of gravity. Figures 1 and 2 show two variations of a brake caliper casting model, using ingate filling and fixed volume filling. The die has been removed for clarity.

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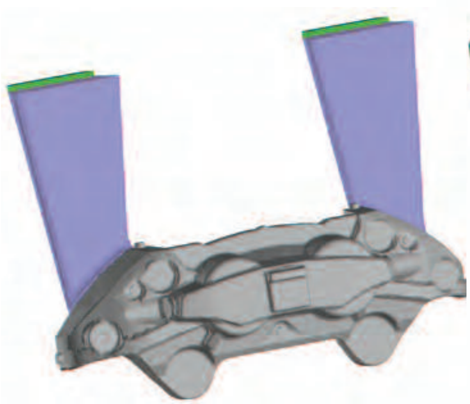


Figure 1: Ingate Filling Model

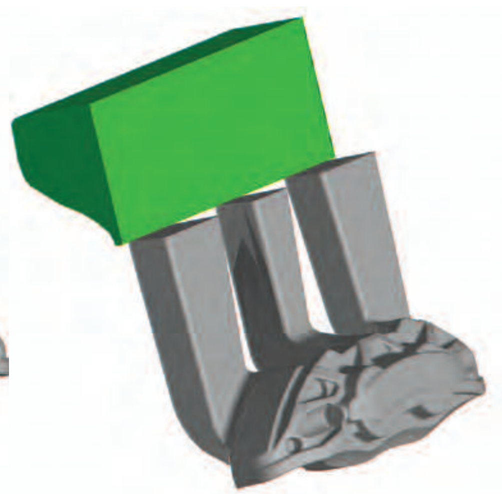


Figure 2: Fixed Volume Fill Model

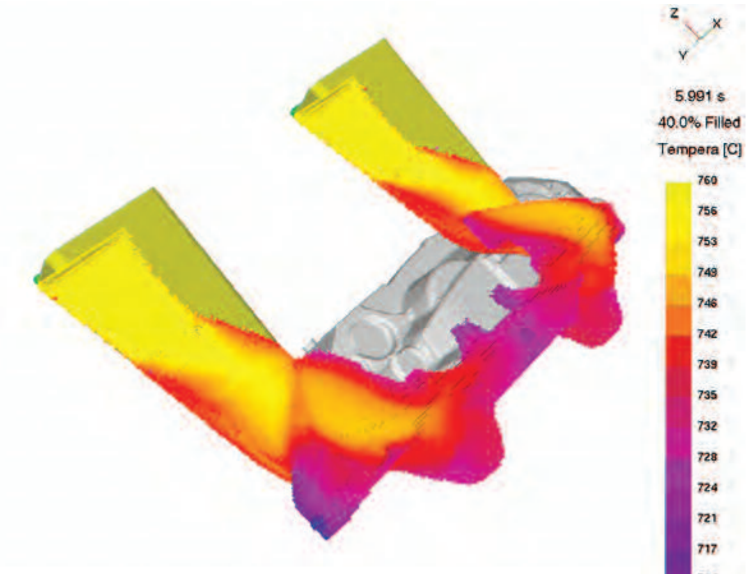


Figure 3:Tilt-Pour Filling Using Ingate Filling

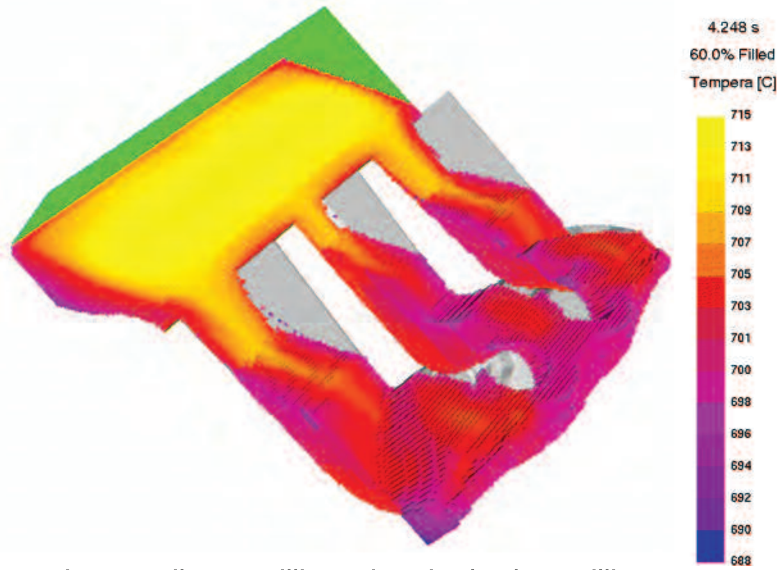


Figure 4: Tilt-Pour Filling Using Fixed Volume Filling

Figures 3 and 4 show a comparison of how the filling process is depicted in simulation.

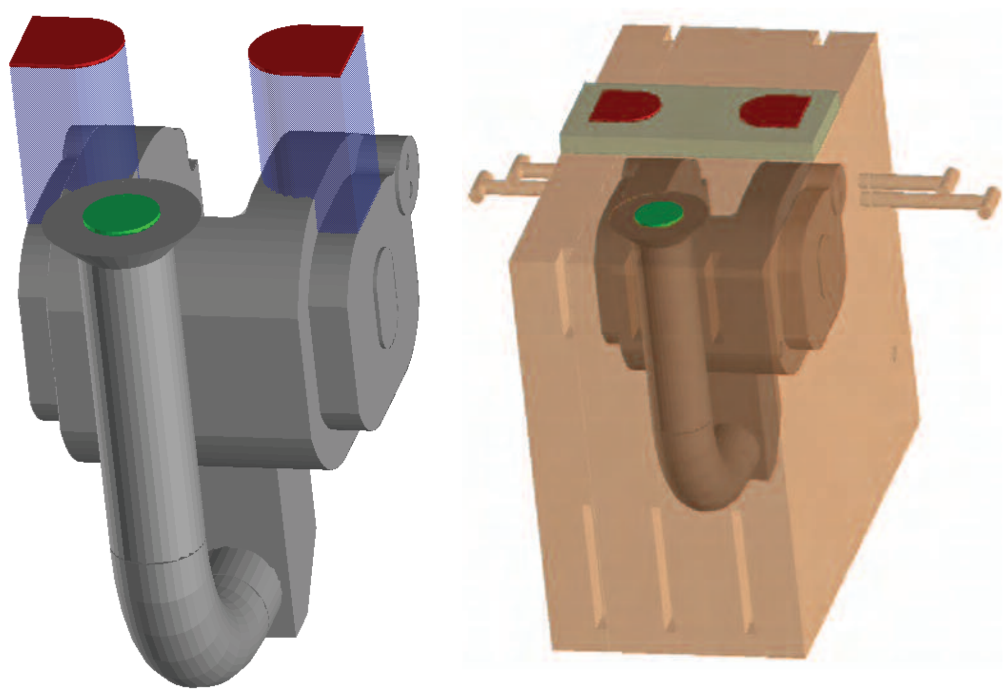
Forced heating or cooling – The use of burners or cooling channels can be handled in a number of ways. The simplest is a constant temperature material, like the burners, highlighted in red in Figures 5 and 6, which are a casting made of lead.

The use of a cooling channel can range from very simple to quite complex. A cooling channel can be always on or activated by time or temperature. There can even be delays in actions, as shown in Figure 7.

SETUP CONSIDERATIONS

One setup consideration is how to appropriately handle heat transfer at casting/die interfaces. Since a metal die is conductive, like the cast metal that is poured into it, die coatings significantly affect heat transfer. This is normally taken into account with a table of Heat Transfer Coefficients, or HTCs, which measure the resistance to heat flow at any surface between two materials, such as casting/die, die/air, gating/die, etc. Use of insulating sprays on the gating/risering can easily be handled using HTCs. You can also

Figure 5 and 6: the lead casting risers heated with constant temperature burners. Shown with and without the die.



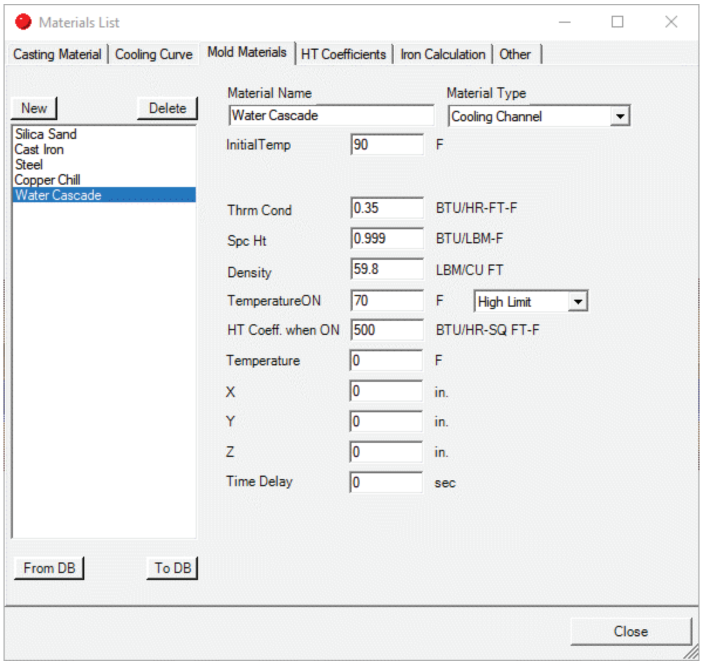


Figure 7: Setup screen for a water-cooling channel

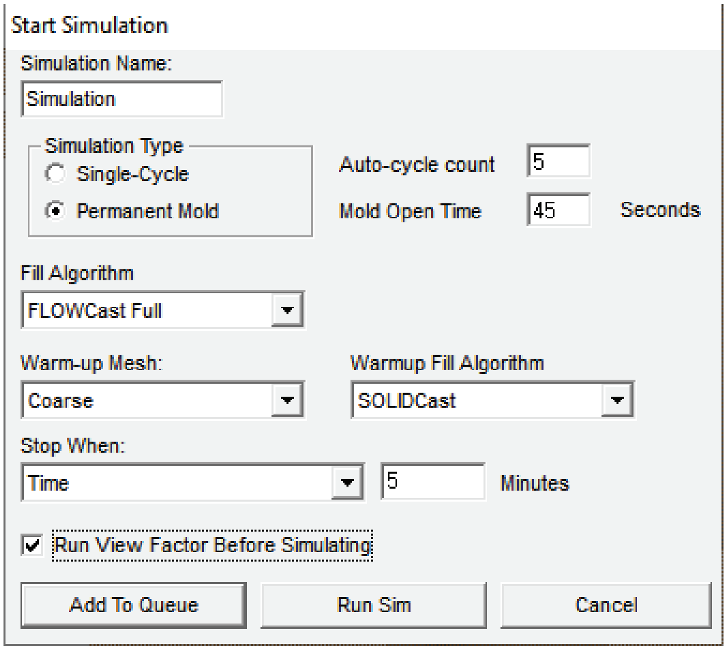


Figure 8: Simulation Setup Using Coarse and Fine Meshes

configure the system to lower the HTC on a casting surface when it solidifies. This is used to simulate the air gap that forms as the casting contracts and tries to pull away from the mold. HTCs and radiation view factor calculations can also be used to predict cooling on the outside of the die, in the foundry environment.

Another major setup consideration is how to handle die cycling. Most dies are preheated before casting starts, but it still takes a number of cycles for the die temperatures to heat up to the operating conditions. In simulation, the number of warm-up cycles can be reduced by starting the die at a hotter temperature than normal, and let the die cool slightly to the operating temperature. For example, you may heat a die to 300°F in the foundry, but the overall operating temperature may be in the 600-700°F range. If you start the die at 800°F in a simulation, it may take, say, 5 cycles to cool to the operating temperature, rather than 15 cycles if the die had to warm up from 300°F.

A final consideration is to speed up the 'warm-up' section of the simulation as much as possible by creating two meshes, one coarse and one fine. The coarse mesh is used for the warm-up phase, where the detailed progression of solidification is not important. With fewer nodes making up the mesh, the simulation progresses quite rapidly. If you use an 8:1 Fine:Coarse ratio, the warm-up phase of the simulation can run up to ten times faster. You can even use simplified filling analysis to speed this up even more. Once the die is at an operating condition, the temperature distribution from the coarse mesh is mapped into a fine mesh, detailed and accurate CFD filling analysis and solidification can be calculated for maximum accuracy, with minimum time spent. An example of the setup for simulation can be seen in Figure 8.

All things considered; permanent mold casting is the most complex of the gravity filling casting processes to simulate. By paying specific attention to several model building and simulation setup techniques, you can produce simulation results that accurately predict what will happen on the shop floor. And those results can be produced in a very reasonable amount of time.

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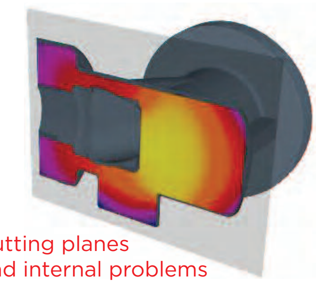

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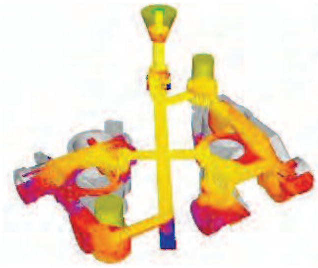

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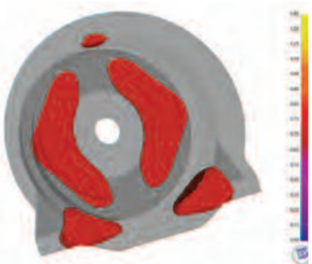

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