# Research Programs

## Modeling of Sand Casting Processes

### Research Team:

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Hitchcock Industries has been a producer of complex, premium aluminum and magnesium sand castings for the aerospace industry since 1916. Until now, much of the success of Hitchcock's engineering has been due to the accumulated practical foundry knowledge over the past 85 years of operation. The design of sand molds, which produce castings with high geometric complexity and material properties, has largely been a reactive engineering endeavor. Typically, mold designs go through iterations before a final configuration is achieved. Much of this is due to the uniqueness and complexity of the process itself; and engineers in this industry are continuously gaining more insight into control of the key variables every day largely through focused experimentation and experience. An ideal situation would be to control all the key influential process variables to produce a mold design robust enough to produce castings to the required specifications-the first time.

One way to examine process variables and to determine their influence on the final product is through the use of computational simulation. In the past, this has not been an option simply because the high geometric and material complexity of Hitchcock's castings made simulation results painstakingly slow that any information gathered was too late to meet the short lead times required for product development. Also, many of the alloys used by Hitchcock are not widely used by those familiar to casting simulation and material properties are not rigorously established. As a result, Hitchcock engineering has continued to rely on vast experiences, standard gating practices and in-house pattern and gating shops. This has demonstrated to serve them with the ability to develop the most complex sand castings in the world. Adding casting simulation to the toolbox would only increase Hitchcock's edge on complex casting development. It is now believed that computational capabilities have reached a point to where this complex casting process and geometry can be modeled in a reasonable amount of time and effort.

The most critical part of the modeling of complex, light-alloy sand castings is the accuracy of results. Since all results are obtained from numerically calculated temperature data, the modeling of heat transfer coupled with fluid flow must be accurate. In order to ensure this, the important material properties must be accurately determined. This involves identifying these properties, and the requirements for their accurate description. This comes in the form of a sensitivity analysis exercise, whereby one important property, or key, parameter is varied by a certain factor while all others remain the same. The results are then compared to a nominal setting to see the effects of the variation, or error in material property data. This is carried out for all key parameters that influence the modeling of any particular casting phenomena. Below is a list of material defects that the foundryman would wish to predict, the physical mechanism behind the defect, and the respective key parameters that may influence the results of that phenomenon. In the list below, the phenomena that are considered are those that MAGMASOFT®, the chosen casting simulation softwere, can predict.

| | |
|---|---|
| **Material Defect:** | Misrun |
| **Mechanism:** | Metal becomes too cold and freezes before the cavity is completely filled. Heat transfer is too high, head pressure is too low. Surface tension of the oxide skin on the free surface |

| | |
|---|---|
| | restricts flow. High back pressure. |
| **Key Parameters:** | Pour Temperature, mold/metal heat transfer coefficient for thin-walled castings, thermal conductivity of the mold, pouring cup height/fill time, filter permeability, metal free surface tension, mold permeability. |
| **Material Defect:** | Shrinkage porosity |
| **Mechanism:** | Region of casting solidifies later than surrounding area, cutting off mass feeding. This is manifested in inadequate heat transfer, lack of head pressure, and bad alloy feeding characteristics. |
| **Key Parameters:** | Thermal conductivity of the mold, pouring temperature, heat transfer coefficient, alloy feeding effectivity/impingement. |

The following figures show the geometry and sensitivity of computationally-generated temperature fields and cooling curves when the constant interfacial heat transfer coefficient (HTC) between the 357 aluminum casting and phenolic urethane bound sand mold is varied by 50% from the nominal value. For the sensitivity analyses, two geometric configurations were used. The first is a simple fluidity spiral, and the second is a more complex thin-walled test casting. Figure 3.2.1 shows temperature field results for the spiral at 80% filled and when the metal freezes in the mold.

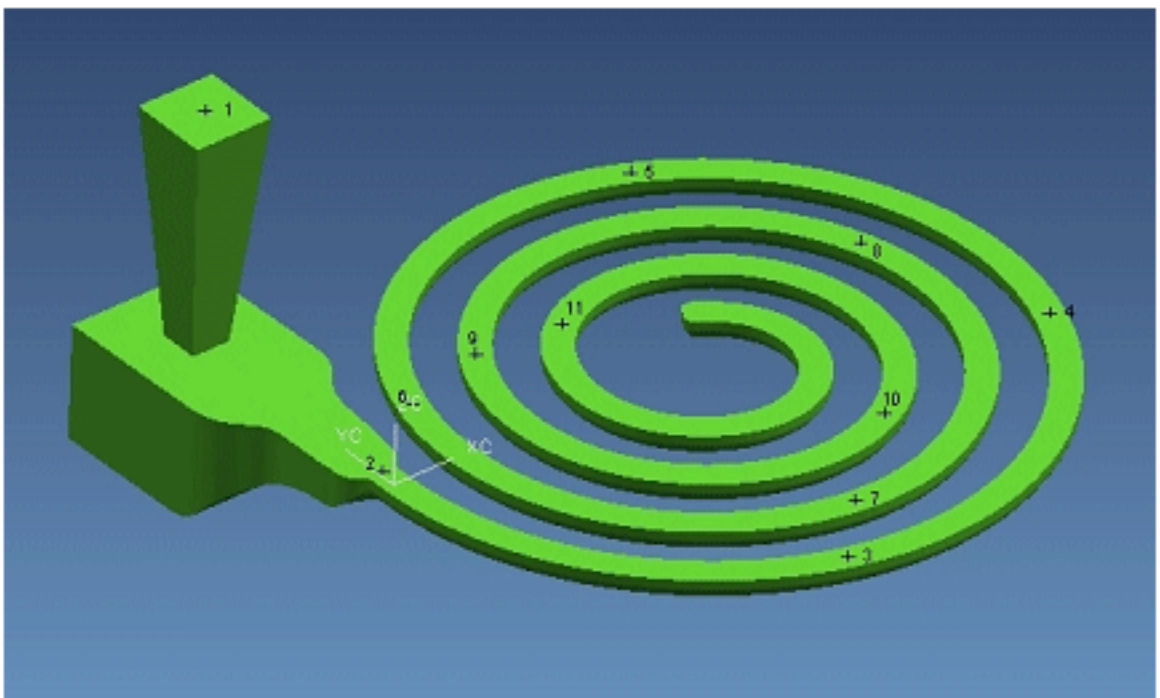



**Figure 3.1.1: Fluidity Spiral and Temperature History Locations**

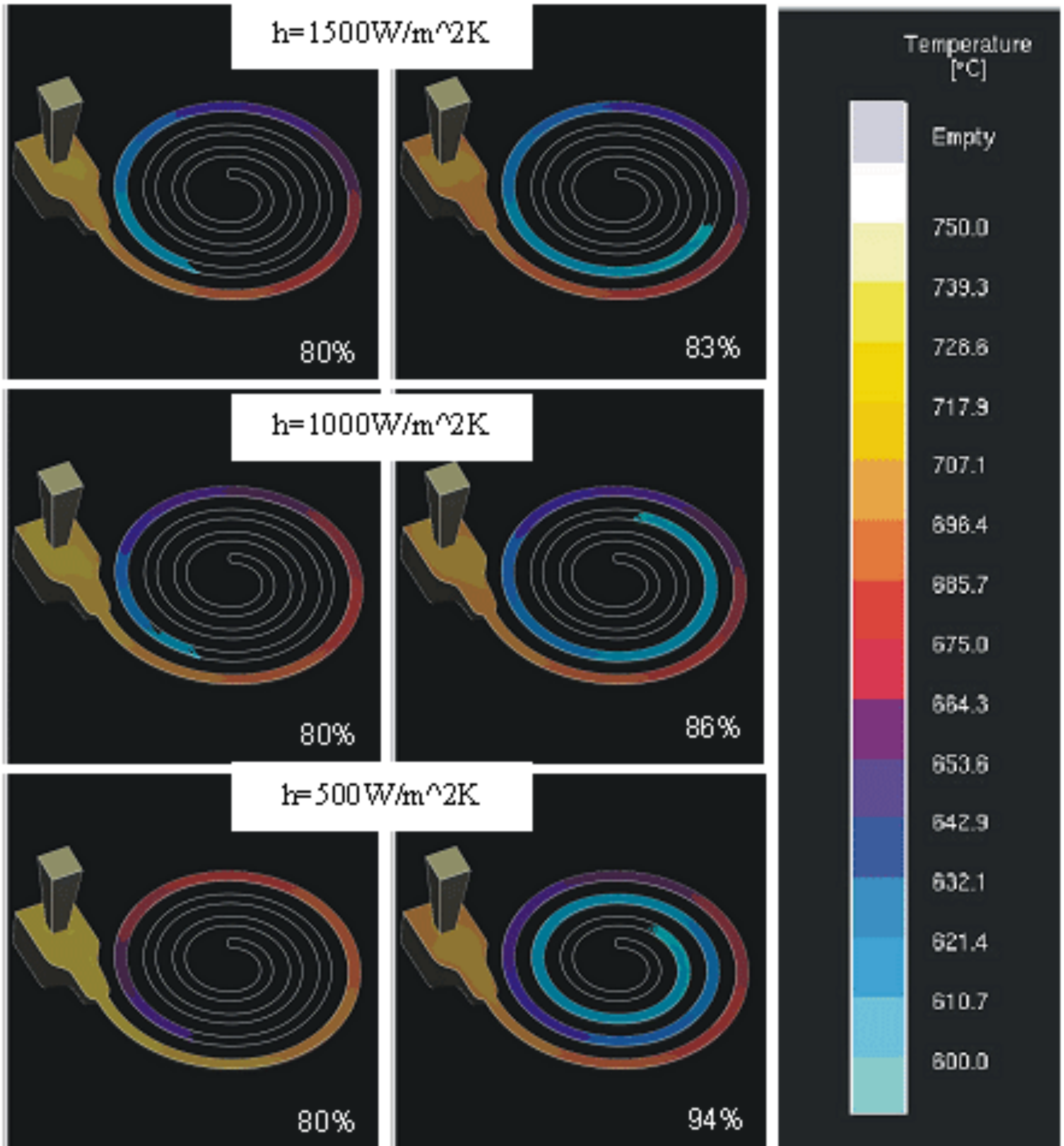



**Figure 3.2.1: HTC Sensitivity Temperature Fields for Fluidity Spiral**

**Figure xxx: Thin-Walled Test Geometry**

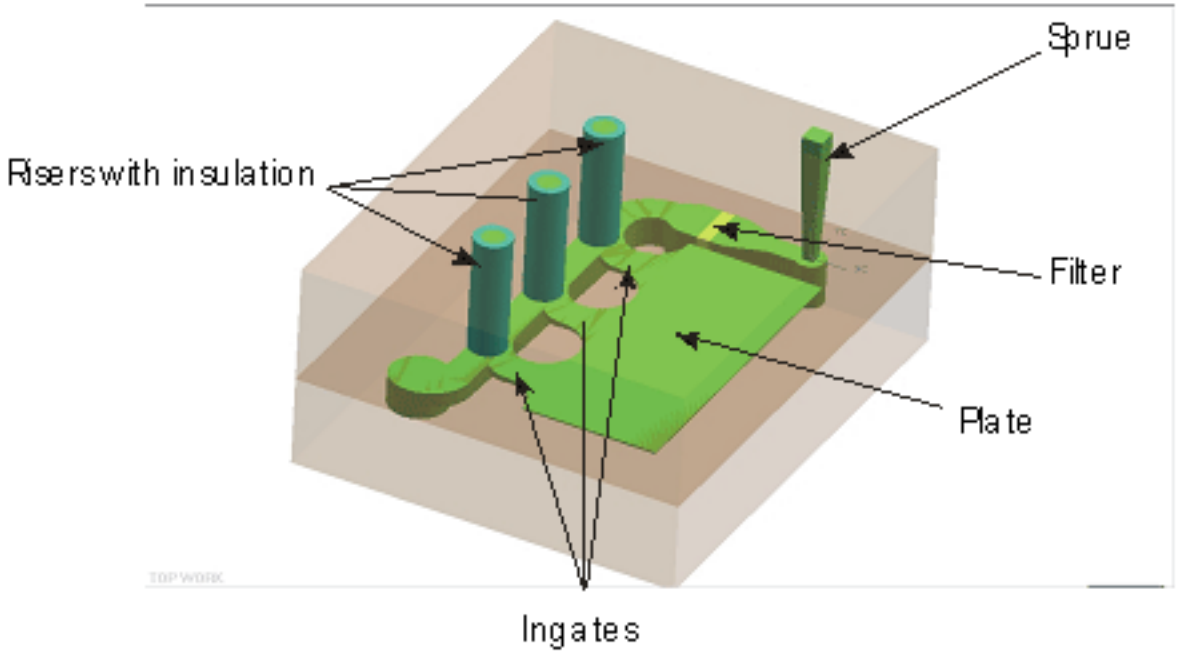
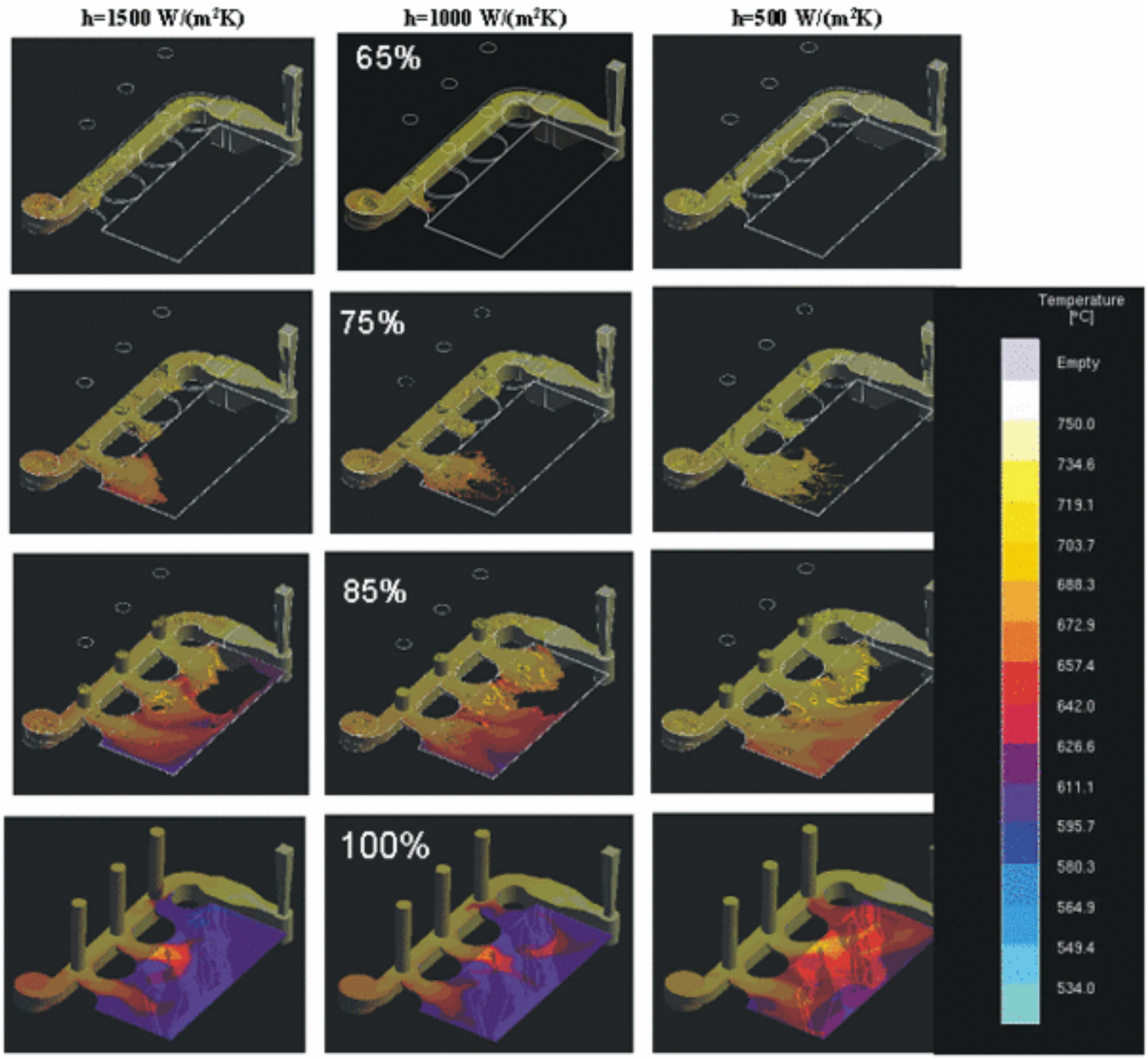


Figure 001: HTC Sensitivity
Temperature Fields




The sensitivity analysis portion and validation of the adjusted database values has been completed. A report will be written and presented in December 2002.