

Computer simulation made easier - accurate thermal data for exothermic/insulating feeding systems

Casting process simulation software is becoming widely used in many North American foundries. The benefits offered by this technology have been well documented. But in order to produce reliably accurate feeding, riser performance and porosity predictions using these systems, accurate material thermal information is paramount.

Casting process simulation uses first principle fluid dynamics and thermodynamics to predict the filling and solidification characteristics of the casting process. Accurate thermal information is required for all of the materials in the casting process so that the thermodynamic characteristics of the system can be predicted.

Until now, the software databases for insulating feeding system materials were generalized, and as a result, not accurate for specific feeding system products. More important, exothermic feeding system thermal data was not readily available. Even when simulation software users made various adjustments to insulating feeding system performance to approximate exothermicity, they were not able to consistently predict the performance of exothermic/insulating feeding systems across the broad range of product sizes and shapes.

Developing Data

Working in a joint development effort with a software manufacturer, Foseco conducted a series of laboratory tests and casting trials to determine the thermodynamic characteristics of exothermic/insulating feeding systems. Thermophysical data were established for each type of feeding system material tested in these experiments and mathematical analyses verified the measured information. This information was incorporated into a widely used mold filling/casting solidification software simulation package and evaluated against actual castings.

As a result of these efforts, insulating and exothermic/insulating feeding system product performance data have been developed for use in the casting process simulation software. These results are "off-the-shelf" inputs for feeding system materials that assist the foundry engineer in obtaining accurate feeding system performance predictions, and directly reduce the software input requirements placed upon the user.

Using these newly developed feeding system thermal data, predictions of exothermic/insulating feeding system performance were proven accurate and consistent, regardless of size and shape of the riser. In fact, feed safety margin predictions were within a few percent for all feeding systems examined. These results were repeatable and consistent for various molding materials.

With this new information, the foundry engineer can confidently optimize the riser size, location and the type of feeding system product chosen using casting process simulation software. This is a major step towards simplifying software inputs, and making the software more practical for daily use in a foundry environment.

Method of Analysis

The thermal data consists of feeding system material thermophysical results, which were obtained from laboratory tests, and inter-facial heat transfer coefficient (IHTC) results, which were obtained from molten metal tests. Material thermophysical information analytically describes the rate and amount of heat transferred through a given material, and is represented by the material's thermal conductivity, specific heat, and density.

The IHTC information describes the rate of heat transfer between two materials. This includes the effect of gasses which, if present, can act as a thermal barrier between the materials. Heat of generation values represent the exothermic energy output of the material.

The thermophysical feeding system data was developed using a combination of conventional laboratory tests, innovative in-house laboratory tests, molten metal tests, and mathematical heat transfer analyses.

Samples of the material were sent to a qualified laboratory, and were subjected to a series of physical tests. Material thermal conductivity, specific heat and density were measured for temperatures ranging from 400°F (200°C) to 2900°F (1600°C). Specific heat characteristics of the material were measured by Differential Thermal Analysis (DTA) and Differential Scanning Calorimetry (DSC) (1-3).

Density characteristics were determined by Thermogravimetric Analysis (TGA) (1). Thermoconductivity characteristics were determined from diffusivity measurements using Laser Holometrix and Guarded Hot Plate tests (1,4). Diffusivity, specific heat and density measurements were compared to published information on similar materials, and were found to be of the same order of magnitude and exhibited similar trends with temperature (5-11). Thermoconductivity characteristics were calculated using diffusivity, specific heat and density.

Molten metal tests were conducted to measure temperature profiles within a given material, as well as temperatures between two materials. Simple cube castings were poured with cylindrical risers. Thermocouples were placed in various locations to measure the metal temperature, the temperature at the metal/feeding system interface and the temperature at the feeding system/molding material interface. Temperatures were recorded as a function of time for steel in both green sand and furan mold. The temperature data was used in two distinct applications.

The final piece of the puzzle involved measuring feeding system exothermic characteristics. A proprietary test apparatus was developed and built to measure feeding system heat of generation. Consistent, accurate heat of generation values were obtained for an extensive series of samples using this apparatus. In addition, the heat of generation values agreed with estimates for the known exothermic chemical reactions that take place within specific exothermic feeding systems (14,15).

The data were input into the casting process simulation software for four types of feeding systems; (a) low density insulating sleeve, (b) medium density exothermic/ insulating sleeve and (c) low density exothermic/insulating sleeve and (d) low density, exothermic/insulating hot topping compound. Cubes were cast and sectioned to validate casting process simulation predictions. Comparison of the results are as follows.

Discussion of Results

In all cases, a simple cube with a cylindrical top riser design was employed. All castings were poured with a top riser covered with exothermic/insulating hot topping. The metal was low carbon steel (WCB), and the molding material was phenolic urethane nobake. An example of the type of model used in the simulation software is shown in figure 1. The casting is a simple cube with a cylindrical top riser. The riser sleeve and hot topping are also shown in the model.

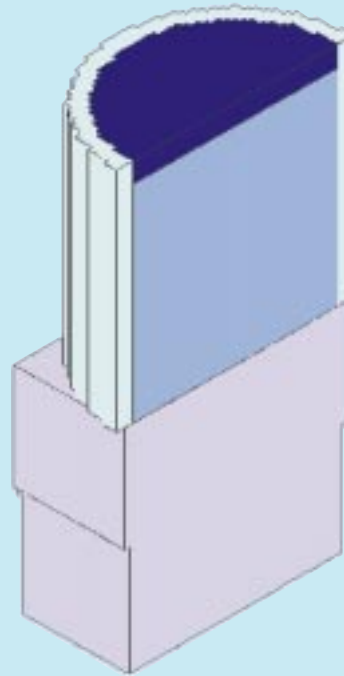


Figure 1: Example of 3-D model of configuration

A 6.25" cube was used to test the feeding performance of a 6" x 6" low density, insulating sleeve with low density, exothermic/insulating hot topping. It should be noted that even standard insulating feeding systems may be composed of a small percentage of combustible materials, and may have a small heat of generation contribution. This effect has been measured and taken into account in the thermal data for this product.

The predicted and measured feeding results comparison is shown for the low density, insulating feeding system in figure 2. The casting is sectioned down the middle of the riser, and the visible macroporosity is shown. The macroporosity prediction results are shown at the same cross-section as the actual casting.

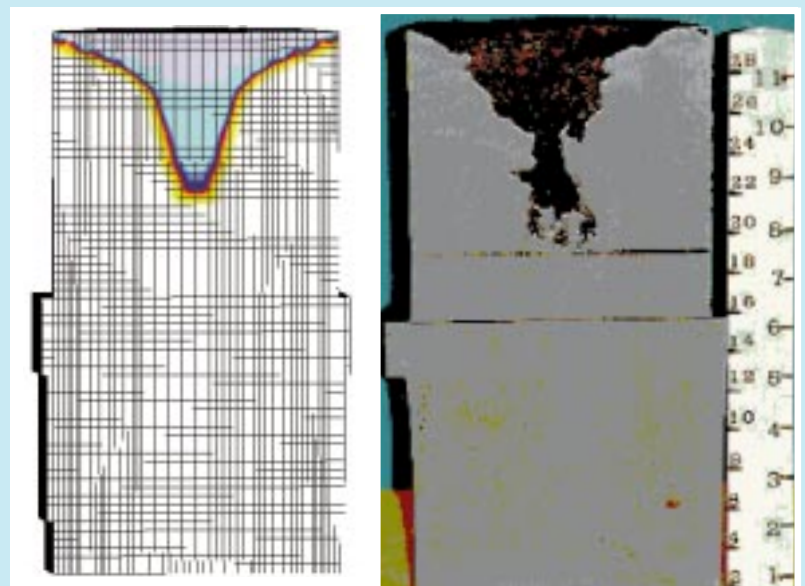


Figure 2: Feeding comparison for 4"x 6" low density, insulating feeding system configuration

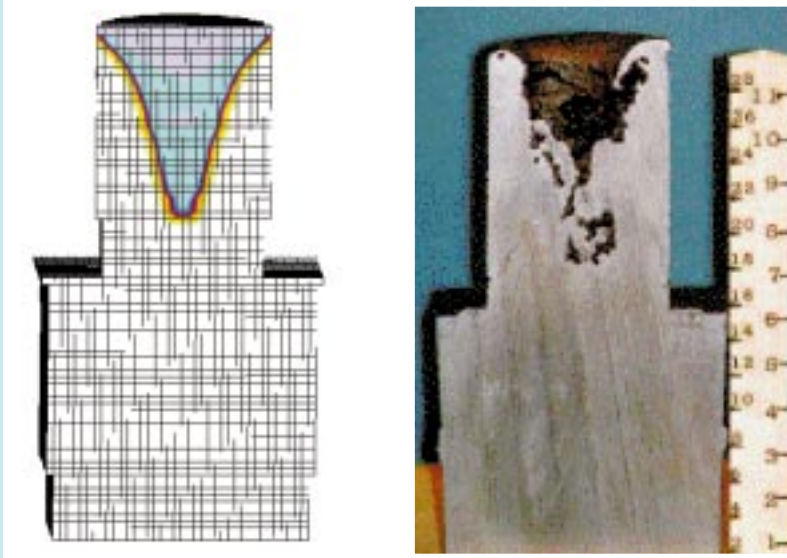


Figure 3: Feeding comparison for 4" x 6" medium density, exothermic/insulating feeding system configuration

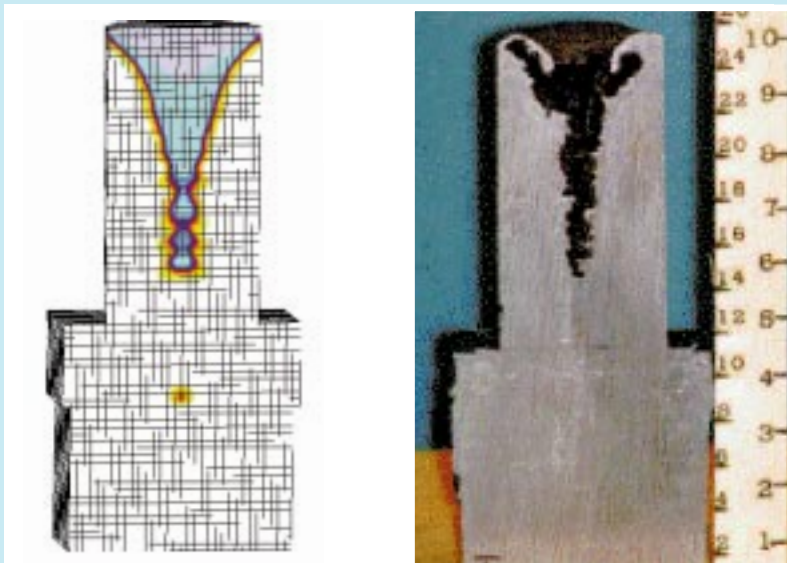


Figure 4: Feeding comparison for 3" x 6" medium density, exothermic/insulating feeding system configuration

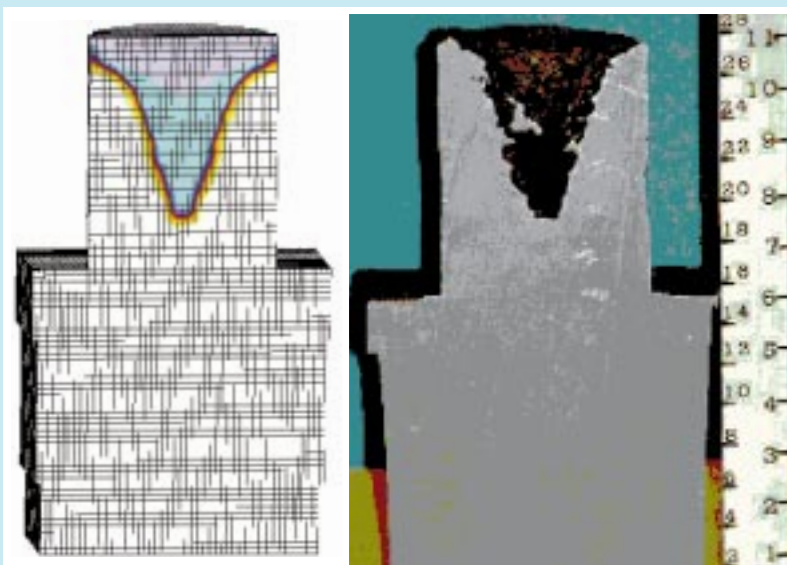


Figure 5: Feeding comparison for 4" x 5" low density, exothermic/insulating feeding system configuration

Feed safety margin is determined visually and defined as the height of sound metal above the riser contact, expressed as a percentage of the poured height of the riser. It is also important to note that the predicted macroporosity should be compared to X-ray results for the highest accuracy, as opposed to the visual comparisons that are made here. However, a valuable comparison can still be made using visual methods.

Figure 2 shows that actual riser had approximately 26% safety margin, while the simulation predicted approximately 32% safety margin. Similar excellent agreement has been experienced between predicted and measured results for other castings using this combination of low density, insulating sleeve and low density, exothermic/insulating hot topping, including low carbon steel in green sand and furan molding materials.

Figure 3 shows the measured and predicted feeding results for a 6.25 inch casting with a 4" x 6" top riser sleeve. The measured results show a 19% safety margin, while the predicted results show 25%. Agreement is within 6%, and the predicted pipe shape is very similar to the actual shape.

Figure 4 shows the measured and predicted feeding results for a 4.5 inch cube with a 3" x 6" top riser sleeve. The measured results show a 22% safety margin, while the predicted results show 19%.

Figure 5 shows the measured and predicted feeding results for a 6.25 inch casting with a 4" x 5" top riser sleeve. The measured results show a 32% safety margin, while the predicted results show 26%.

Figure 6 shows the measured and predicted feeding results for a 4.5 inch cube with a 3" x 6" top riser sleeve. The measured results show a 40% safety margin, while the predicted results show 37%. For all of the sectioned cube castings analyzed, the predictions agreed with the measured results within +/-6% for insulating and exothermic/insulating feeding systems. The results are summarized in table 1.

Sleeve type (size)	Figure	Predicted safety margin (%)	Measured safety margin (%)
Low density, insulating	2	32	26
Medium density, exothermic/insulating	3	25	19
Low density, exothermic/insulating	4	19	22
Low density, exothermic/insulating	5	26	32
Low density, exothermic/insulating	6	37	40

Table 1: Measured vs predicted safety margin

The data was also evaluated using actual castings. The predicted feeding results are in agreement with actual results. Feeding predictions agreed within +/-10% with test results for 6" to 20" diameter riser sleeves. These results cannot be shown at this time due to the proprietary nature of the castings. However, additional foundry trials are underway to further validate this information.

Conclusion

The riser pipe performance for a series of test castings was quantified for visual porosity (riser pipe), and safety margin was calculated from these results. Comparisons of predicted and measured feed safety margin for the test castings showed that the predicted results agreed within +/-6% of measured safety margin. Comparisons of actual foundry castings show +/-10% agreement for risers from 6" to 20" in diameter.

Feeding system performance can be accurately and reliably predicted using the newly developed thermal data and current casting process simulation software. Development will continue to improve the accuracy of the thermal information, and to test and develop other products.

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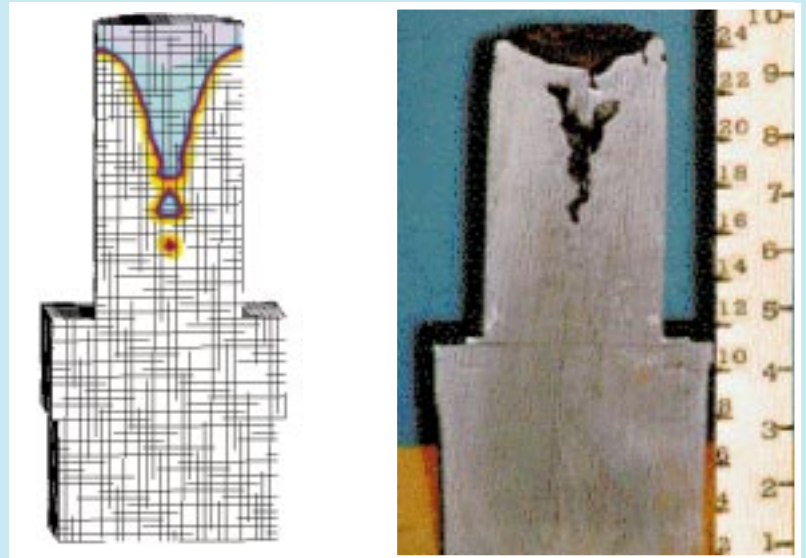


Figure 6: Feeding comparison for 3"x 6" low density, exothermic/insulating feeding system configuration

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