Process Optimization to Maximize Simulation Payback

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ARTICLE TAKEAWAYS:

- Casting Simulation is much more efficient than shop-floor trial-and-error
- Optimization can maximize simulation paybacks
- For larger production volumes, savings of over $100,000 in melt costs are possible

Casting process simulation has been used by many foundries to design the process for production of castings before castings are made or before equipment is built or altered. Computer modeling has the ability to evaluate process designs in much less time, and at much less cost, than building equipment and producing sample castings.

In effect, we have replaced the traditional trial-and-error on the foundry floor with trial-and-error on the computer. The advantage is that the time and cost have been reduced. However, we are still dependent upon the foundry engineer to interpret simulation results and decide what changes are required for the next design iteration. And, once an acceptable result has been achieved, we still do not know if the result is optimum. For example, is this the smallest riser size that would produce a sound casting, or could we have gone smaller?

To advance beyond the trial-and-error stage, **OPTICast**™ was developed to apply optimization methods to simulation, so that the design of a given casting with its rigging could be automatically modified to produce an optimum condition, thereby maximizing simulation payback.

Optimization requires the identification of three basic parameters:

1. Design Variables

These are features of a design that can change as the system searches for an optimum condition. Design variables may be geometric features such as the diameter and height of a riser. They may also be process specifications such as the metal pouring temperature.

For geometric variables, a scaling factor is used on both horizontal and vertical dimensions to adjust the feature size within an operating 'envelope.' For process data, you specify the allowable range for that item.

2. Constraints

Constraints are values of process data above or below which a result is not allowed. Constraints may be specified as a minimum or a maximum condition value. One or more constraints may be specified for each optimization run. An example would be a maximum allowable porosity level.

3. Objective Function

The objective function specifies what is trying to be achieved with a given process design. The user selects an objective function and specifies whether the function is to be minimized or maximized. You might select minimizing shrinkage porosity, or you might want to maximize process yield. Only one objective function can be specified for each optimization run.

OPTIMIZATION SEQUENCE

Optimization takes place according to the process flow diagram shown in Figure 1.

The sequence of an optimization run is, first, for the user to create an initial process design, i.e., a three-dimensional model of the casting with gating and risering, and all relevant material data. This is the same data required for any casting simulation. The user then selects the design variables, constraints and objective function and launches an optimization run. Optimization consists of running a series of simulations automatically, varying the values of the design variables, checking to make sure that constraints are not violated,

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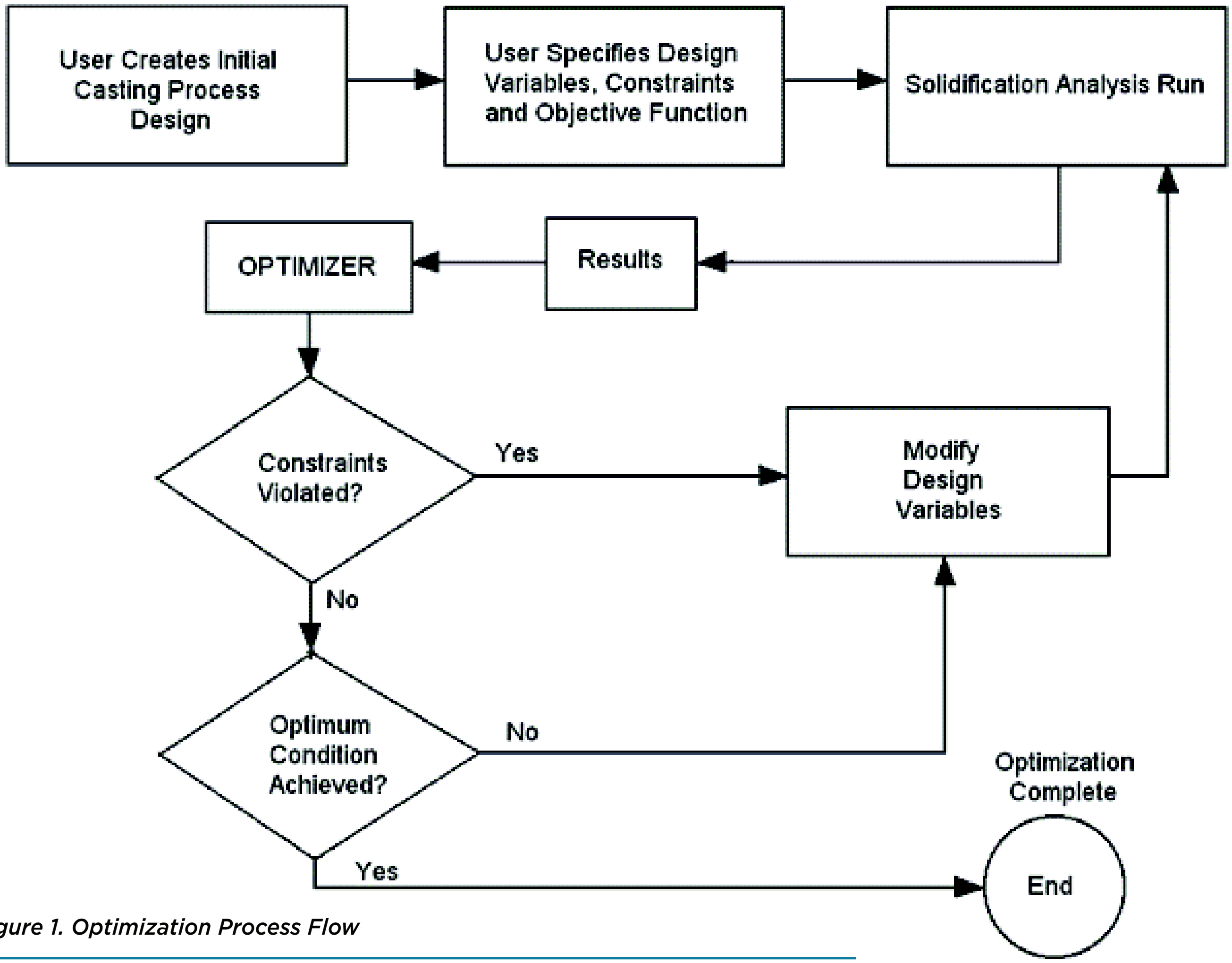

Figure 1. Optimization Process Flow

and searching for a maximum or minimum value for the selected objective function.

The most common method for optimizing a casting for soundness would be to specify one or more porosity predictors as constraints, and then maximize the process yield. This allows the system to identify those designs which produce a sound casting, then select the design which maximizes the material yield.

OPTIMIZATION CASE STUDY

Here is a quick example to show how optimization has been applied in the foundry.

The casting was being made successfully. That is, a sound part was being produced. The goal was to maximize casting yield by reducing the riser size, while still maintaining part soundness. Figure 2 shows the shrinkage prediction for the part with the original riser.

The variables selected for optimization were the height and diameter of the riser. Since there were 8 castings per mold with one riser each, the risers were linked together for optimization. Figure 3 shows two of the risers selected. The height and diameter were scaled, so that the riser and contact would expand and/or shrink during the optimization runs.

A single constraint was selected; macro-porosity. The casting needed to be shrinkage-free to be considered good. Loss of density in any part of the casting would be cause for rejection.

The objective function of the optimization was to maximize casting yield. Since the casting shape would not change, this means that the riser size would need to be reduced to maximize the yield.

Once the optimization run starts, the entire process is automatic. In this example, 26 simulations

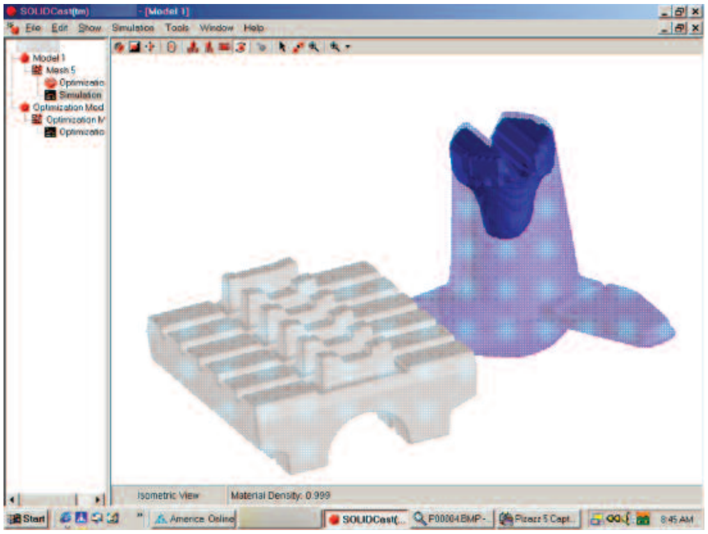

Figure 2. Shrinkage Predication for Original Risering

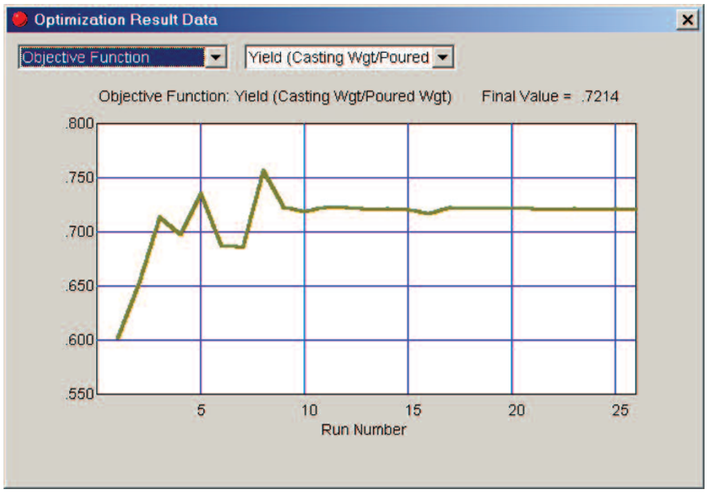

Figure 4. Progression of Yield Improvement during the optimization run.

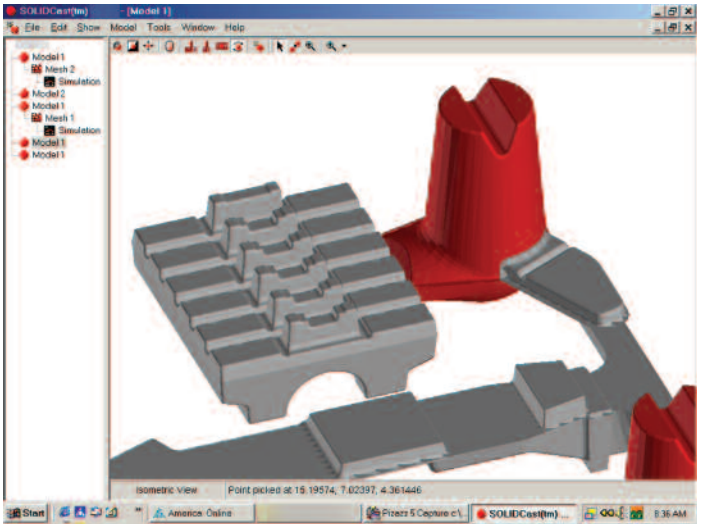

Figure 3. Riser Height and Diameter were selected as optimization variables

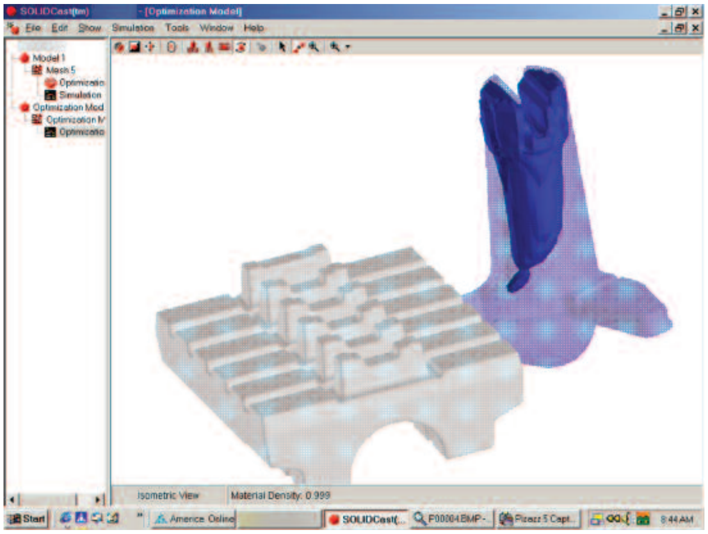

Figure 5. Shrinkage Prediction in the Optimized Riser Configuration.

were required to achieve the optimum result. Total computer time was less than 2 hours.

Figure 4 shows the progression of process yield during the simulations. The original riser design gave a process yield of 60%, and the final result was a process yield of over 72%.

You can see that in some of the earlier runs there appears to be a better process yield than the final result. These runs violated the constraints for the run in that there was shrinkage detected in the casting. Final shrinkage predication for the optimized risering is shown in Figure 5. You can see that the riser is used much more effectively than the original configuration.

The riser size reduction was 6.64 lbs. Since each mold had 8 impressions, the total weight savings per mold was 53.1 lbs. Since this was a high production situation, this resulted in a melt savings of over 1800 tons of metal per year. The annual energy savings was 1,980,000 KWH and the annual cost savings was over $100,000.

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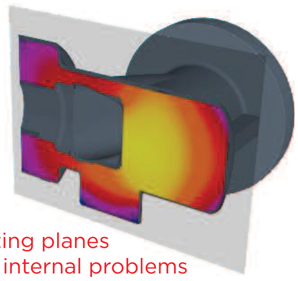

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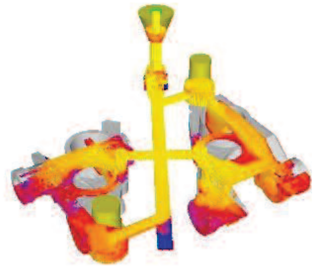

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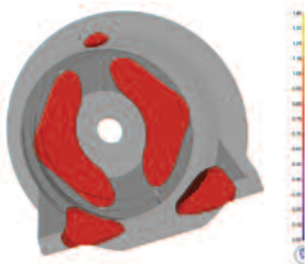

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Finite Solutions Inc. has spent over 35 years developing the world's most PRACTICAL simulation solution. We use simulation to help CREATE an effective rigging system, not just to test an existing design. Results from an unrigged simulation of the casting are used directly to design efficient gating and risering, both for shrinking alloys and for graphitic irons. Methods are confirmed using CFD-based fluid flow analysis and combined thermal/volumetric solidification calculations. We provide the most accurate analysis, in the least amount of time, all at the lowest cost.

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