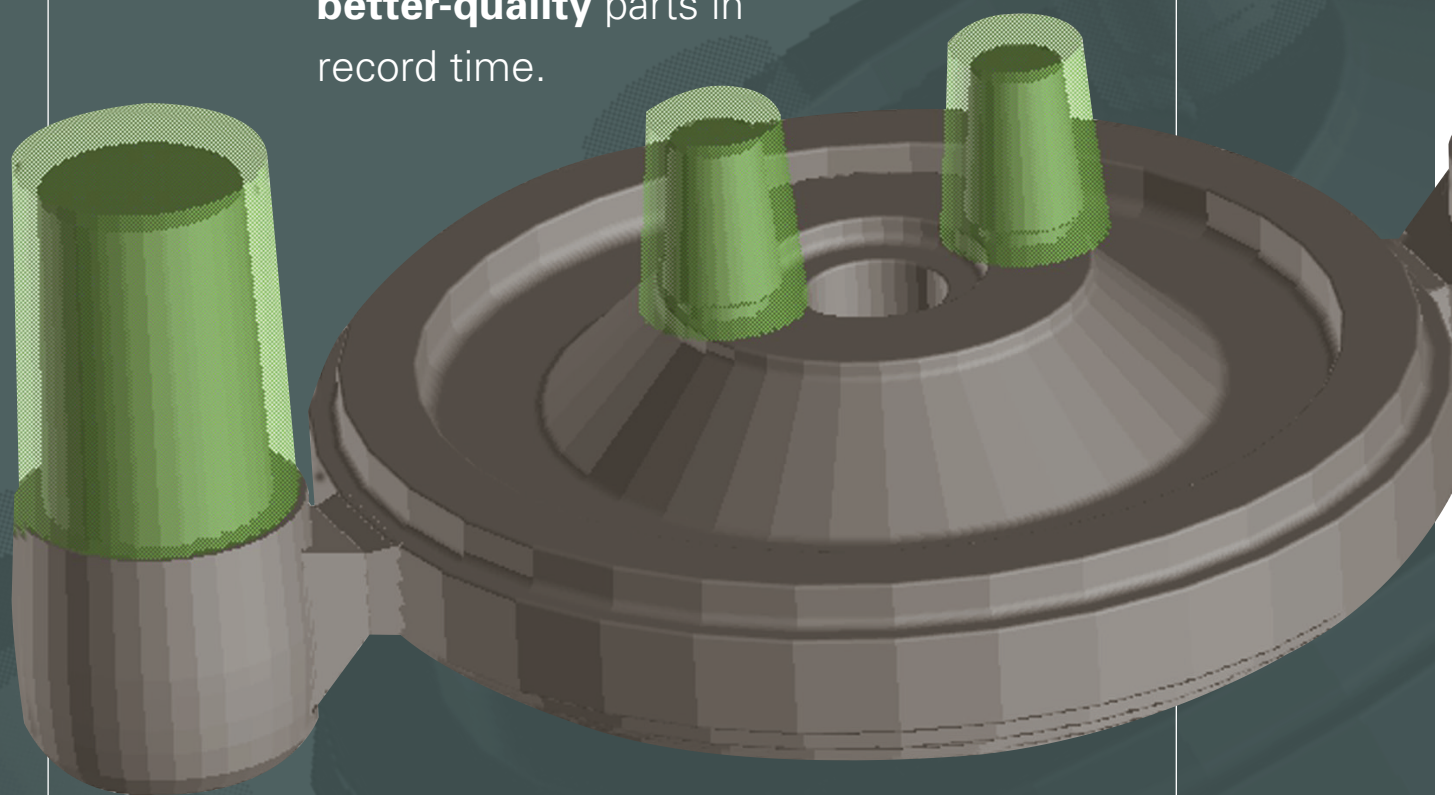
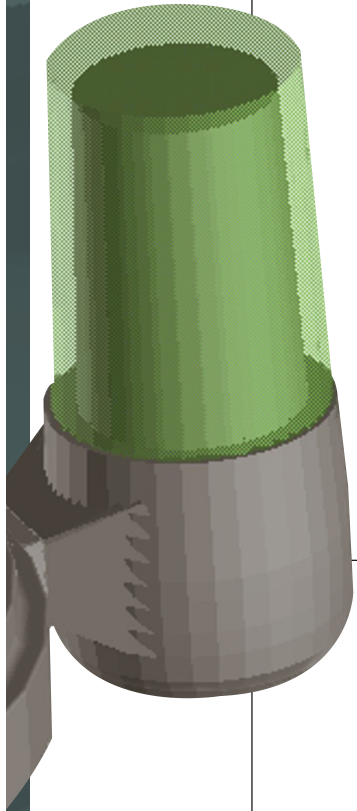


By applying
**optimization
technology** to **casting
process** design,
manufacturers can
produce less-expensive,
better-quality parts in
record time.



This model of a process design for a cast iron flywheel was optimized with OPTICast simulation software.



Get the Most from Your Casting Process

By **Lawrence E. Smiley**
Finite Solutions, Inc.

One of the most fundamental processes for manufacturing metal parts is casting. This technology can be traced back several thousand years to a time when ancient civilizations cast weapons and cooking utensils. Today, casting thrives and is widely used to make automotive, aeronautic and machine parts.

The science of process design for casting has developed relatively slowly until recently. Rule-of-thumb and empirical procedures, along with much trial and error, characterized this discipline over the past century. Within the last decade, computer simulation of the process has come into general use, providing the casting engineer with a more scientific basis upon which to design. However, even with simulation, the design process itself has tended to be basically a trial-and-error search for an "adequate" design.

The state of the art in simulation is now changing even more rapidly. In August 2001, the first commercial system for optimization of the casting process was released. Based on a marriage of Altair Engineering's optimization software and Finite Solutions' SOLIDCast simulator, the new system – dubbed OPTICast – offers casting engineers a rational and automated design methodology that was not previously available.

Riser Relevance

Casting engineers struggle with physics to produce a good, high-quality part. One of the basic complications is that when liquid metal cools and freezes, it contracts and becomes dense. If the casting process is not designed correctly, then this contraction will result in holes, or "shrinkage porosity," within the metal part. Such a defect can cause a cast part to fail under stress or even interfere with the function of the part if machining operations expose the defect.

The usual solution is to provide a shape attached to the casting which can serve as a delivery source of liquid metal during solidification, "feeding" metal into the casting to compensate for the contraction. In the jargon of the trade, these

shapes are known as “risers” or “feeders” and are removed from the casting net shape by cutting or grinding operations.

This situation creates something of a dilemma for the casting engineer. Larger risers tend to ensure the absence of shrinkage defects in the casting. However, risers add to the cost of producing a part: the metal in the risers is not part of the finished casting, but it must be melted, poured, removed and handled as part of the process. Therefore, the smaller the risers, the lower the cost of producing a casting.

Given today’s extremely competitive environment, it is essential to find the “perfect” riser size, not only to keep defects from forming but also to hold extraneous metal cost to a minimum. The OPTICast system does just that – and more.

On the Optimization Path

The initial design of the OPTICast system began in early 2000 as a project sponsored by the Edison Materials Technology Center (EMTEC), an organization in the state of Ohio whose mission, in part, is to encourage technology development and application in materials processing industries, including foundries. EMTEC provided the funding for the project and brought together the participants, whose mission was to link casting simulation and optimization technology to further improve the casting design process.

To accomplish that goal, Altair and Finite Solutions’ team members developed an interface to the Altair optimization software and created a method to automatically adjust model geometry and initial conditions based on changes suggested by the optimization system. Developers considered other issues, such as identifying

which features of the model would be made available as “design variables” and which outputs could be used for “objective functions” and “constraints.”

For example, developers designated the size of the riser, initial material temperatures and pouring time as key design variables. They determined that one of the most useful combinations of potential constraints and objective functions involved specifying the level of predicted shrinkage porosity within the casting as a constraint and asking the system to maximize the process yield – defined as the ratio of the net weight of the casting to the weight of total metal poured – as the objective function. This results in the system finding the least amount of metal which will produce a cast part with a desired quality level.

OPTICast in Action

The optimization software speeds up the casting design process, as illustrated in the following example, in which the casting designer’s goal is to decide if the current design has resulted in a “good part” at the lowest possible cost.

The first step is for the user to identify the model features which are to be considered design variables, as shown in Figure 1. Here, one of the large side risers, displayed in red, has been selected. The minimum and maximum scale factors are specified, defining the design space for this riser. The user also needs to indicate a “pin point,” which is a point on the selected shape that will stay at a constant location while the shape expands and contracts.

Once these items are specified, the next feature (one of the other risers) is selected as an additional design variable, and the same information is entered. This continues until all risers have been selected.

The user then optionally selects one or more constraints and the objective function from a list of system outputs. Once these selections have been made, the optimization project is launched. This just requires the user to click a menu selection. The process after that point is totally automatic.

The software runs a series of process simulations with changes in the design variables. The system automatically modifies the model each time, and results are compared to the constraint(s) and objective function.

Once the optimization is complete, the final model is available for display and postprocessing of results within SOLIDCast. In addition, the progress of the optimization

To optimize the design of one of the flywheel’s risers, the user simply selects the riser (shown in red) and enters the horizontal and vertical limits on its size. The software does the rest.

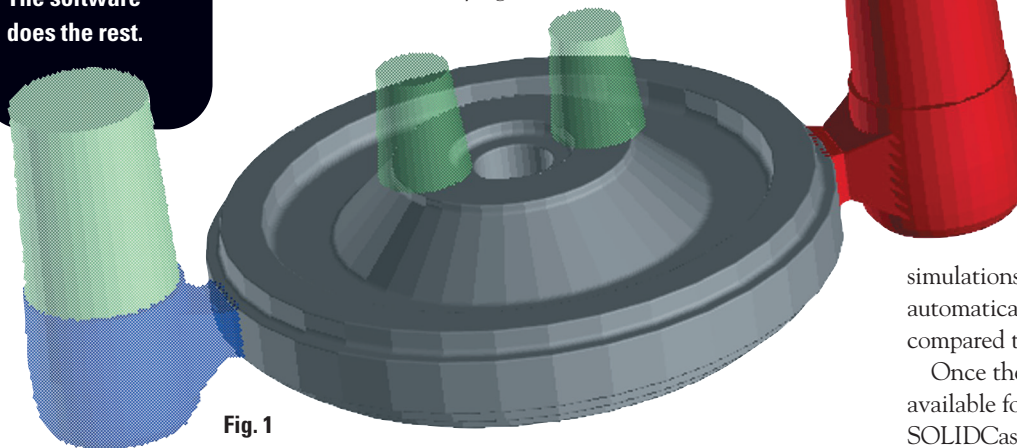


Fig. 1

can be examined either graphically or by loading a spreadsheet showing progressive values of design variables and output data.

Seeing is Believing

One of the reports OPTICast generates is a plot of progressive values of the objective function. The process yield in the example was increased from an initial value of 63% to more than 80% by running 15 process simulations. This yield increase was achieved by downsizing the risers to about 73% of their initial size.

In this case, the amount of metal saved per casting poured was about 100 lbs (45 kg); total material savings were 75,000 lbs/yr. The annual cost savings for production of 750 parts amounted to about \$9,000 (U.S.) dollars. What's more, annual energy savings due to reduction in the amount of metal required to be melted were about 27,000 kwhr, with a projected cost savings in kwhr of \$2,700/yr.

For verification of the optimization results, the user can examine the final optimized model. For example, a time plot shows progressively solidified areas within the casting and risers (Figure 2). Another plot demonstrates calculated metal feeding patterns due to contraction of the metal (Figure 3).

From one relatively simple example, you can see that optimization has the potential to significantly reduce costs and energy usage while maintaining or improving quality in the casting process. The total amount of time required to define this project, run the optimization and analyze results was less than half a day, yet the annual payback was more than the initial cost of the software. Given the number and variety of parts cast in the world industry, the application of optimization to casting process design has tremendous potential.

In addition to yield improvement, it is possible to approach quality maximization for critical parts through proper selection of constraints and the objective function. For example, the strength of the material in a casting is related to the cooling rate of the metal while the casting is

Postprocessing results from OPTICast include a time plot of progressive solidification within the cast part (Fig. 2) and a plot of final results showing feed material as supplied by the risers (Fig. 3). No indication of shrinkage porosity is seen in the casting itself.

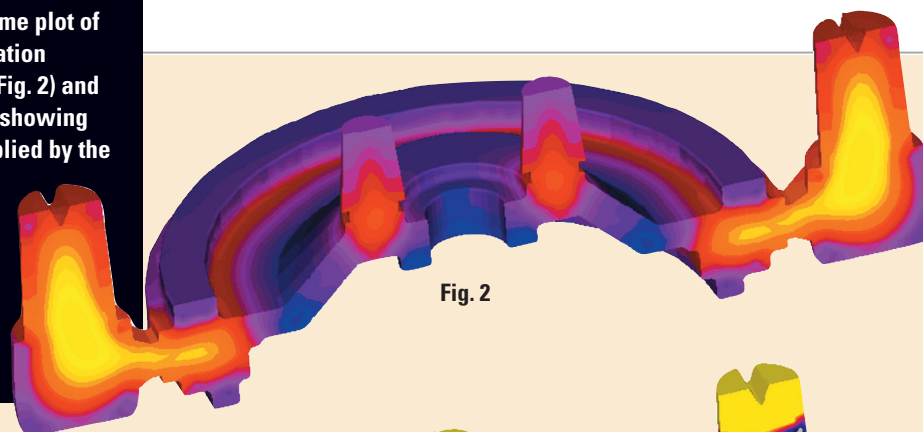


Fig. 2

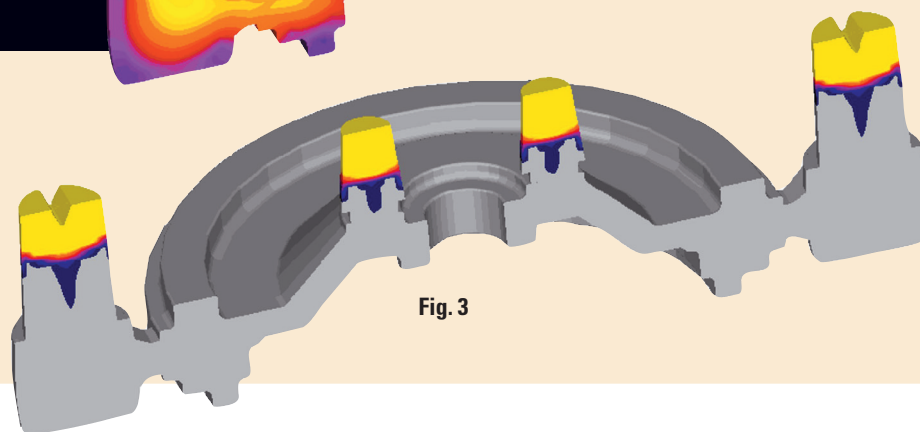


Fig. 3

solidifying: higher cooling rates generally translate into better material properties (higher yield and ultimate strength). Optimizing a casting for maximum cooling rate, while constraining the formation of internal defects, can result in a part that can withstand higher loads – and that performs better over its lifetime.

In the past several months, there have been a number of successful applications of OPTICast in a variety of casting processes. EMTEC Program Manager Percy Gros says, "We have member companies that have expressed their desire to immediately make great use of this new OPTICast product."

Application of optimization to casting process design essentially represents a new paradigm in the industry. It is no longer necessary for the design engineer to examine each process simulation and make a decision as to whether the process is complete, and if not, what should be changed next. Using optimization, the engineer can spend his/her time more productively on problem definition. This nudges the design engineer, perhaps unconsciously, into taking a more rational approach to the overall design process and will ultimately result in more successes. Those companies that aggressively adopt this new technology will find themselves at a competitive advantage in today's global market. **C2R**

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