OPTIMIZING INVESTMENT CASTED PARTS WITH SIMULATION AND 3D-PRINTING

Investment casting is a valued manufacturing process known for its ability to produce detailed components with accuracy, repeatability, and in a variety of different metals, waxes, and high-performance alloys. Producing high-quality casted components is less prone to common design errors when a simulation-driven approach is used, leading to easier, more accurate analysis and optimization during the design phase.

The process for investment casting begins with forming a shell made of a certain material around a wax pattern. From there, the wax pattern is melted and removed in a furnace, and before the shell cools, a metal alloy is poured into the shell to create the casting.

Designers value investment casting for creating complex shapes and molds that would be difficult or impossible with other casting methods. Although the investment casting process enables intricate part design, this type of manufacturing process comes with high material expenses and can be susceptible to manufacturing defects that require multiple rounds of redesign and prototyping.

Challenges Faced by Mold Designers

Casting defects such as air entrapment, porosity, mold degradation, and cold shuts can be overseen during design when a simulation-driven design approach isn't implemented early in casted part development. Designers want to avoid the "trial and error" approach when evaluating parts because that only leads to longer time-to-market and major frustration for design and production teams.

In terms of cost, wax patterns can only be used once each time a part is made. This requires foundries to have access to master molds so that multiples can be produced, but this becomes expensive quickly as each part has its own unique requirements. Because of the intricacies of the investment casting process, making the right design choices the first time around is the key to cost savings for these manufacturers.

By using simulation tools for manufacturing, beginners and experts alike, from product designers to foundry engineers, can easily navigate product workflows within a highly intuitive casting simulation environment. Designers can visualize potential mold and die errors before having to face costly corrections down the line.

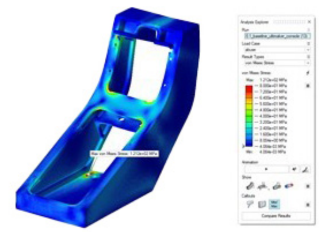
Aerospace Casting Optimization at Solidiform

Solidiform is an aluminum aerospace investment casting foundry based out of Fort Worth, Texas. Partnering with Altair and two other companies, they were tasked with optimizing and reducing weight on an aircraft instrument housing for a defense supplier customer.

The original design of the aircraft instrument housing to be optimized.

Using investment casting simulation and topology optimization methods, the project aimed to reduce weight of the component without compromising strength and durability in critical areas. The ultimate objective was to reduce aircraft fuel consumption, while exceeding the performance of the baseline existing design. Altair Inspire™ software was used as the platform for the design optimization, as well as for modeling the gating design and for creating both a filling and solidification simulation. This simulation-driven design tool includes structural analysis and optimization tools in a streamlined, designer-oriented interface.

Along with Solidiform, Ultimaker, a 3D printer company that led development of the printed patterns for the casting, assisted in the project. The fourth company was Polymaker, a supplier of additive manufacturing materials whose Polycast material was used for the 3D printed pattern.



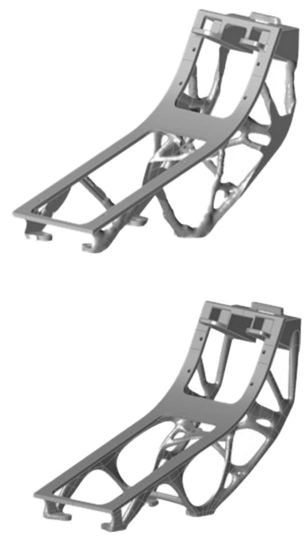
The stress contour plot of the original design shows where stresses were found in the casting.

Determining Design Stress Limits

Before beginning the component's optimization, the team had to determine a stress limit for the component that could not be exceeded under load. To estimate that limit, a finite element model of the design was created in Inspire to test two separate load cases. The first was the load exerted on the housing by the instruments themselves undergoing g-forces. The second was an abuse load, due to the housing being located in a position where it became a convenient footrest for pilots. After finding the stress limits, the team began the optimization process.

Optimizing the Design

Optimization is an iterative process. Wherever stresses found in the model are low, material is removed. Wherever stresses are high, material is added to the model to reduce stress levels. The analysis is then repeated on the modified model. This process is repeated dozens or even hundreds of times to reach an ideal optimized geometry, and all the calculations and iterations are completed by the tool automatically. The optimized geometry is often organic in appearance, sometimes looking very much like a bone structure.



The optimized geometry before and after smoothing.

In Altair Inspire™ software, users can indicate the manufacturing process that will be used to manufacture the design, and the software will apply constraints specific to the chosen manufacturing process. For example, if casting is selected, there will be a minimum wall thickness and draw direction constraint to consider. Manufacturing processes that can be specified in Inspire include casting, machining, 3D printing, and stamping. Without process-related constraints, the optimization process may result in a design that is not manufacturable by traditional manufacturing processes. By applying constraints, users can be confident that their chosen design will be as efficient as possible and manufacturable with the selected manufacturing process.

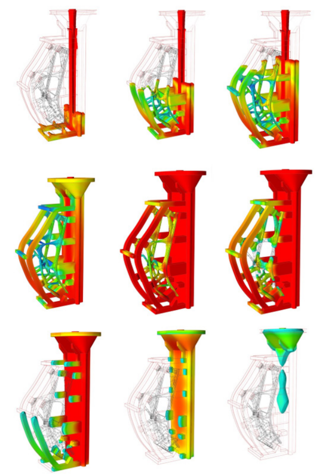
To improve the surface finish, the software was used to automatically generate a smoother geometry to satisfy both the structural and manufacturing requirements. The optimized casting would weigh 1.66 pounds, a reduction of 3.06 pounds. This 65% reduction in weight far exceeded the customer's goal.

Addressing Manufacturability Issues

The optimization results were successful, but two main issues with casting the optimized design were found. First, the design was complex and not easily moldable, requiring printed patterns to be used. Second, the design was challenging to cast due to two potential casting issues: filling and shrink voids.

The gating design created by Solidifom.

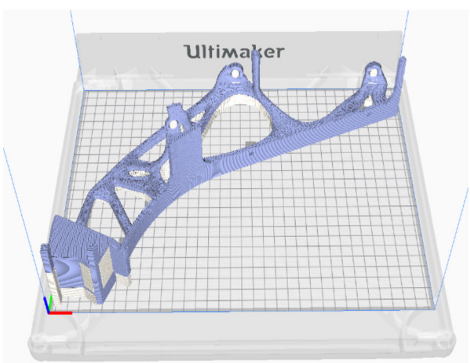
To combat these issues, Solidiform created a gating design which could be validated through a filling and solidification simulation using Inspire Cast. When utilized early in the design process, users can visualize common casting defects such as air entrapment, shrinkage porosity, cold shuts, or mold degradation within the module. The tool allowed the team to quickly determine whether the gating design would result in a casting filled completely and with no shrink voids. The analysis showed that the mold could be filled without excess turbulence and solidify without significant porosity or residual stress.

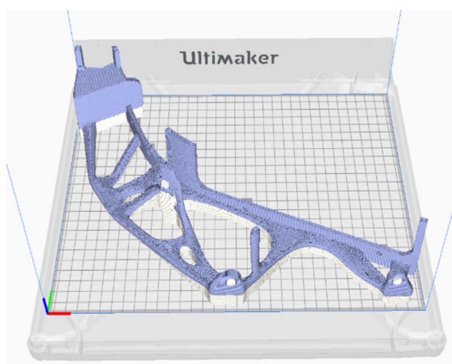


The filling and solidification analysis at several different points in a 4-second fill and 25-minute solidification.

Once determining that a casting could be created with the proposed gating system, Ultimaker provided patterns for the optimized casting design. It was printed using Polycast, a filament designed specifically for investment casting.

Initially, the pattern was going to be printed as a single piece. However, because of all the supports required, the team decided to build the pattern in two halves. By doing so, this cut the build time and material required in half. In conjunction with Altair, the design was divided in two parts with locating features as shown below, processed in Ultimaker Cura.





For more information on this simulation-driven design project, click here.

The final casting after proceeding through the entire investment casting process is shown here. With the new design, the team was able to reduce the component's weight by 3.06 pounds for an annual fuel savings of $60.71 per aircraft. Although the cost of moving forward with the new design for the company would be higher than costs of the current design, the benefits of outfitting a fleet of aircraft with this lightweight instrument housing outweighed the upfront cost of the design change.

The optimized casting.

Working with Altair

Tools that guide manufacturing processes should make simulation as easy as possible, with both designers and manufacturers in mind. Altair's manufacturing technology was developed so that designs can be validated early in any given manufacturing process, and optimization can be completed efficiently with full access to specific manufacturing constraints.

Learn more at altair.com/manufacturing-applications