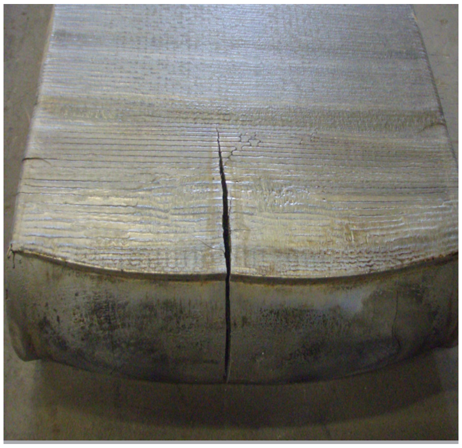
Eliminating Defects and Saving Energy in Aluminum Manufacturing

Livermore and Oak Ridge apply machine learning tools to optimize off-the-shelf modeling software for aluminum casting.



Energy expended to remove cracks in aluminum ingots to meet high quality standards costs the U.S. aluminum industry millions of dollars annually.

High Quality Aluminum Comes with High Costs

Coils of aluminum sheet metal get their start as immense ingots that are drawn from molten aluminum in Direct Chill (DC) Casting facilities. Some aluminum ingots must be reprocessed to meet high quality standards set by customers in the aerospace and automotive industries. Ingots may be cropped to remove end cracks or individually machined to remove defects on the rolling face. Occasionally, casting rounds are completely abandoned. While aluminum can be readily melted for another casting round, the energy expended to remove cracks and melt recycled aluminum is wasted.

Metal engineering and manufacturing company Arconic and other domestic producers cast billions of pounds of aluminum annually. An estimated $60 million per year in energy savings could be achieved if the entire U.S. aluminum industry cut its ingot scrapping rate by 50%. Those savings do not include the additional energy expended during downstream processing of scrapped ingots.

However, predicting the probability of defects across all possible process conditions—such as casting speed and cooling rate—for each alloy can be difficult. Pilot experiments are expensive, hazardous, and difficult to control, preventing manufacturers from moving beyond commonly accepted practices and finding unexpected innovations. Computer simulations provide an alternative to the experimental approach by predicting the likelihood of defects for different manufacturing conditions.

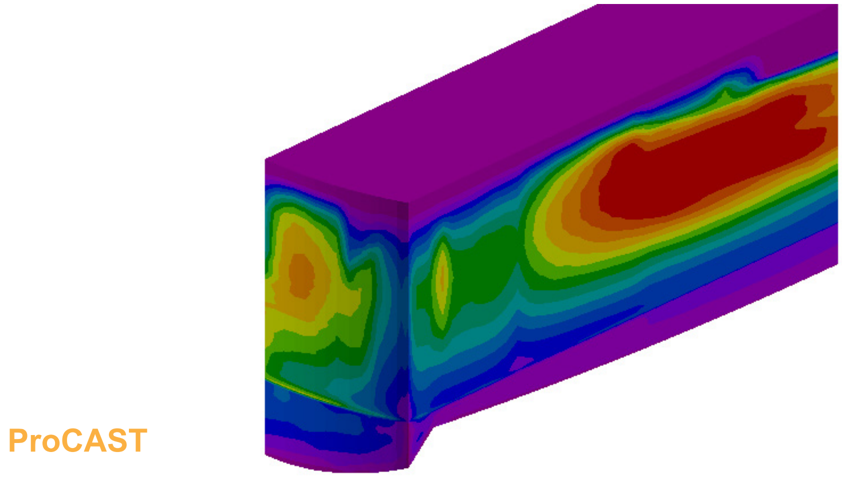
Arconic learned about Oak Ridge and Livermore's past success using the Lab's high performance computing (HPC) capabilities to model industrial processes quickly and accurately.

The company entered into a Cooperative Research and Development Agreement (CRADA) supported by the Department of Energy's High Performance Computing for Manufacturing (HPC4Mfg) program. HPC4Mfg aims to provide expertise and supercomputing resources to industry partners to improve industry competitiveness and reduce energy consumption.

Modeling Outperforms Trial-and-Error Approach

The industry/laboratory team at Oak Ridge optimized off-the-shelf modeling software ProCAST to quickly identify ingot processing inputs that minimize cracks by developing a casting model on high performance computing hardware. The model was validated through multiple casts under a range of manufacturing conditions. Each simulation required several days. Researchers determined that the model successfully predicted the interaction of heat, solidification, microstructure, and strength development to support improved aluminum DC casting.

Next, the Livermore team coupled the casting simulation data to numerical optimization and sampling codes. The resulting machine learning solution quickly determined the success or failure of casting with any set of parameters.



Commercial modeling software—ProCAST—was optimized at Oak Ridge for high performance computing simulations. Casting parameters simulated in this example would yield high potential for defects in the red, orange, and yellow regions.

As a result, predictions that used to take days to complete in the initial model now take Arconic minutes using ProCAST in its own offices. In addition, the researchers found casting solutions unlikely to be revealed by trial-and-error experiments.

Improving U.S. Competitiveness in Metals Manufacturing

The HPC4Mfg project potentially opens new markets to Arconic by enabling the company to cost effectively meet standards from aerospace and automotive customers. The company will save time and energy by casting ingots with fewer defects and save the volume of cooling water required when recasting scrapped ingots.

With modifications, the model could apply to all materials manufacturing including steel, titanium, nickel-based alloys, and different aluminum alloys. Based on Arconic's estimates, eliminating half of scrapped materials across all U.S. structural material casting industries could save $365 million per year in energy costs. By increasing the production and material quality at lower prices and reduced energy consumption, U.S. materials companies could gain greater advantage in an industry with many foreign competitors.

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