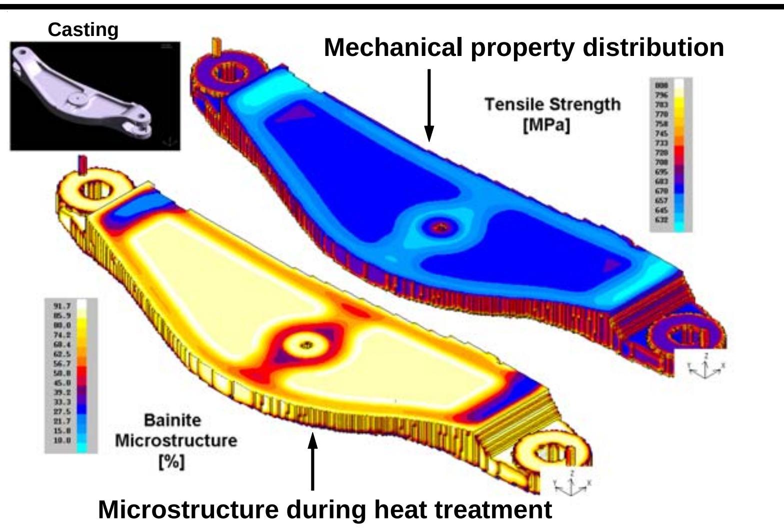
Industrial Technologies Program

Simulation of Distortion and Residual Stress Development During Heat Treatment of Steel Castings

Heat treatment and associated processing, such as quenching, are critical during high strength steel casting production. These processes must be managed closely to prevent thermal and residual stresses that may result in distortion, cracking (particularly after machining), rework, and weld repair. The risk of casting distortion limits aggressive quenching that can be beneficial to the process and yield an improved outcome. As a result of these distortions, adjustments must be made to the casting or pattern design or tie bars added. Straightening castings after heat treatments can be both time-consuming and expensive. Residual stresses may reduce a casting's overall service performance, possibly resulting in catastrophic failure. Stress relieving may help, but expends additional energy in the process. Casting software is very limited in predicting distortions during heat treatment, so corrective measures most often involve a tedious trial and error procedure.

According to researchers from the University of Iowa, the casting process must be considered when attempting to predict the final dimensions and residual stresses that may develop after heat treatment. These researchers have investigated the stresses and distortions that develop during solidification and cooling, before the heat treatment stage begins. Extending modeling capabilities to the heat treatment processes, the researchers will examine microstructural and property changes in the steel, in addition to heat transfer and stresses that develop during the heating and quenching processes. The proposed project will develop and verify a model for predicting the distortions and residual stresses that occur during heat treatment of steel castings.



Mechanical property and microstructure development (shown above at a cross-section of the casting) will be integrated into prediction of stresses and distortions that form during heat treatment of steel castings.

Benefits for Our Industry and Our Nation

- *Accurately predict stress development and relief during heat treatment so that full advantage can be taken of improvements in furnace control.*
- *Increased casting yield from reduced scrap and the efficient use of heat treatment resources gives an energy reduction of 1.43 trillion Btu/year.*
- *Significant casting weight savings and longer service lives for steel castings.*

Applications in Our Nation's Industry

This research will develop and verify a computer model to predict microstructural changes, heat transfer, and residual stresses in the steel that occur during heat treatment of steel castings. This model will assist the steel castings industry in designing high strength steel castings and preventing distortion, cracking, rework, and weld repair.

Project Description

The goal of this project is to develop a model for predicting the distortions and residual stresses that develop during heat treatment of steel castings. Foundry engineers will then be able to reduce trial and error processing, and economically use heat treatment resources.

The objectives of this research are:

- Develop and implement a model into an existing casting simulation code to predict distortion and residual stress development during heat treatment of steel castings.
- Perform a casting/heat treatment experiment to test and validate the model.
- Apply the simulation model to a production casting in a case study illustrating the use of the model in foundry practice.

Milestones

The tasks for this project are:

1. Develop a model of microstructural evolution during heat treatment: Develop a model of microstructural evolution during heat treatment and an improved model during plastic deformation.
2. Develop a model of heat transfer and stresses during heat treatment: Develop a model of microstructural evolution during heat treatment, properties and an improved model of their effects on plastic deformation.
3. Implement models into a commercial casting simulation code in MAGMASOFT: Researchers from the University of Iowa will directly collaborate with MAGMASOFT to implement the model into a commercial casting simulation code.
4. Perform validation experiment and compare to the results of a simulation of the experiment: Perform a small-scale experiment to test and validate the model at participating steel foundries.
5. Perform a case study on production part illustrating the use of the model in foundry practice: Carefully compare predictions of the model to casting measurements to illustrate the use of the model in foundry practice.

Project Partners

University of Iowa
Iowa City, IA

Steel Founders Society of America
Crystal Lake, IL

Cast Metals Coalition Partnership
Charleston, SC

Atlas Casting Technology
Tacoma, WA

Magma Software
Arlington Heights, IL

Matrix Metals Co.
Richmond, TX

Pacific Steel Casting Company
Berkeley, CA

Sivyer Steel Corp.
Bettendorf, IA

Stainless Foundry & Engineering
Milwaukee, WI

A Strong Energy Portfolio for a Strong America

Energy efficiency and clean, renewable energy will mean a stronger economy, a cleaner environment, and greater energy independence for America. Working with a wide array of state, community, industry, and university partners, the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy invests in a diverse portfolio of energy technologies.

U.S. Department of Energy
Energy Efficiency
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