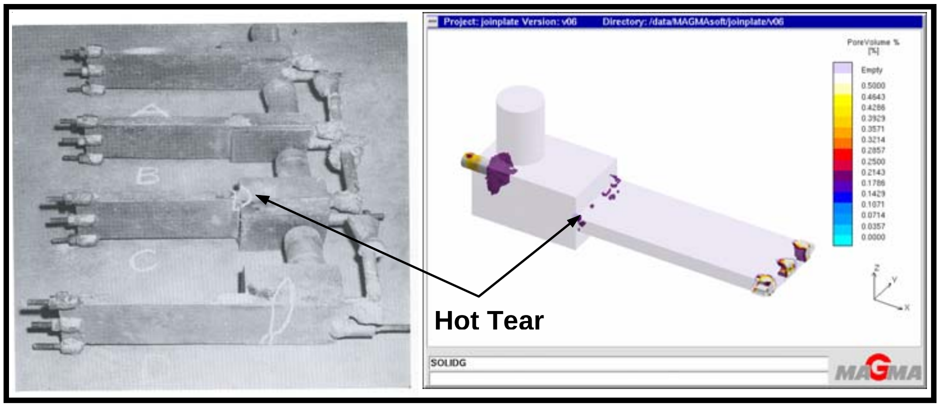
Industrial Technologies Program

Simulation of Dimensional Changes and Hot Tears During Solidification of Steel Castings

Solidification is a crucial stage in steel casting production. Cracks, called "hot tears," may form in the casting during the late stages of solidification and occur when contractions can no longer be accommodated by residual liquid flow or solid displacement. During subsequent cooling of the solidified steel, contractions and distortions of the steel, known as "dimensional changes," can cause the final product to vary significantly from the original pattern. Dimensional changes and hot tears are major problems. Their occurrence is difficult to anticipate and correct using traditional foundry engineering methods. While dimensional changes are accommodated using pattern allowances, the final dimensions of the casting are often inaccurate. Castings that form hot tears must be scrapped or weld repaired, expending unnecessary energy. Correcting either of these problems requires a tedious trial-and-error process that may not necessarily yield accurate results.

Research conducted by the University of Iowa has shown that large dimensional changes are not possible without liquid flowing into or out of a casting section. Hot tears occur along the grain boundaries during the terminal stages of solidification when the strain across adjacent grains creates void space that cannot be filled by liquid flow. Thus, hot tears are initiated in the residual liquid, which is ruptured by contraction strains. Some successes have been reported in predicting the final dimensions of and residual stresses in castings using stress analysis. However, these models cannot always adequately predict results, in part due to their inability to account for liquid flow. Recently, the researchers developed a model that predicts feeding flow and porosity. formation during solidification, but that model assumes the solidified steel to be rigid and immobile. Hence, the occurrence of hot tears cannot be predicted. This project will combine these recently developed stress analysis and feeding flow/porosity models to form a reasonable starting point for a comprehensive, physics-based model of dimensional changes and hot tearing.



Benefits for Our Industry and Our Nation

- *An estimated energy savings of 2.44 trillion BTU's/year.*
- *An estimated economic savings of $14.7 million/year.*
- *An increase in yield.*
- *A reduction in scrap.*

Applications in Our Nation's Industry

The research will develop a computer model to predict dimensional changes and hot tears during the solidification process of steel castings. This will improve yield rate, reduce scrap rate, and increase riser efficiency of steel casting productions.

Project Description

The goal of this project is to develop a model to predict dimensional changes and hot tears during solidification of steel castings. This model would result in a reduction in scrapped castings and rework/repair due to dimensional changes or hot tears, as well as an increase in mold yield due to reduction in the use of padding and improved placement of risers, leading to better riser efficiency.

The objectives of this research are:

- Develop and implement a model into an existing casting simulation code to predict dimensional changes and hot tears during solidification of steel castings.
- Perform a casting 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 stress and hot tear model: Develop a model of dimensional changes and hot tears during solidification of steel castings.
2. Implement the model into a commercial casting simulation code: Researchers from the University of Iowa will directly collaborate with MAGMASOFT to implement the model into their commercial casting simulation code.
3. Perform a validation experiment based on simulation results: Perform a small-scale experiment to test and validate the model.
4. Perform a case study on production parts illustrating the use of the model in foundry practice: Carefully compare model predictions 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
Charelston, SC

Atlas Casting Technology
Tacoma, WA

Harrison Steel Casting Co.
Attica, IN

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
and Renewable Energy

November 2004