Industrial Technologies Program

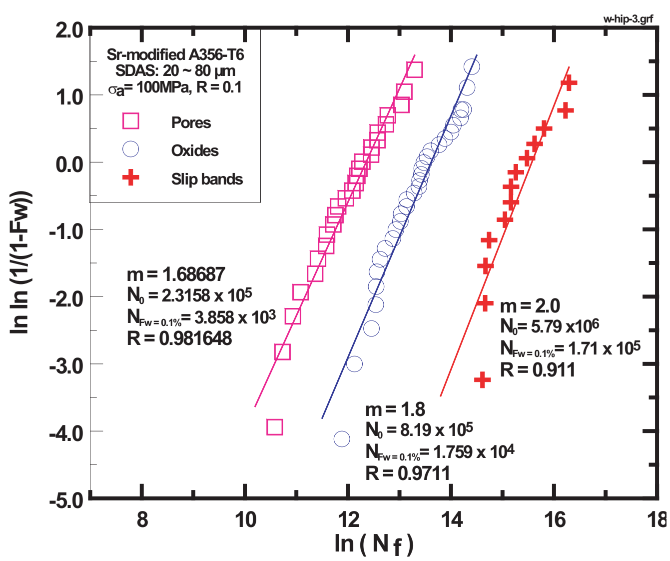
Computational Tools for Assurance of High-Strength, Fatigue-Resistant Aluminum Castings

Microporosity and oxide films are major detriments to the fatigue resistance of aluminum castings. Unfortunately, there is still a lack of knowledge as to how the porosity and oxide films form and how eutectic modification and solidification mode affect porosity. At this time, no computational model can quantitatively predict pore size distribution, morphology, and location. There is no physical model available for simulating the formation of oxide films. Developing simulation tools for defect prediction is key for prediction of the distribution of mechanical properties throughout a casting.

In addition to porosity and oxide films, other microstructural features such as eutectic and precipitate structure in cast aluminum alloys also play an important role in plastic deformation and crack propagation. Optimizing heat treatment using kinetic modeling and simulation together with thermodynamic and thermophysical information can minimize residual stress and distortion while maximizing resistance to crack propagation and fracture.

Project Description

This project is aimed at the development of computational techniques for alloy design, melt treatment, microstructure control, and heat treatment optimization to produce aluminum castings with minimum discontinuities, having an optimal eutectic structure and a high matrix shear strength. The presence of computational tools could enable designers of aluminum components and casting engineers to optimize the alloy, as well as the casting and heat treatment processes to achieve strength and fatigue life requirements with minimum lead time and cost. The models developed should predict porosity, oxide formation, and brittle developed will be tested against real castings, and the potential to implement them within the constraints of rapid design cycles will be assessed.



Infuluence of microporosity, oxides, and microstructural features on fatigue life of Sr-modified A356 castings

Benefits for Our Industry and Our Nation

- *Total projected cost savings of over $400 million per year*
- *Potential scrap reduction of one percent*
- *Anticipated five percent increase in metal yield*
- *Estimated 20 percent reduction in heat treat energy use*

Applications in Our Nation's Industry

By using these computational tools, designers of aluminum components and casting engineers can optimize the alloy to achieve the strength and fatigue life requirements with minimum lead times and costs. This will benefit major aluminum casting producers such as the automotive industry.

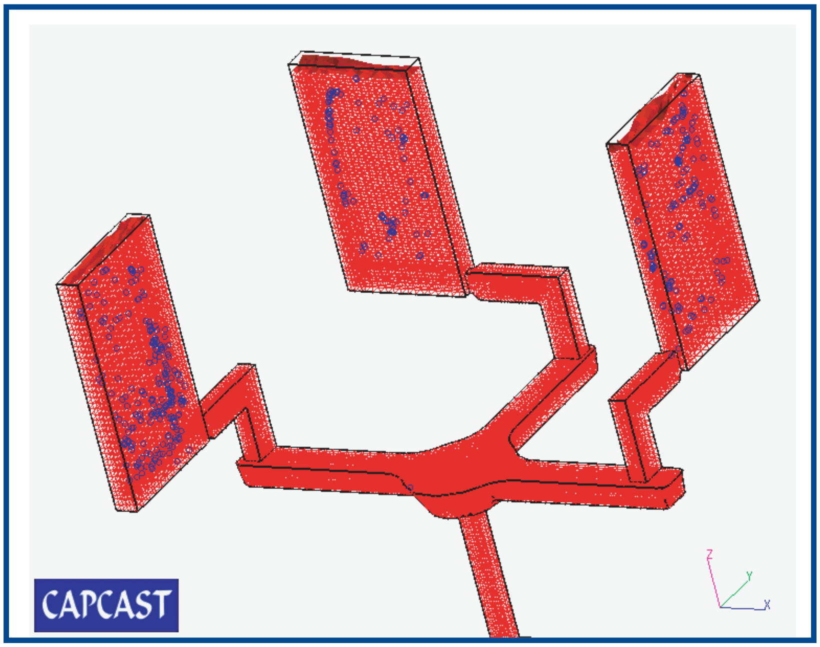
The objectives of this research are:

- To understand the physics that govern the formation of microporosity;
- To develop thermodynamic database and kinetic models for prediction of phase equilibrium and formation in multicomponent alloys with a variety of trace elements;
- To improve computer modeling and quantitative simulation of microporosity by accounting for the coupled influences of eutectic solidification mode and oxide films;
- To simulate the formation and distribution of oxide films during mold filling;
- To develop sophisticated kinetic models to simulate solution, quench, and precipitation hardening processes;
- To understand the influence of residual stress and precipitate structure (related to heat treatment) on the fatigue performance; and
- To design aluminum casting alloys and heat treatments to ensure high strength and fatigue resistance based on thermodynamics, kinetics and experiment.

Milestones

This project is aimed at:

1. Investigation of fundamental physics governing porosity nucleation and growth.
2. Development of thermodynamic database and kinetic models.
3. Prediction of microporosity.
4. Modeling oxide inclusions in the casting.
5. Computational design of aluminum casting alloys.
6. Modeling and simulation of heat treatment.
7. Development of step solution and aging heat treatments.
8. Understanding the influence of residual stress and precipitate structure on fatigue performance.



Prediction of oxides (blue) in low-pressure fill aluminum test castings

Project Partners

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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.

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Energy Efficiency
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