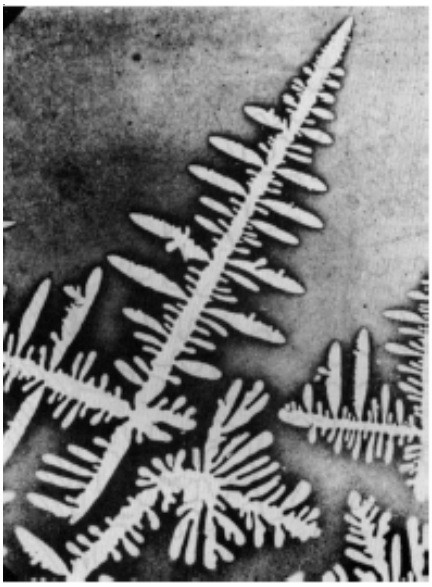
Industrial Technologies Program

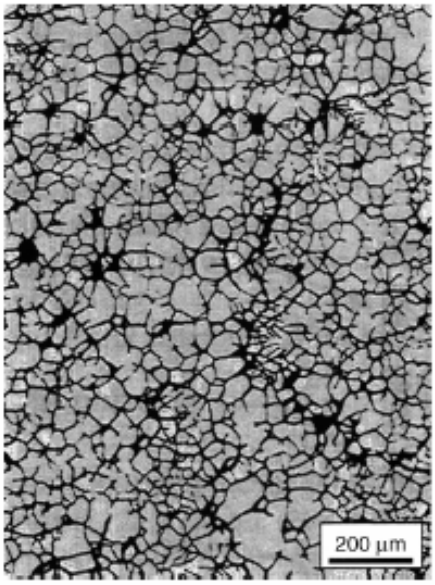
Ultrasonic Processing of Materials

Use of ultrasonics will enhance degassing during melting and grain refinement during casting for optimized microstructure

Ultrasonic effects on the microstructure of alloys include a reduction in the grain size, control of columnar structure, formation of equiaxed grains, improvement of material homogeneity, segregation control, and the uniform distribution of second phases and inclusions. Although many studies of the use of ultrasonic energy during solidification have been carried out in the laboratory, there has been limited industrial-scale application. In addition, there have been no fundamental studies on the effects of ultrasonic vibration on the nucleation and growth of grains during solidification.



Typical dendritic microstructure that forms early in solidification in the absence of grain refinement, showing 50-micron arm spacing.



Typical improved solidified structure that occurs after grain refinement.

Benefits for Our Industry and Our Nation

- *The experimental results provide core principals and establish quantitative bases for nucleation, growth, and fragmentation processes during degassing and alloy solidification in an acoustic field.*
- *The creation of novel and fine-grained alloy microstructures by ultrasonic processing has been demonstrated.*

Applications in Our Nation's Industry

This technology has the potential to impact a wide range of alloy processing, in particular:

- *Die Casting - The technology can be incorporated into a die casting machine to produce castings with small spherical grains, less porosity, and reduced oxide content.*
- *Semi-Solid Metal Processing - The creation of semi-solid metal directly from the liquid in the die casting process can result in better mold-filling plus the elimination of several energy intensive processing steps.*
- *Forging at High Solid Fractions - Alloys containing high solid fractions of fine spherical grains have the potential of being forged into complex shaped components.*

Project Description

The goals of the project were to evaluate the core principles, establish a quantitative basis for the ultrasonic processing of materials, and to demonstrate key applications in the areas of (1) grain refinement of aluminum and steel alloys during solidification, and (2) degassing of aluminum alloy melts.

Barriers

Presently, many casting products have porosity and coarse grain size. Ultrasonic processing has been shown to reduce porosity and refine microstructures. Although many studies on the use of ultrasonic energy during solidification have been carried out in the laboratory, there has been limited industrial-scale appliaction. In addition, there have been no fundamental studies on the effects of ultrasonic vibration on the nucleation and growth of grains during solidification.

Pathways

This study focused on the application of ultrasonic processing for microstructure refinement in aluminum alloys and specialty steels. The tasks undertaken in this project included:

- Study of ultrasonic degassing of aluminum metals
- Thermodynamic modeling to determine alloy phases and solid fraction temperature curves
- Solidification of alloys using ultrasonic energy
- Characterization of solidified microstructures
- Determination of the applicability of ultrasonic technology to industrial processes

Milestones

- Demonstrated ultrasonic processing grain refinement of aluminum alloys. (20-30 µm grain size compared to 50 µm grain size for commercial material)
- Demonstrated degassing of aluminum alloys in minutes using ultrasonic energy.
- Demonstrated grain refinement of 4340 steel.
- Developed a new concept for producing semi-solid metal casting feedstock.
- Developed an approach to incorporate ultrasonic technology into commercial die casting processing.

Commercialization

This project demonstrated the feasibility of applying ultrasonic technology in materials processing. Future work will include obtaining industrial support for the creation of a prototype ultrasonic die casting system that can be used for application development.

Project Partners

University of Tennessee
Knoxville, TN

Oak Ridge National Laboratory
Oak Ridge, TN
(Qingyou Han: hanq@ornl.gov)

Secat, Inc.
Lexington, KY

Carpenter Technologies, Corporation
Reading, PA

Ohio Valley Aluminum Company
Shelbyville, KY

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
January 2005

CPS #1784