ORNL 99-03331/jpp

Advanced Industrial Materials (AIM) Program Activities Impact Metalcasting

Charles A. Sorrell
AIM Program Manager
U.S. DOE

OIT Expo 1999

Advanced Industrial Materials (AIM) Program

- The AIM Program is a crosscutting program in the Office of Industrial Technologies (OIT), U. S. Department of Energy
- Mission

  "support development and commercialization of new or improved materials to improve energy efficiency, productivity, and product quality in the major process industries"

Outline:

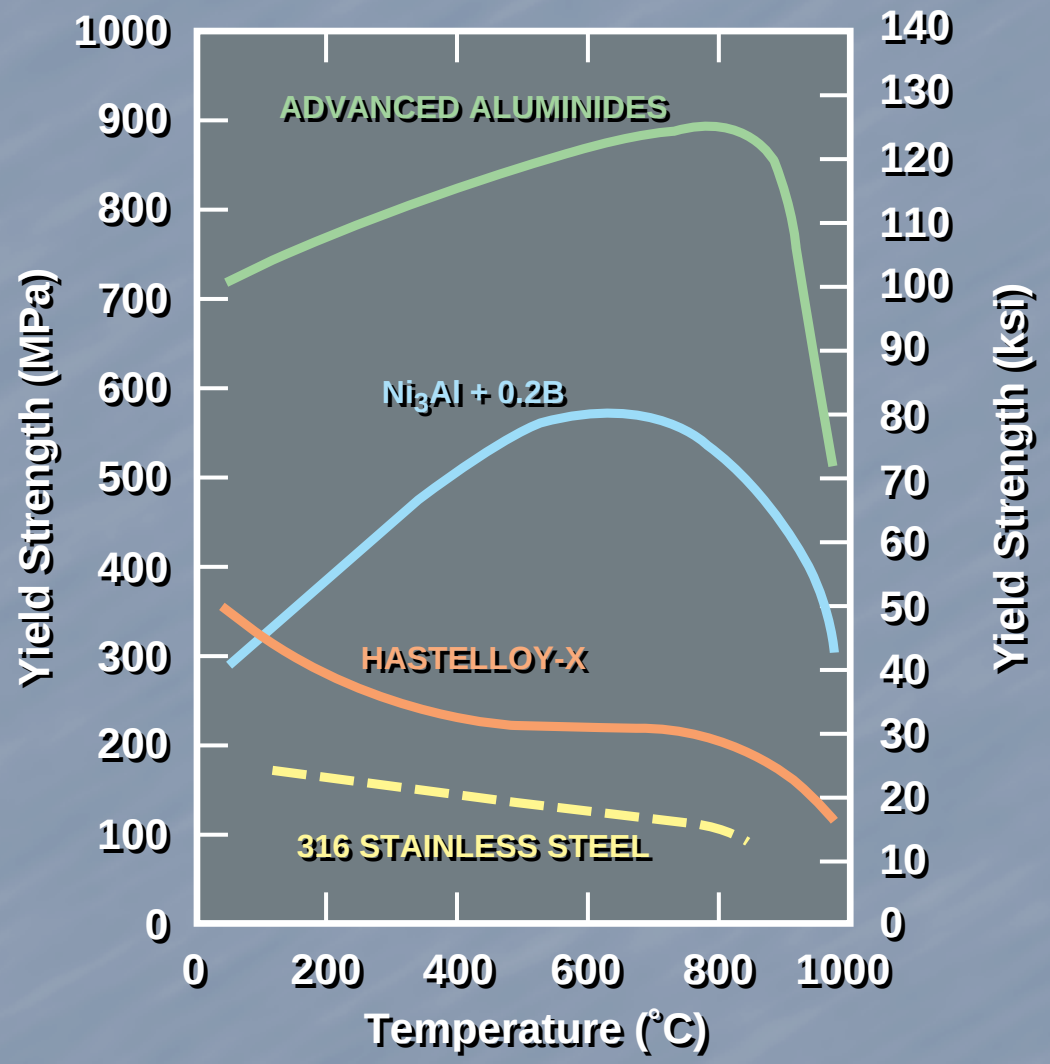
AIM Program Impacts Metalcasting Industry in Various Ways

- Development of castable and weldable intermetallic alloys
- Interactions with North American Die Casting Association (NADCA)
- Initiation of the Metals Processing Laboratory User (MPLUS) Facility
- Programmatic – facilitate identification of industry needs

Castable and Weldable Intermetallic Alloys that Have Superior High Temperature Properties are Being Developed at ORNL

- Intermetallic Alloys
  - (Ni_3Al; FeAl; Ni_3Si; TiAl)
  - Example:
  - Ni_3Al
    - alloy development; high temperature strength, oxidation and carburization resistance
    - thermophysical and thermomechanical properties
    - casting of laboratory heats
    - development of models for casting processes
    - experimental verification of modeling/experimental results
    - working with industry – develop fabrication technologies

Castable and Weldable Intermetallic Alloys Have Superior Strength



– AIM developments based on DOE ER R&D

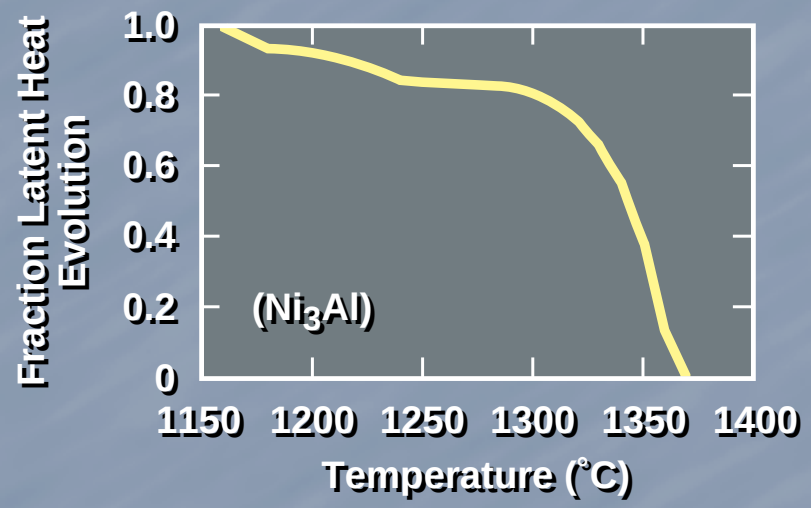
Accurate Thermophysical Properties of Alloys Are Critical for Modeling Casting Processes

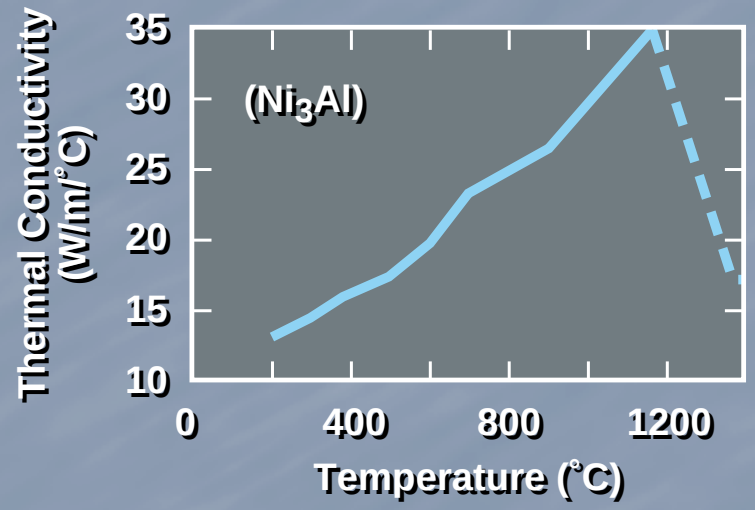
Thermophysical properties

- Specific heat
- Thermal conductivity
- Thermal diffusivity (solid and liquid)
- Latent heat evolution
- Emissivity

Mechanical properties of

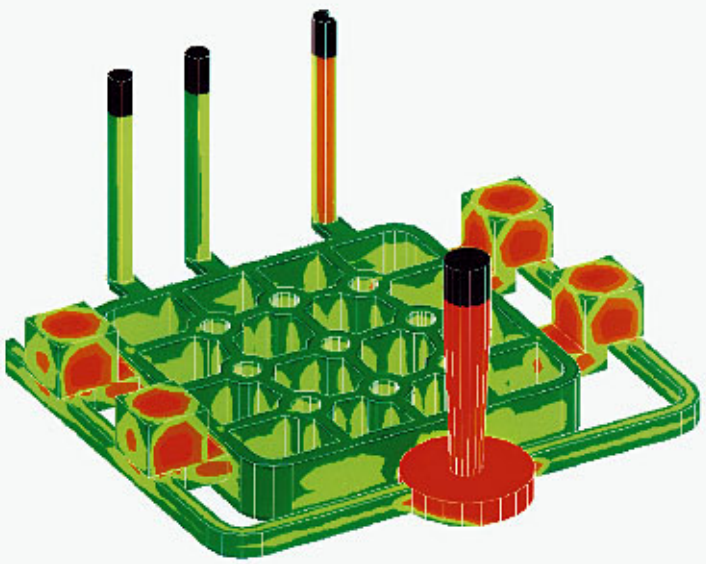
- Solids
- Solid-liquid region



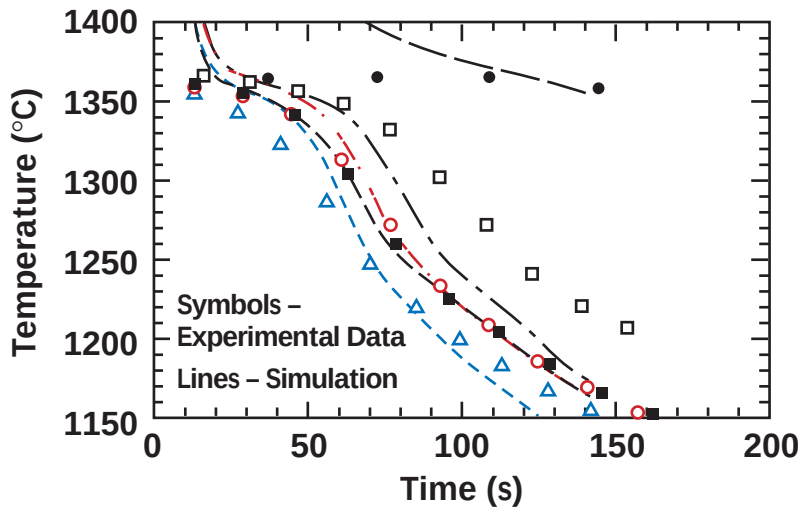


– availability of High Temperature Materials Laboratory (HTML) enables thermophysical property characterization

Modeling and Foundry Trials Were Performed for Efficient Casting Process Development and Component Fabrication



Modeling of Ni_3Al heat treating tray

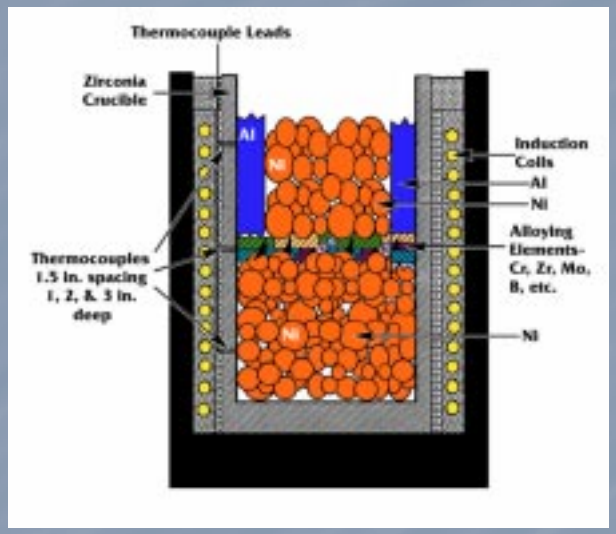


Validation (9"× 9" Ni_3Al Tray – cast at ORNL; Experiment vs Simulation)

– validated models are critical

Development of Exo-melt™ Process Enables Melting of Nickel Aluminides in Industry

- Enables casting of Ni_3Al alloys with commercially available foundry equipment



Exo-melt Process Furnace Loading Schematic

Exo-melt

Conventional (vaporization of constituents)

- Saves 50% of energy and 50% processing time
- Safe and reproducible process
- Developed at the Oak Ridge National Laboratory (ORNL) and currently in use by United Defense/FM, Sandusky International and Alloy Engineering
- Over 200,000 lb have been melted by the process
  - R&D 100 Award in combination with FE and ER activities

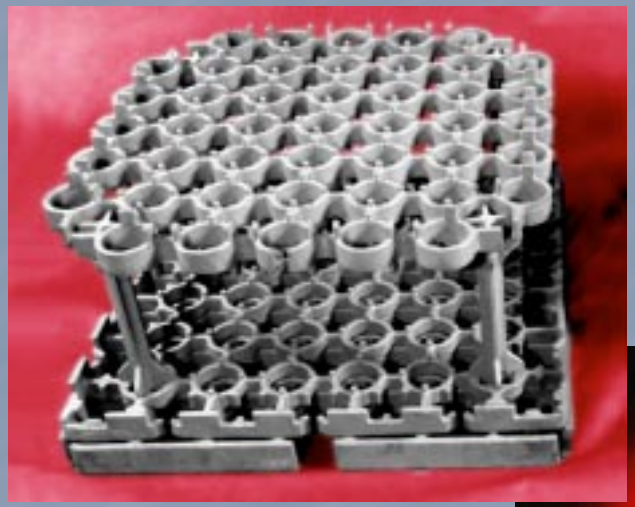
Ni_3Al Heat Treating Furnace Assemblies Are Being Tested

Benefits:

- Carburization resistance
- Oxidation resistance
- High temperature strength
- Improved furnace efficiency

Participants:

- GM – Saginaw Division
- Alloy Engineering & Casting Company
- Oak Ridge National Laboratory (ORNL)



Nickel Aluminide Furnace Assembly

Over 60 assemblies being tested in commercial facilities

Assembly In Furnace

- Assemblies can be sandcast
- Over 5000 tons of steel parts are processed per day
- CRADA was the first to be signed between ORNL and GM

Centrifugally Cast Ni_3Al Rolls are Being Tested in Steel Heat Treating Furnaces

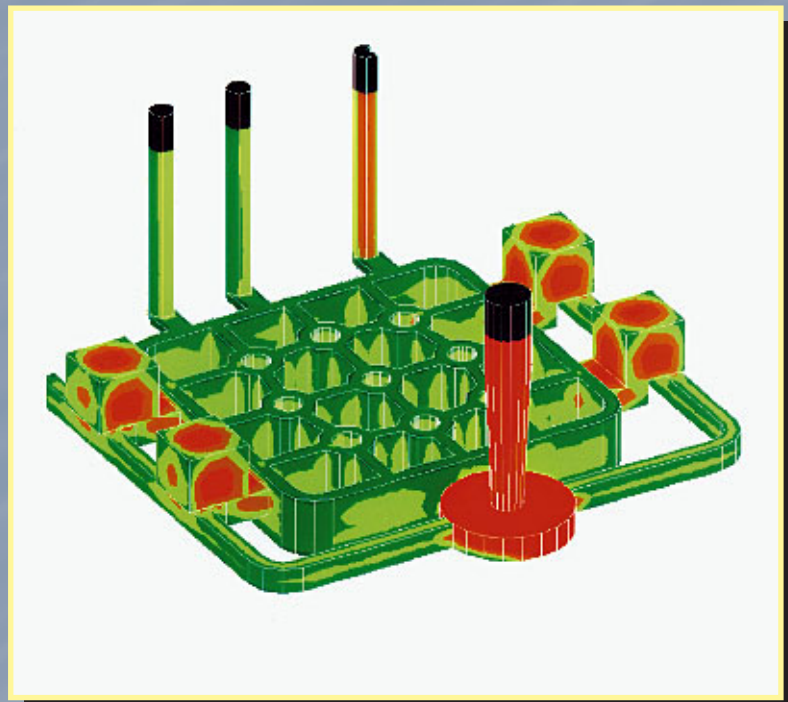
- Benefits
  - Improve furnace operation
  - Eliminate need for water cooling
  - Decrease materials rejection rate
  - Reduce energy use
- Status
  - Initial test of two rolls—successful operation for over two years (20 currently in test)
  - Future plans—testing of a large number of rolls
- Participants
  - Bethlehem Corporation
  - Sandusky International
  - United Defense
  - Oak Ridge National Laboratory (ORNL)
    - Metals Processing Laboratory Users (MPLUS) Facility

Prototype rolls and trunnions prior to installation

Massively Parallel Implementations of Casting Codes Can Enable Rapid Turnaround for Solutions to Highly Coupled Process/Material Interactions

Goal: Use of advanced casting processes and materials in complex shapes for critical applications

Approach: Develop and experimentally verify a parallel scalable version of ProCAST for the Intel Paragon™ Computer



Relevance to Metalcasting Industry:

- Melting
- Mold filling
- Coupled heat/fluid flow/stress solutions

Technology Transfer Activities Include Metalcasting Companies, Welding Wire Suppliers, and National Laboratory

- Ni_3Al alloys
  - Oak Ridge National Laboratory
  - Industrial Licensees
    - Casting Companies
      - Alloy Engineering and Casting Company
      - Alcon Industries
      - Sandusky International
      - United Defense
    - Welding Wire Suppliers
      - Stoody
      - Polymet Corporation

AIM Program Collaborates with Industry to Leverage Capabilities and Facilities

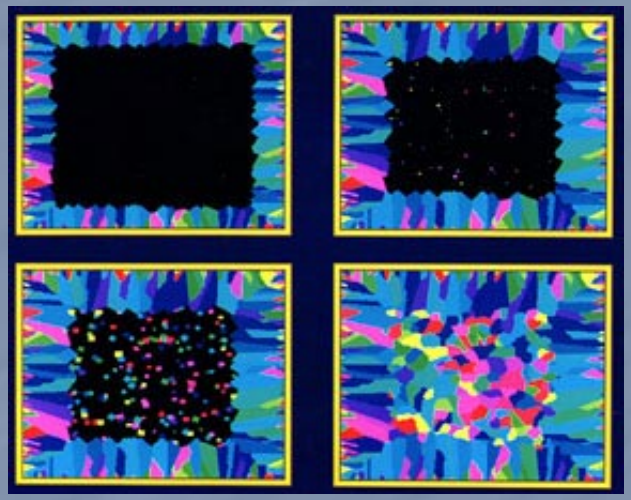
- The North American Die Casting Association (NADCA) has collaborated with industry and ORNL to install a research die casting machine at ORNL
  - NADCA – die casting machine
  - ORCMT – rebuild and upgrade
  - AIM – installation and operation
  - Prince Machine – control system
  - TTE Inc. – dies
  - Prince Machine and TTE – technical training

Dedicated Research Die Casting Facility Is Being Utilized in Activities of Various Programs

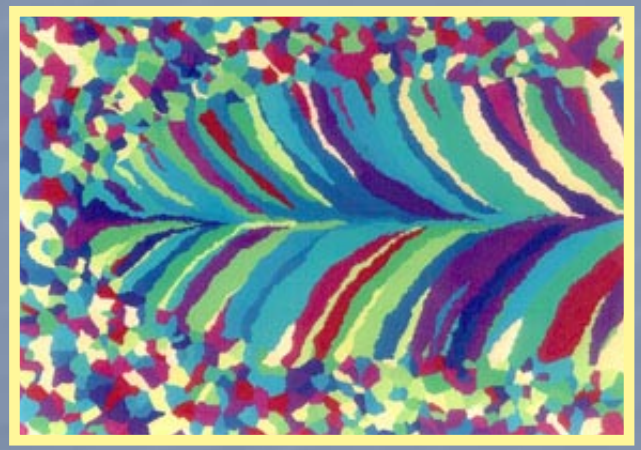
- Developing improved corrosion resistant materials for use in die casting machines

- Facility is being utilized by various programs, including OIT-Metalcasting, OIT-AIM, OIT-MPLUS, OTT-Lightweight Materials

Modeling of Cast Microstructures Is Important to Achieve Desired Material Characteristics



Simulation of Casting Solidification
(example Al-7% Si alloy)



Simulation of Directional Solidification
(example Al-7% Si)

- Heat and fluid flow codes (Procast, Phoenix, others) coupled with multi-component phase equilibria predict
  - local thermal history
  - macrosegregation
- Monte Carlo method used to predict local microstructure

The AIM Program Has Facilitated the Initiation of the Metals Processing Laboratory User (MPLUS) Facility

- MPLUS is a U.S. DOE Designated User Facility
  - Focused on OIT activities including
    - Industries of the Future activities, national programs, and crosscutting activities
  - Purpose
    - Enable access to national laboratories by industry and academia to improve energy efficiency, competitiveness, and environment

ORNL 99-03347/dlr

A Prosperous U.S. Economy Requires National Commitment and Collaboration Between Industry, Academia and National Laboratories

DOE Facilitates Process and Catalyzes Industry Interactions

Advanced Industrial Materials (AIM)
Office of Industrial Technologies (OIT)

Crosscutting Industries
- Forging
- Heat Treating
- Welding

National Programs
- ATS
- CFCC

Within the 1st 2+ years: 63 Companies in 25 states have requested MPLUS USER PROGRAM

Prosperous U.S. Economy

MPLUS USER PROGRAM

MPLUS at ORNL Provides Technical Experience and Specialized Facilities

The Metals Processing Laboratory User (MPLUS) Facility is a DOE designated user center. The purpose of MPLUS is to help industry improve energy efficiency and enhance U.S. prosperity

MPLUS

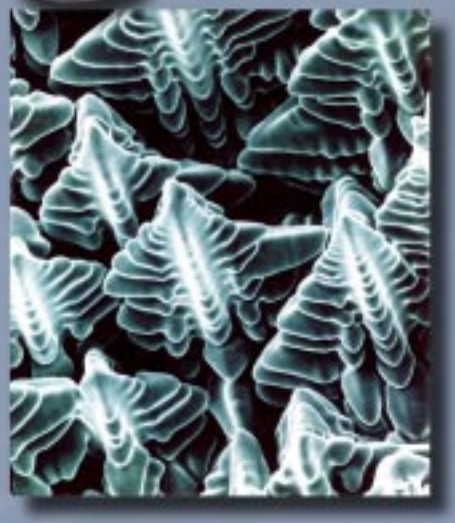
Approach

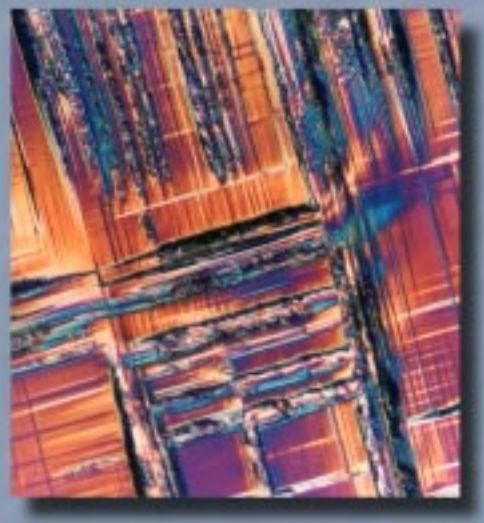
- Provide industry and academia access to unique DOE national laboratories capabilities
  - specialized technical expertise and facilities
  - focus is to solve metals/metals processing issues that limit the development and implementation of materials in industry

M PLUS+: Metals Processing Laboratory User Facility

User Centers Include:

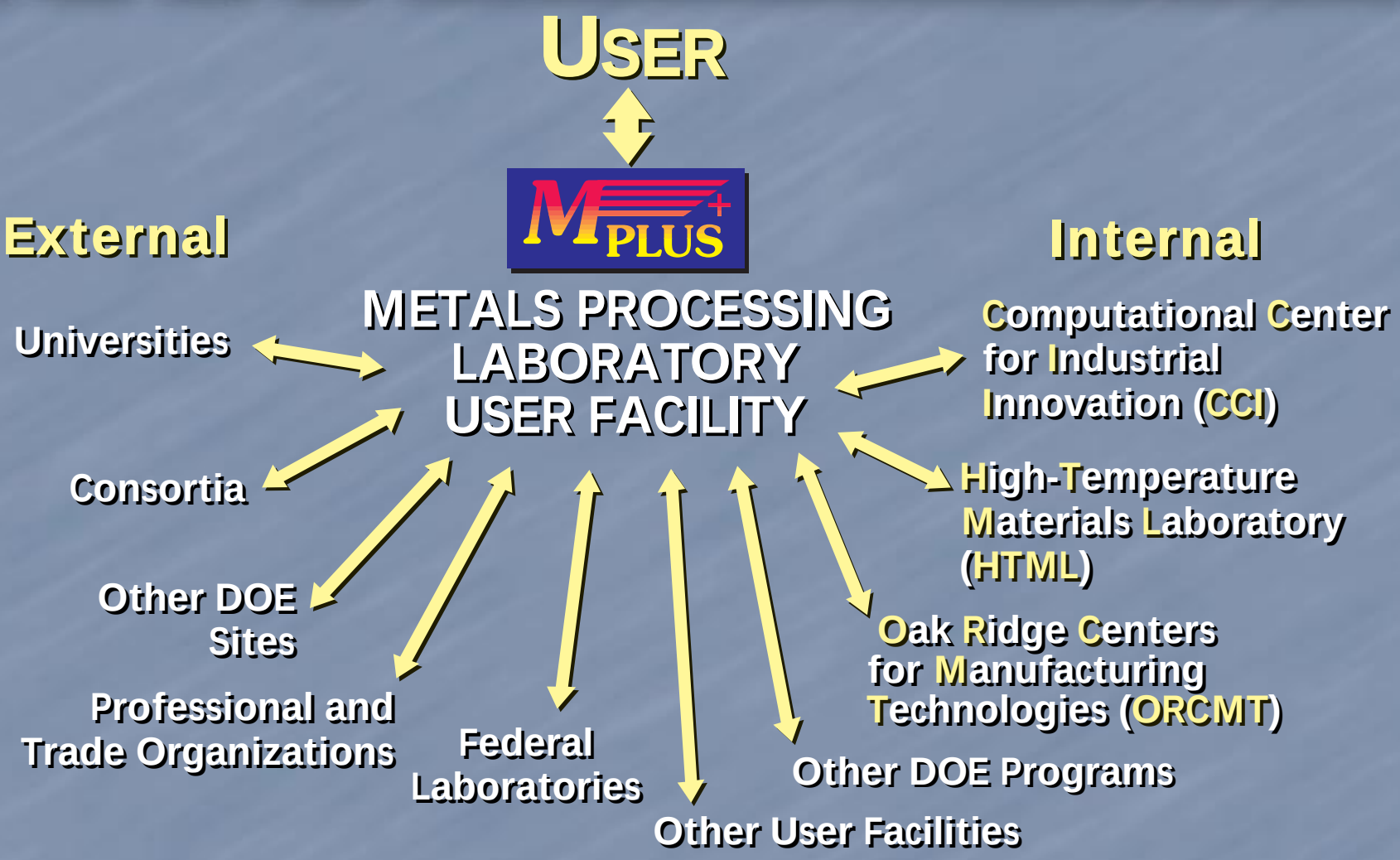
- Processing
- Joining
- Characterization
- Process modeling





Contact: Gail M. Ludtka, Technical Coordinator, Oak Ridge National Laboratory, (423) 576-4652, Fax: (423) 574-5118, *http://www.ms.ornl.gov/emfacility/mplus/mplus.htm*

M PLUS+ Interacts with Other User Centers and Organizations – *Spans the Gap Between R&D Technologies and Full-Scale Prototypes*



ORNL 99-03351/dlr

MPLUS+ Provides a Mechanism for Industries to Network

External

- Universities
- Consortia
- Professional and Trade Organizations
- Other DOE Sites
- Other Federal Laboratories

Metals Processing Laboratory User Center

Internal

- Computational Center for Industrial Innovation
- High-Temperature Materials Lab
- Oak Ridge Centers for Manufacturing Technologies
- Other user facilities

63 Companies in 25 States have requested MPLUS+

1. Westinghouse (3)
2. Reynolds (2)
3. ForMat Industries
4. U.S. Filter
5. E.R. Johnson
6. Sandusky Int'l
7. Waudesha Electric
8. Weyerhaeuser (2)
9. A. Finkl & Sons (2)
10. Feffrey Chain Corp.
11. Materials Tech.
12. ABB C-E Services (3)
13. Union Camp Corp.
14. United Defense (2)
15. CO School of Mines
16. Doehler-Jarvis
17. General Motors (2)
18. Univ. of AL (2)
19. Cornell Univ.
20. Cummins Engine (3)
21. Bethlehem Stell (2)
22. American Axle
23. FMC Corp.
24. ARCO
25. Finite Solutions
26. Starmet Corp.
27. Lincoln Electric
28. CarboMedics
29. IPST
30. Univ. of Tenn.
31. PPG Industries (3)
32. Owens Corning (2)
33. Columbia Falls Al
34. AFFCO
35. Allison Engine
36. Alloy Engineering
37. Southwire
38. Wagner Castings
39. Rhenium Alloys
40. Uniform Metal Tech.
41. West Virginia Univ. (2)
42. J&L Specialty Steel
43. LTV Stell
44. Univ. of Michigan
45. Welding Services
46. General Electric
47. Weirton Steel (2)
48. Park Ohio Transptn. Grp.
49. Stoody
50. Torrington (2)
51. Ford Motor Co.
52. Eaton Corp.
53. Hoskins Mfg. (2)
54. AHT Inc.
55. Amer. Spring Wire
56. VA Polytec. & St. Univ.
57. INCO Alloys Int'l (4)
58. Caterpillar
59. Smelter Services
60. Westvaco
61. Pressure Vessel Council
62. Acutus-Gladwin
63. Univ. of Pittsburgh

MPLUS+ Program Status

84 MPLUS Proposals received

- 74 Proposals approved
- 20 projects completed
- 17 pending additional funding

Evaluation of Processing Effects on Increased Fluidity of Gray Cast Iron

- Benefits
  - Thin wall castings
  - Increased yield
- Objectives
  - Understand and verify role of degassing on fluidity of gray cast iron
- Tasks
  - Processing effects
  - Thermodynamic modeling
  - Thin wall castings
  - Properties
- Partners
  - Citation Corporation
  - Oak Ridge National Laboratory (ORNL)

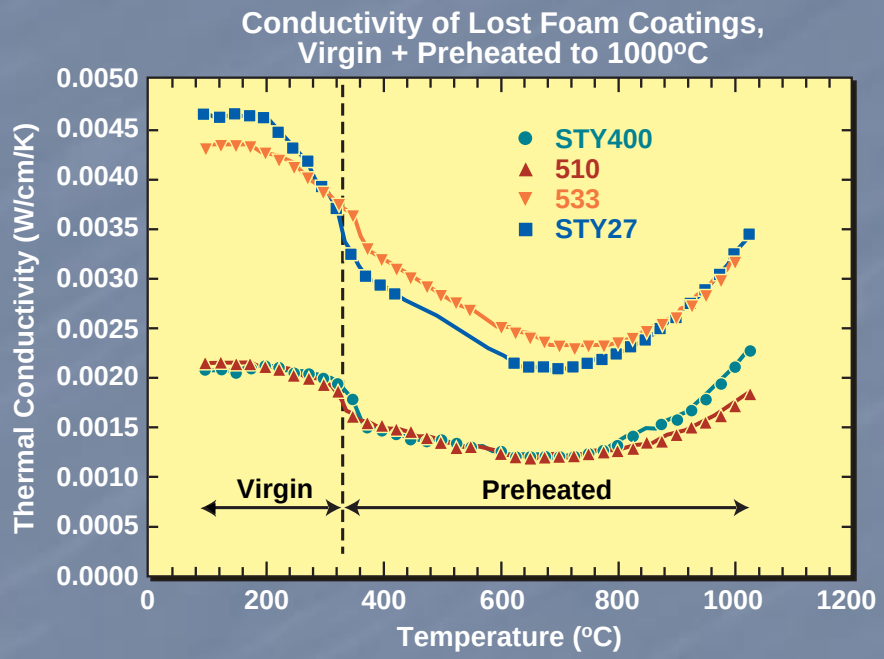
Citation Corporation's Columbiana, Alabama, foundry produces both gray and ductile iron lost foam castings

ORNL's Materials Processing Group has experimental and analytical capabilities for casting research

The University of Alabama and ORNL Team Up To Study the Thermal Conductivity of Ceramic Coatings for Lost Foam Casting

Laser Flash Thermal Diffusivity System:

- Operates from –150°C to 2500°C
- Solids, coatings, and molten metals
- Vacuum, inert gas, and oxidizing atmospheres
- Measures up to 6 specimens per run
- Quench furnace for metastable phases
- Special molten metal cell



- Evaluated 4 coating systems
- Thermal conductivity calculated from:
  - Thermal diffusivity
  - Specific Heat
  - Density

Composition Optimization, Weldability and Properties of Thin Wall Components Cast by Counter Gravity Casting

Objective: optimize composition for castings and fabrication

Benefits:

- capability to cast thin wall high quality castings
- net shape process
- improved efficiency and productivity

Tasks:

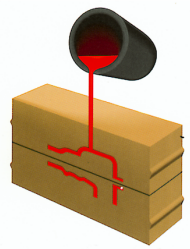
Industry

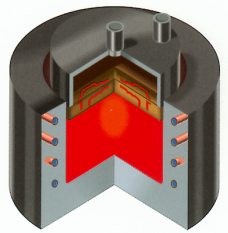
- cast components by the Hitchner Process

Laboratory

- melting characteristics
- fluidity
- weldability
- microstructure/properties/process relationshps

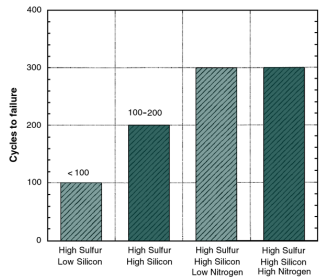
Jim Lytle, President of Alloy Engineering and Casting Co., discusses weldability testing with Vinod Sikka during a visit to ORNL



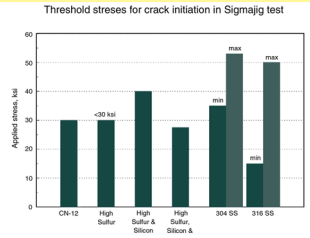


CONVENTIONAL CASTING	VS	COUNTER GRAVITY CASTING
• Fluid dynamics can create mold/core erosion (inclusions) • A.S.T.M. minimum section 6.0 to 10.0 mm • Difficulty in evacuating gases created by metal and mold/core reaction		• Mold cavity fills in less than two (2) seconds with minimum turbulence • Section capability of 1.75–2.75 mm minimum • Vacuum assists in removal of gases

Stainless steel exhaust manifolds produced by counter gravity casting



Optimizing S, Si, N content in alloy improves castability, machinability, and high-temperature mechanical properties



- Sigmajig testing assists in optimizing composition for weldability

Partners:

alloy engineering & casting company — Ford — CATERPILLAR — ornl — GM POWERTRAIN

The AIM Program Has Strong Industrial Participation and Relevancy

- National Materials Advisory Board
  - Panel on Intermetallic Alloy Development *(completed)*
  - Panel on crosscutting materials *(planned)* – Identify crosscutting materials needs of the Major Process Industries
- AIM Guidance and Evaluation (G&E) Board – advises DOE AIM program manager on overall program areas

Summary:

The AIM Program is Addressing Needs of the Metalcasting Industry in a Number of Ways

- Development of castable and weldable intermetallic alloys
- Collaboration between industry–universities–national laboratories
- Metals Processing Laboratory User (MPLUS) Facility
- Programmatic – facilitate identification of industry needs