Innovative Research, LLC
Engineering Productivity via Computational Flow Modeling
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MeltFlow-VAR™

A Comprehensive Simulation Tool for the Vacuum Arc Remelting (VAR) Process

The VAR Process for Ingot Production

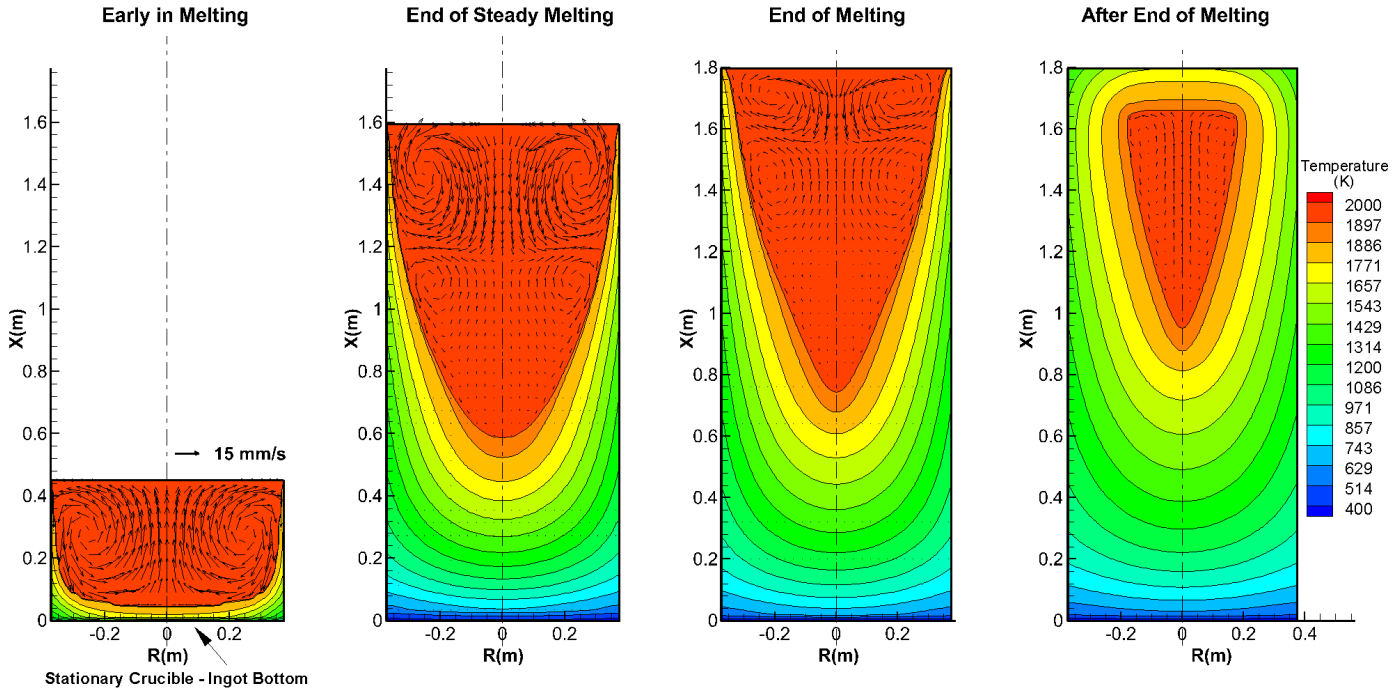
Vacuum Arc Remelting is a consumable electrode remelting process used for producing ingots of Titanium alloys, superalloys, and steel.

The performance of the VAR process is governed by complex interactions among electromagnetics, flow, heat transfer, and phase change phenomena. Effectiveness of the process for minimizing compositional nonuniformity, obtaining desired metallurgical structure, and eliminating inclusions is determined by alloy properties, ingot size, and melt schedule. Due to the complexity of the VAR process, empirical trial-and-error approaches are often indequate and yield designs that are seldom optimal.

A Powerful Predictive Capability

MeltFlow-VAR offers a scientific and cost-effective approach for evaluating the effects of process conditions on the quality of the ingot produced.

MeltFlow-VAR analyzes all underlying physical phenomena in a comprehensive and computationally efficient manner for a detailed prediction of the flow, temperature and electromagnetic fields, and phase change in the growing ingot during the entire melting process. Thermal history and redistribution of alloying elements due to macrosegregation in the solidifying ingot are also analyzed to determine the metallurgical structure and chemical composition of the final ingot produced.



Velocity and Temperature Fields, and Molten Metal Pools During the VAR Process for a Titanium Alloy

Comprehensive Analysis of Process Physics

MeltFlow-VAR performs a rigorous analysis of the VAR process by considering all phenomena of importance.

- Electromagnetic Fields for DC Power Without and With Magnetic Stirring
- Turbulent Flow and Heat Transfer in the Pool
- Phase Change in the Ingot During and After Melting
- Temperature Dependent Alloy Properties
- Effect of Ingot Shrinkage on Heat Loss to Crucible
- Thermal History and Metallurgical Structure
- Macrosegregation of Alloying Elements
- Motion and Dissolution of Inclusions

Efficient Computational Technique

The computational method incorporates several physically motivated algorithms for effective treatment of the unique aspects of the VAR process.

- Nonlinear Heat Transfer from Ingot Surfaces
- Transient Effects due to Ingot Growth
- Automatic Determination of the Time Step
- Lagrangian Techniques for Thermal History and Inclusion Motion

Therefore, MeltFlow-VAR performs a robust and efficient calculation of the transient behavior of the ingot during the entire remelting process.

Easy Setup and Examination of Results

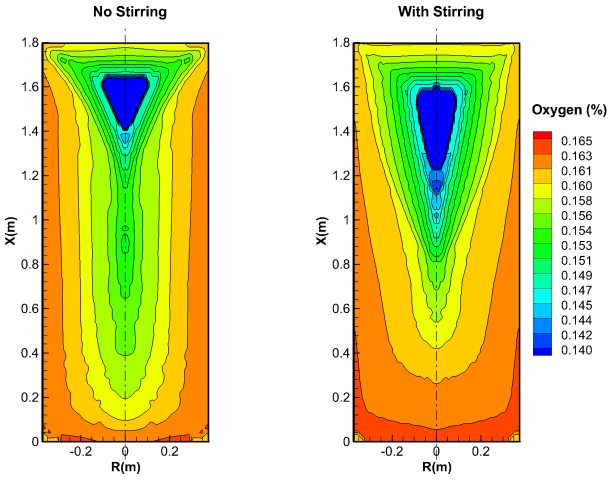
MeltFlow-VAR enables easy creation of a process model by specifying ingot geometry, alloy properties, and melt schedule through a graphical interface and data files. Results of analysis are conveniently examined using powerful graphics and animation capabilities.

Engineering Benefits

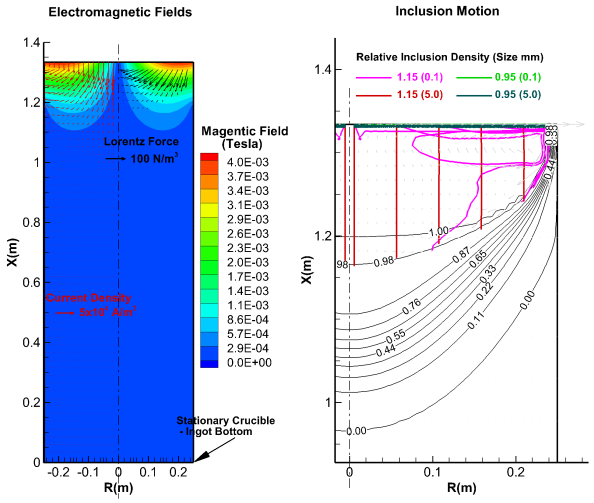
MeltFlow-VAR has been extensively validated for accurate prediction of the performance of a variety of practical VAR processes. It is in active use by leading specialty metals companies for the processing of Steels, Titanium Alloys, and Nickel Alloys in the manner below.

- Refinement of Melt Schedules
- Investigation of Process Anomalies
- Process Scale-Up
- Exploration of Processes for New Alloys

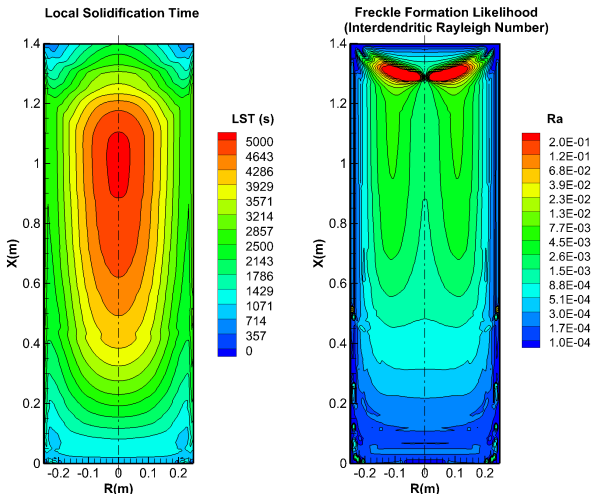
Such use has significantly improved the productivity of process design and quality of ingots produced.



Concentration of Oxygen in Ingots of a Titanium Alloy Produced in the VAR Process Without and With Magnetic Stirring



Electromagnetic Fields and Inclusion Motion in an Ingot of a Nickel Alloy During the VAR Process



Thermal History and Probability of Freckle Formation in an Ingot of a Nickel Alloy Produced in the VAR Process

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