Innovative Research, LLC
*Engineering Productivity via Computational Flow Modeling*
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# MeltFlow-ESR™

## A Comprehensive Simulation Tool for the Electroslag Remelting (ESR) Process

### The ESR Process for Ingot Production

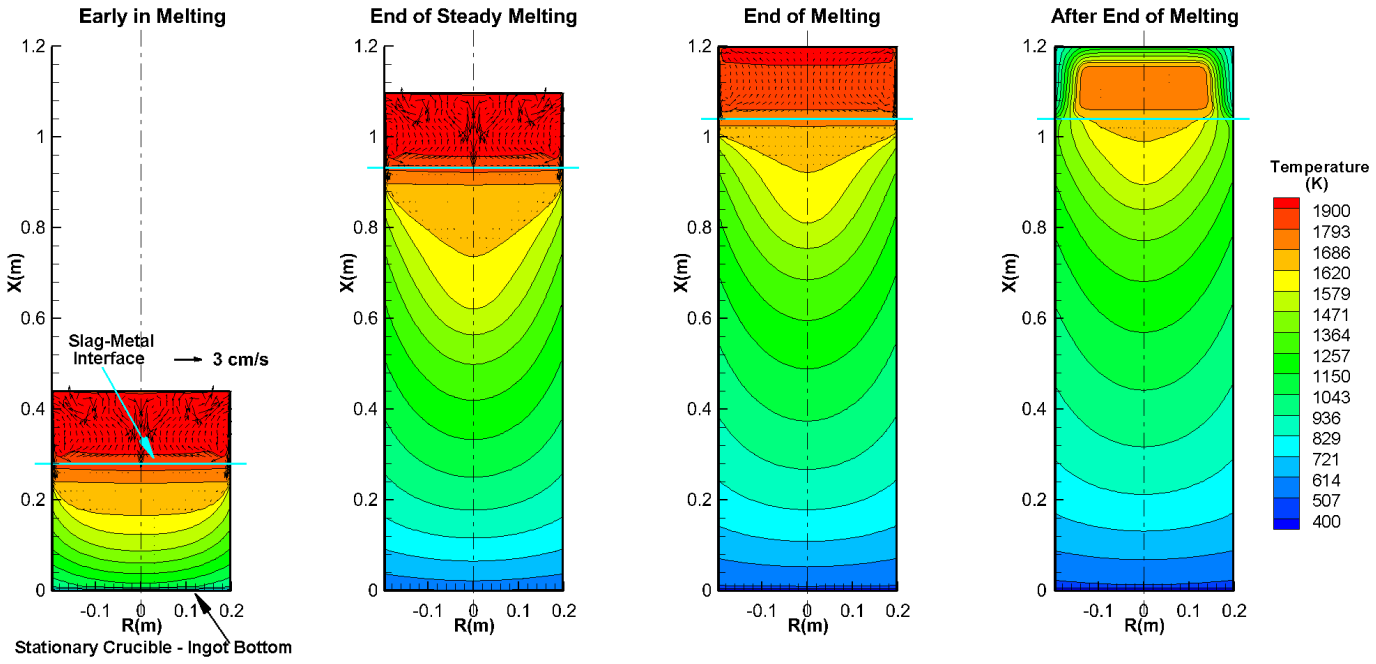
Electroslag Remelting is a consumable electrode remelting process used for producing high-quality ingots of superalloys and steel through controlled solidification and chemical refining.

The performance of the ESR process is governed by complex interactions among AC electromagnetics, flow, heat transfer, and phase change phenomena. Effectiveness of the process in obtaining the desired metallurgical structure and compositional uniformity of the cast ingot is determined by alloy and slag properties, processing scale, and power schedule. Due to the process complexity, empirical trial-and-error approaches are often inadequate and yield designs that are seldom optimal.

### A Powerful Predictive Capability

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

MeltFlow-ESR 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 slag and 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 in the ESR process.




**Velocity and Temperature Fields, and Molten Slag and Metal Pools During the ESR Process for a Nickel Alloy**

## Comprehensive Analysis of Process Physics

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

- Electromagnetic Fields for AC Power
- Turbulent Flow in the Molten Slag and Metal Pools
- Heat Transfer and Phase Change in Slag and Ingot
- Temperature-Dependent Slag and Alloy Properties
- Effects of Formation of Slag Skin and Shrinkage of Ingot 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 ESR process.

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

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

## Easy Setup and Examination of Results

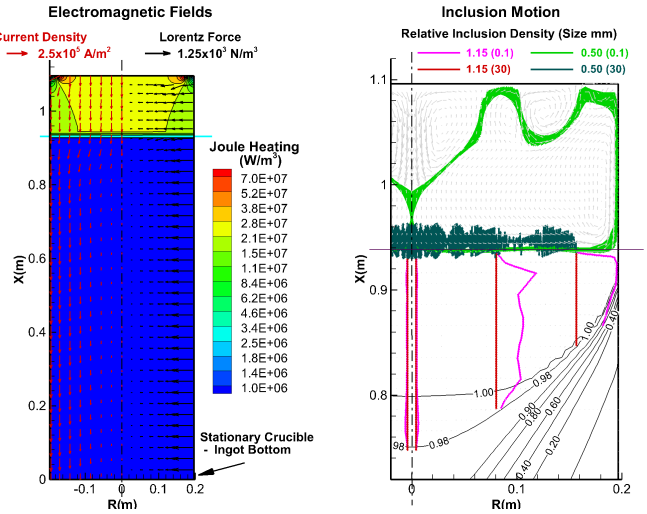
MeltFlow-ESR enables easy creation of a process model by specifying process geometry, alloy and slag properties, and process schedule through a graphical interface and data files. Results of analysis are conveniently examined using powerful graphics and animation capabilities.

## Engineering Benefits

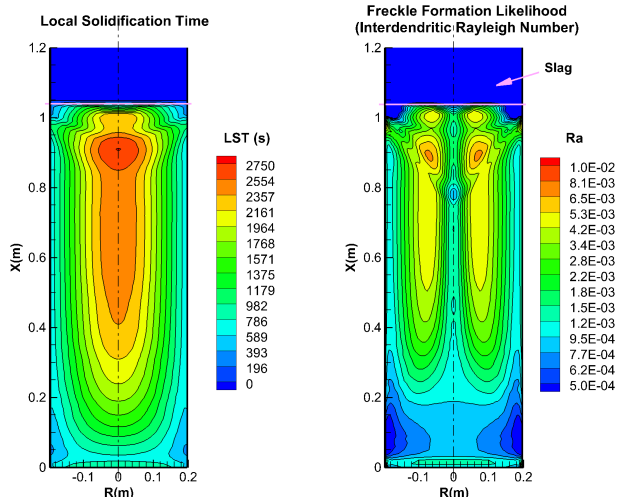
MeltFlow-ESR has been extensively validated for accurate prediction of the performance of a variety of practical ESR processes. It is in active use by leading specialty metals companies for the processing of Steels and Nickel Alloys in the manner below.

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

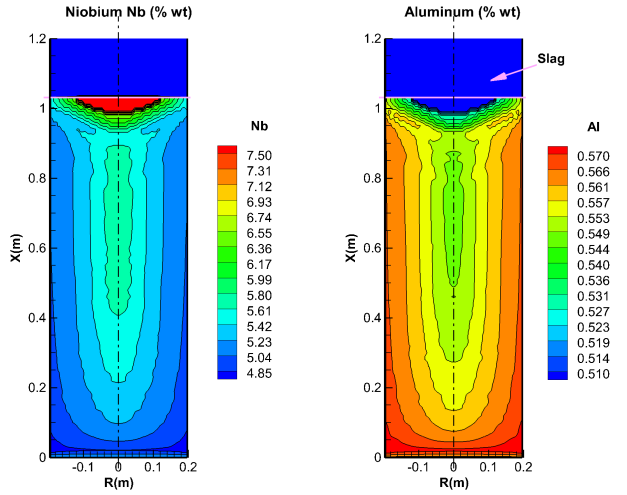
Such use has significantly improved the productivity of process design and quality of ingots produced.




**Electromagnetic Fields and Inclusion Motion in the Slag and Ingot During the ESR Process for a Nickel Alloy**




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




**Concentrations of Niobium and Aluminum in an Ingot of a Nickel Alloy Produced in the ESR Process**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