

ELECTROSLAG REMELTING (ESR) and VACUUM MELTING (VAR)

Electroslag remelting (ESR) is a sophisticated metallurgical technique for refining high-performance alloys and specialty steels. This method is essential in critical fields such as aerospace, energy, and the medical sector, where improved cleanliness, uniformity, and mechanical properties of materials are essential to meet stringent standards.

ESR Process Description

In the ESR process, a consumable electrode melts and solidifies by passing through liquid slag inside a water-cooled copper vessel for gradual crystallization of the final ingot. The main steps include:

- **Preparation** of the electrode, often derived from an initial ingot of the same alloy, inserted into the system.
- **Melting** using an electric current that heats the slag by resistance, liquefying the tip of the electrode.
- **Refining** , with metal droplets filtering into the slag, eliminating impurities and non-metallic particles.
- **Solidification** of the purified metal at the bottom of the mold, obtaining a fine and coherent crystalline structure.

Main benefits

- **Greater purity** , thanks to the slag that traps contaminants and inclusions.
- **compositional and microstructural uniformity** , minimizing segregations.
- **Improved mechanical performance** , including toughness, plasticity and fatigue resistance.
- **Drastic reduction of anomalies** such as voids or macroscopic segregations, for total reliability.

Sectors of application

- **Aerospace** : turbine blades, engine parts and structures requiring extreme robustness.
- **Energy** : elements for gas turbines, nuclear reactors in extreme environments.
- **Medical** : biocompatible prostheses and implants with excellent properties.
- **Tooling** : steels for high-wear molds, dies, and blades

ESR in superalloys

Electroslag remelting is particularly suitable for advanced superalloys such as GH4169 (Inconel 718), which are widely used in extreme environments of high temperature, pressure, and mechanical stress, such as aircraft engines or gas turbine components. These alloys, characterized by complex compositions with elements such as nickel, chromium, molybdenum, and niobium, require precise control of the microstructure to maximize resistance to creep, corrosion, and thermal fatigue. ESR optimizes these materials by reducing dendritic segregation, oxide inclusions, and compositional variations, allowing for a uniform distribution of precipitated phases (such as gamma-doubles and carbides) that enhance in-service performance. This process is often integrated into multi-stage production lines to achieve higher levels of quality than primary melting alone, making superalloys ideal for critical applications where even small defects can compromise safety and durability.

Differences between ESR and VAR

ESR and VAR are two complementary secondary remelting processes: VAR operates in a vacuum to minimize gases, ideal for extreme chemical purity; ESR uses liquid slag in an inert atmosphere to filter out inclusions and uniform the structure.

ESR vs VAR comparison

	VAR (vacuum arc remelting)	ESR electroslag remelting)
Environment	Vacuum to minimize gases and oxides	Inert or atmospheric with refining waste
Fusion	Direct electric arc	Resistive heating of slag
Applications	Low gas content and chemical uniformity	Removal of inclusions and homogeneous microstructure