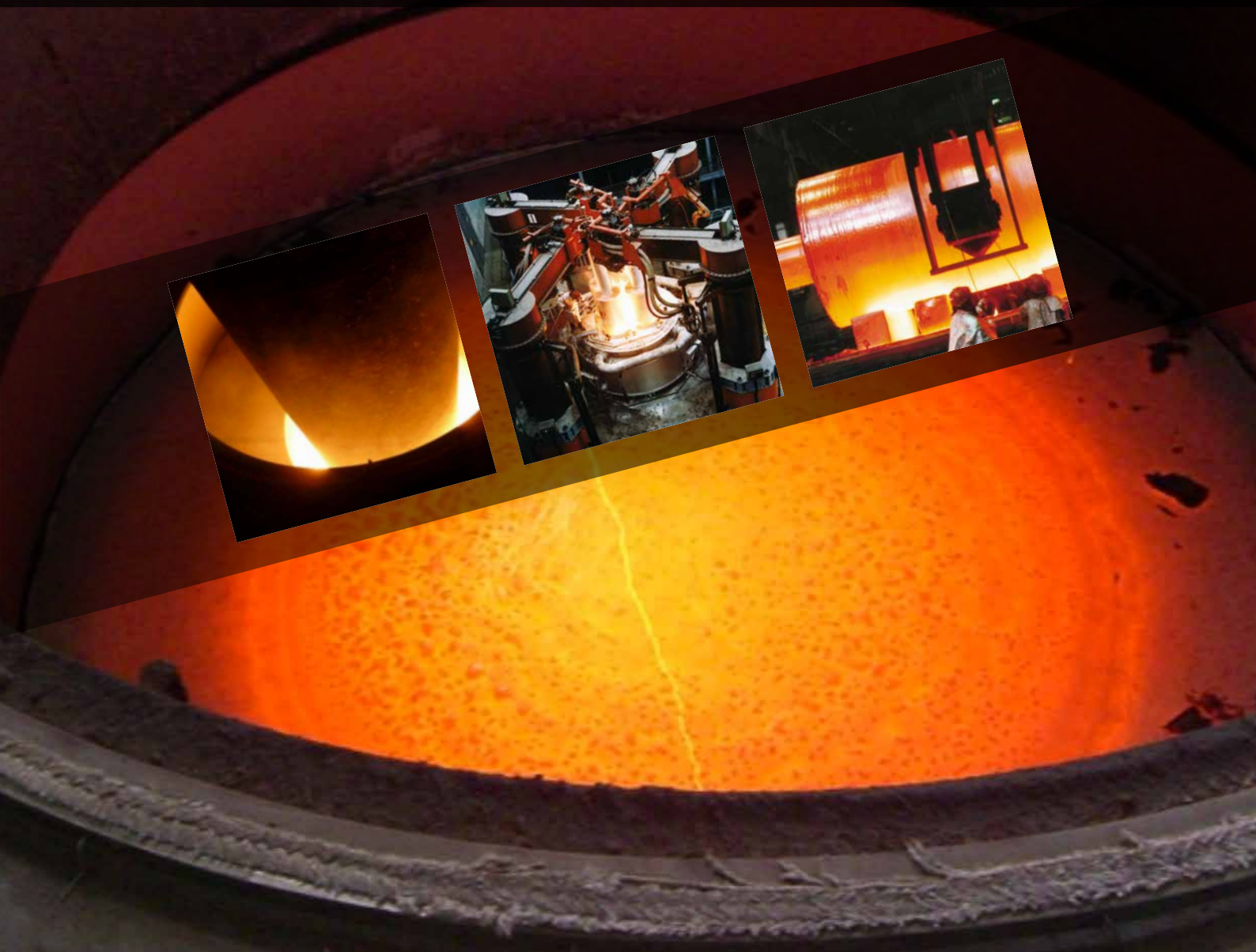
ALD Vacuum Technologies

High Tech is our Business

# Electro Slag Remelting (ESR)

Electro Slag Remelting Processes and Furnaces



# Electro Slag Remelting

ALD is one of the leading suppliers of vacuum and inert gas melting furnace technologies for engineered metals.

**Generally, the ESR process offers a very high, consistent and predictable product quality. Finely controlled solidification improves soundness and structural integrity. Ingot surface quality is improved by the formation of a solidified thin slag skin between ingot and mold wall during the remelting operation. This is why ESR is recognized as the preferred production method for high-performance superalloys that are used today in industries such as aerospace and nuclear engineering as well as for heavy forgings.**

## ESR Technology

**ESR is the continuous remelting of a consumable electrode by means of a resistance-heated slag.**

The main process stages are:

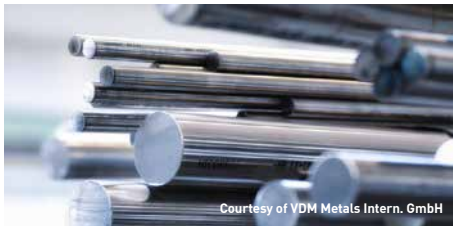
- A consumable ESR electrode is generated by secondary metallurgy or VIM
- Process condition is established (inert gas, vacuum, pressure)
- Slag is added to the bottom of the crystallizer (mold)
- AC power heats the slag
- The intense heat generated by slag resistance melts the tip of the electrode and a new ingot grows in the mold
- De-oxidant or nitriding agents are added
- The melt rate and the immersion of the electrode is precisely regulated by the ESR control system
- Ingot cooling is controlled for directional solidification

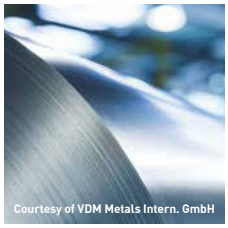
ALD has improved the basic design of the ESR furnace in computer control and regulation continuously over the years to achieve:

- Fully-automatic remelting processes
- Improved reproducibility of the metallurgy properties.

# ESR Features & Advantages

Electros Slag Remelting
is used wherever high quality
material is required.




## ESR Materials/Alloys

- Tool steels for milling cutters, mining, etc.
- Die steels for the glass, plastic and automotive industries
- Ball-bearing steels
- Cold rolls
- Stainless steels
- Steels for turbine and generator shafts
- Superalloys for aerospace and power turbines
- Nickel-based alloys for the chemical industry

## Fields of Application

- Aerospace
- Power generation/Heavy forgings
- Chemical industry
- Medical and nuclear industries
- Tool and die industries
- Construction industries
- Automotive industry

## Primary benefits of ESR

- Homogenous, sound and a directionally solidified structure
- Achievement of directional solidification of the ingot from bottom to top
- Free of macro-segregation and reduction of micro-segregation
- High degree of cleanliness
- Remaining inclusions are very small in size and evenly spread
- Excellent mechanical properties in transversal and longitudinal directions
- Free of internal flaws (e.g. hydrogen flakes)
- Smooth ingot surface resulting in high ingot yield
- Thin slag skin improves heat transfer to the mold

## Further Advantages

- High material yield in ingot
- No shrinkage cavities in ingot
- No conditioning of ingot surface is necessary prior to forging
- Electrodes for remelting can be used in the as-cast condition

# ESR Process Technology and Characteristics

ALD's process expertise guarantees high process reproducibility and material quality.

## ALD ESR Features

- Ingot weights from 100 kg to above 200 metric tons
- AC-current used as remelting energy, from 3 kA to 92 kA
- Ingot diameters from 80 mm to > 2000 mm, depending on material being remelted
- Round, square and rectangular ingot shapes are possible
- ALD offers systems for special processes such as remelting under pressure, protective inert gas or vacuum. A growing market share is anticipated for these processes, especially the ESR process under inert gas atmosphere.
- ESR configurations are available with multiple heads and/or melt withdrawal stations for faster preparation or multiple electrode exchange techniques for larger ingot.

## Slags in ESR

Slag chemistries for ESR are usually based on calcium fluoride ($CaF_2$), lime (CaO) and alumina ($Al_2O_3$). Additions such as magnesia (MgO), titanium dioxide/titania ($TiO_2$) and silica ($SiO2_2$) may also be added, depending on the alloy to be remelted. To perform its intended functions, the slag must have some well-defined properties, such as:

- Its melting point must be lower than that of the metal to be remelted
- It must be electrically efficient
- Its composition should be selected to ensure the desired chemical reactions
- It must have suitable viscosity at remelting temperature

## Inert ESR

- Oxidation of electrode and slag is completely avoided.
- Oxidizing loss of elements such as Ti, Zr, Al, Si, etc. is almost completely avoided. This is especially important when remelting high Al- and Ti-containing alloys, like superalloys with very narrow analytical ranges.
- Better cleanliness in the ingot is achieved.
- When using argon as the inert gas, pick-up of nitrogen and hydrogen is avoided; (when using nitrogen as the inert gas, some pick-up of nitrogen is possible.)

# ALD ESR Furnace Stationary Mold

## Inert Electro Slag Remelting


### Design Features of ALD ESR Furnaces

- Stable or free-standing gantry design of furnace head superstructure features a simple platform installation, with no flexing of the superstructure under load, and provides a consistent centering of the electrode.
- Proven electro-mechanical, dual-electrode drive system for very precise control of slow ram speeds during the remelting process and faster speeds for charging procedures.
- Remotely controlled, pneumatically operated electrode/stub clamp with maximum melting current transfer to the electrode.
- Fully coaxial design avoids stirring action of the melt bath due to stray magnetic fields.
- Power supply with space saving design, either thyristor or saturable reactor control, designed specifically for fast response, tight current control and power control.
- Sophisticated weight management system including highly accurate, fully temperature compensated load cell system and statistical based melt rate algorithm.
- Completely automatic operation of the furnace by the use of password-protected preset melt recipes, stored locally or downloaded from any host system.
- Statistical Process Analysis (SPA) is possible with the data acquisition system of the Operator Interface PC in combination with the optional Supervision System PC.

### Atmospheric Protection Systems

Two furnace concepts are available, one with a protective hood system of relative tightness, the other with a fully vacuum-tight protective chamber that allows the complete exchange of air against an inert gas atmosphere prior to starting the remelting process.

# ALD ESR Furnace Special Designs

## Pressure and Vacuum Electro Slag Remelting

### Electro Slag Remelting under Pressure (PESR)

For the production of high nitrogen steels, it is essential that a sufficiently high amount of nitrogen above the solubility limit under normal pressure is introduced into the molten steel and that nitrogen loss is prevented during solidification.

### PESR Features

- Nitrogen content above the solubility limit at atmospheric pressure
- Continuous nitrogen feed into the furnace interior
- Operating pressures up to 42 bar in production and 70 bar in laboratory
- Pressure level depends on composition of the alloy and desired nitrogen content in ingot
- Pressure prevents nitrogen loss during solidification
- Liquid solidifies under high pressure

### Electro Slag Remelting under Vacuum (VESR)

Remelting is carried out under vacuum as in VAR, however, using a slag. The advantages of both ESR and VAR are combined in one process.

### VESR Features

- Combined process (VAR and ESR)
- Avoid hydrogen and nitrogen pick up
- No moisture from slag
- No oxidation of the melt
- Danger of white spots reduced to a minimum

# ALD ESR Furnaces Ingot Withdrawal

Whenever large dimensions and heavy weights become necessary

## Ingot Withdrawal Systems

System configurations are available with a central ingot withdrawal station and electrode exchange capability, and two outer stations for remelting in stationary molds. The central station is particularly suited for the remelting of large diameter ingots. Smaller diameter ingots may be remelted simultaneously in the outer stations.

## Special Design Features

- 2 heads, 1 center withdrawal station
- 2 optional outer stations for simultaneous melting
- Electrode pre-heating device
- Short electrodes possible
- Electrode exchange technique (automatic)
- Long ingots in center station
- Flexible in ingot length
- Insulation of the ingot in center station to maintain ingot bottom temperature
- Fully enclosed electrode melting

# ESR Process Control

ALD's automatic melt control system (AMC) is unsurpassed in the world for its accuracy, reproducible metallurgical quality and ease of operation.

ALD provides precise control of all ESR remelting parameters for the reproducible production of homogenous ingots, which are free of macro-segregation and show a controlled solidification structure and superior cleanliness.

Computer controlled process automation used by ESR furnaces fulfill today's most stringent material quality specifications.

## ALD's ESR control system handles

- Logic control functions
- Continuous weighing of the consumable electrode
- Closed loop control of process parameters (e.g. remelting rate, immersion depth using resistance swing)
- Data acquisition
- Data management
- Communication via field bus or specific interfaces

## Operator Interface PC (OIP)

- Acts hierarchically as master of the automatic melt control system (AMC)
- Utilized as interface between operator and ESR process
- Server for process visualization, featuring parameter indication, graphic displays and soft keys for operator commands, editing and handling of remelting recipes, data acquisition and storage and for generation of melt records
- Can be optionally equipped with an Ethernet network interface which may be utilized for data transfer to other computers connected to the local area network (e.g. supervisory PC, customer's mainframe, etc.)

## Melt Recipes

ALD furnaces work with established remelting parameters stored as remelting recipes on a hard disk, for the repeatable ESR production of specific ingot sizes and material grade combinations, and to assure full metallurgical ingot quality.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