Vacuum Induction Melting for Investment Casting

Gurkan Birben – GURAR Investment Casting, Istanbul, Turkey

Vacuum induction melting produces parts with more optimal chemical and physical characteristics after casting. For this reason, it is possible to cast strategic alloy parts – where weight, durability and precision are of great importance – for the aerospace and electronics industries as well as for inner-body prosthesis.

Current aerospace-market demand is growing every day, so being experienced in vacuum casting is an advantage in Turkey. In order to catch the rapid growth of investment casting technology in the world, GURAR commercialized investment casting under vacuum. As a result, for the first time in Turkey we commercialized the casting of special alloys, such as nickel, cobalt-based and aluminum under vacuum.

Vacuum Induction Melting

Vacuum casting (vacuum induction melting – VIM) was developed for processing of specialized and exotic alloys, and it is consequently becoming more commonplace as these advanced materials are increasingly employed. VIM was developed to melt and cast superalloys and high-strength steels, many of which require vacuum processing because they contain refractory and reactive elements such as Ti, Nb and Al. It can also be used for stainless steels and other metals when a high-quality initial melt is desired.

As the name suggests, the process involves melting of a metal under vacuum conditions. Electromagnetic induction is used as the energy source for melting the metal. Induction melting works by inducing electrical eddy currents in the metal. The source is the induction coil, which carries an alternating current. The eddy currents heat and eventually melt the charge.

The furnace consists of an airtight, water-cooled steel jacket capable of withstanding the required vacuum for processing. The metal is melted in a crucible housed in a water-cooled induction coil, and the furnace is typically lined with suitable refractories.

Metals and alloys that have a high affinity for gases – in particular nitrogen and oxygen – are often melted/refined in vacuum induction furnaces to prevent contamination/reaction with these gases. The process is therefore generally used for processing of high-purity materials or materials with tight tolerances on chemical composition.

Industrial Uses of Vacuum Induction Melting

- Refining of high-purity metal and alloys
- Electrodes for remelting (VAR or ESR)
- Master-alloy stick for processes such as investment casting
- Casting of aircraft-engine components

Advantages of VIM Melting

Depending on the product and metallurgical process, vacuum levels during the refining phase are in a range of 10^{-1} to 10^{-4} mbar. Some of the metallurgical advantages of vacuum processing are:

- Melting under oxygen-free atmosphere limits formation of non-metallic oxide inclusions and prevents oxidation of reactive elements
- Achievement of very close compositional tolerances and gas contents
- Removal of undesired trace elements with high vapor pressures
- Removal of dissolved gases – oxygen, hydrogen, nitrogen
- Adjustment of precise and homogeneous alloy composition and melt temperature
- Melting in a vacuum eliminates the need for a protective slag cover and decreases the potential of accidental slag contamination or inclusions in the ingot

Fig. 1. Vacuum casting furnace

Fig. 2. Induction furnace in vacuum chamber

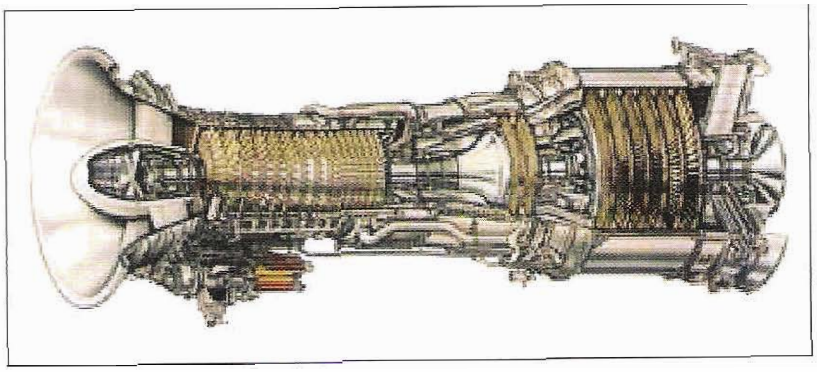

Fig. 3. Turbine motor

For this reason, metallurgical operations such as dephosphorization and desulphurization are limited. VIM metallurgy is primarily aimed at the pressure-dependent reactions, such as reactions of carbon, oxygen, nitrogen and hydrogen. The removal of harmful, volatile trace elements, such as antimony, tellurium, selenium and bismuth, in vacuum induction furnaces is of considerable practical importance.

Exact monitoring of the pressure-dependent reaction of excess carbon to complete the deoxidation is just one example of process versatility using the VIM process for production of superalloys. Materials other than superalloys are decarburized, desulfurized or selectively distilled in vacuum induction furnaces in order to meet specifications and guarantee material properties. Because of the high vapor pressure of most of the undesirable trace elements, they can be reduced to very low levels by distillation during vacuum induction melting, particularly for alloys with extremely high strengths at higher operating temperatures. For various alloys that must meet the highest quality requirements, the vacuum induction furnace is the most suitable melting system.

The following methods can be easily combined with the VIM system to produce clean melts:

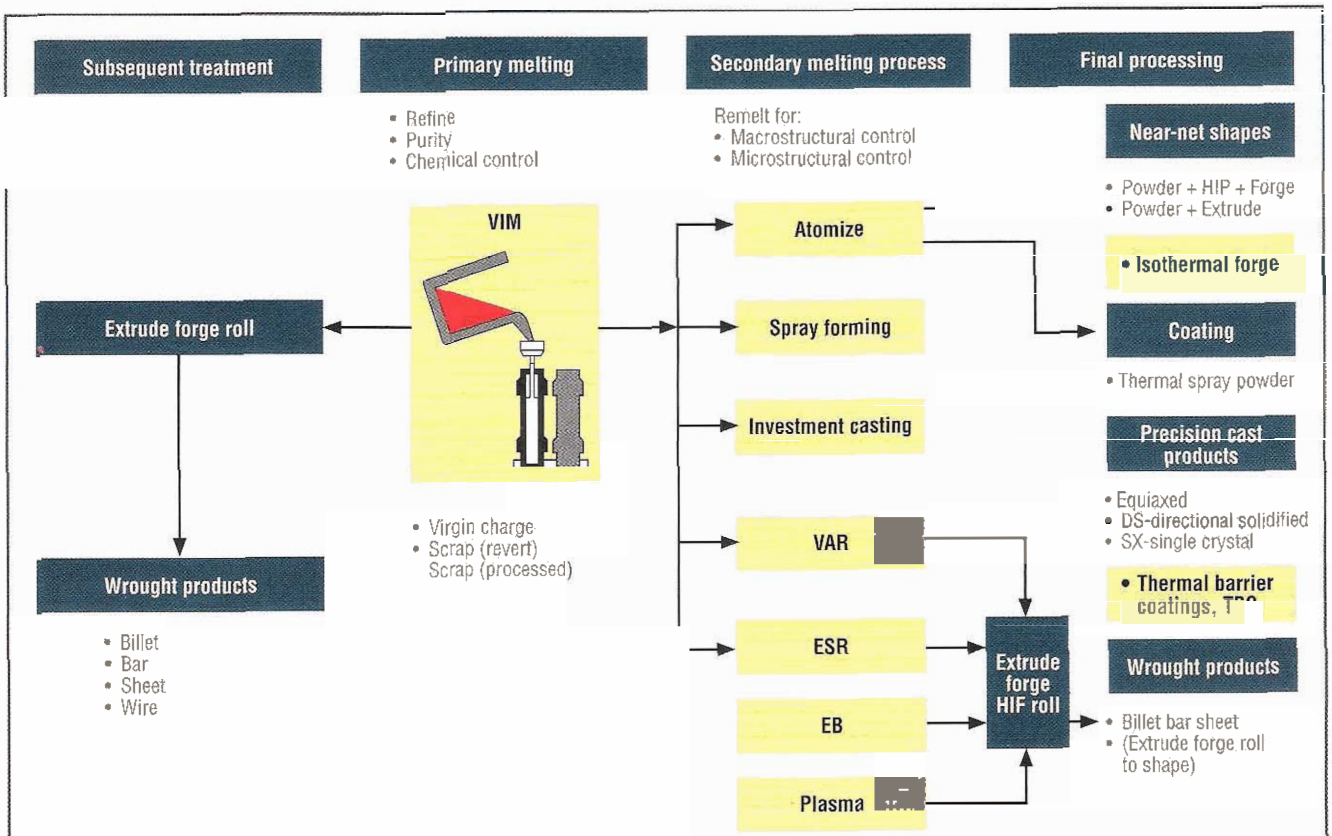

Fig. 4. Processing route for products cast from VIM furnaces

- Atmosphere control with low leak and desorption rates
- Selection of a more stable refractory material for crucible lining
- Stirring and homogenization by electromagnetic stirring or purging gas
- Exact temperature control to minimize crucible reactions with the melt
- Suitable deslagging and filtering techniques during the casting process
- Application of a suitable launder and tundish technique for better oxide removal

Applications of VIM Melting

Vacuum induction melting is mainly used in the manufacture of superalloys. These are usually nickel, cobalt or iron-based alloys offering high strength at elevated temperatures. VIM is also used to melt special copper base, titanium, aluminum and other unique materials. It is often combined with other processes in production premium high-performance parts.

Superalloys comprise the majority of VIM production. About 60-100 million pounds are produced per year mainly due to the demand for aircraft engines. About 80% of all superalloys are used in aircraft and aerospace applications. The next largest use is in power generation – 13%. The petrochemical industry and miscellaneous applications account for the remaining 7%.

Total electric power consumption per unit of product is high for VIM because of the small quantities produced and the energy required to produce a vacuum. While no exact figures are available, knowledgeable individuals estimate the consumption rate is twice that of normal induction melting, or about 1,200 kWh per ton. **IH**

REFERENCES

"Vacuum Melting of Metals – State-of-the-Art Assessment EPRI Report No. EM-4508, April 1986 AZoM.com"

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