GINATTA TORINO TITANIUM
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NEW ADVANCES IN ELECTRON-BEAM REFINING

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The electron beam cold hearth refining and casting process uses a water cooled copper trough or "cold hearth" placed between the melting station and the casting station. Thus separating the melting and refining steps from the solidification operations.

The water cooled copper trough or cold hearth is so configured as to provide an extended surface area in a high vacuum, where the residency time of the metal can be controlled.

The electron beam energy applied to the molten metal provides a stirring action to the shallow metal bath resulting from the intense heating of a localized area and the immediate temperature balancing by the surrounding, relatively cooler metal. This stirring results in the liberation of low density particles (such as oxides) tram the bath and allows them to float to the top where they are retained by the surface tension of the metal pool.

These oxides tend to volatilize during refining.

The stirring action on the cold hearth resulting from the temperature gradients surrounding the beam impact areas liberates carbides, oxy and carbo-nitrides which dissolve and resolidify as a fine, two phase liquid-solid mixture of fine micro-segregates suspended in a highly fluid metal, containing an estimated 30%-40%

solids of small dendritic crystallites with a secondary arm spacing of about 50 microns.

The solidification of the metal is accomplished under carefully controlled heat transfer conditions. By maintaining these heat flux patterns, the solidified metal maintains the very small scale dendritic micro-structure uniformly throughout the resulting cast product.

High Density Inclusions in titanium alloys. A program has been carried out where titanium alloy was purposely seeded with broken tungsten carbide pieces, molybdenum and tantalum wires and titanium nitride seeds simulating hard alpha particles, these were added to a hearth during the melt. The skull was later X-rayed and chemically analyzed. All of hearth skulls examined exhibited a similar pattern, the seeded HDIs has dissolved within a short distance from the entry location on the hearth, none had reached the exit zone of the hearths.

EB refining also benefits in the removal of the volatile

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Torr should be maintained. While the Electron-Beam can be maintained at higher operating pressures of 50 to 100 microns these pressure are too high to facilitate the necessary thermochemical reactions.

Vaporization losses during electron-beam refining has become a very misunderstood matter. For the moment let us separate the EB cold hearth refining conditions for titanium and its alloys from superalloy refining and casting because they are the same process practiced in two different modes.

The superalloys are introduced to the hearth as a previously consolidated and homogenized VIM ingot. In order to affect the refining on the hearth as described earlier in this paper, care is taken to add heat to the hearth to allow only clean metal to flow to the solidification station. The liberated non-metallics present on the surface, luminesce and are obvious to the E.B. furnace operator. A repeatable, programmed sweep beam pattern with a beam power density of 35 to 60kW is sufficient for refining a full hearth of metal of approximately 18 to 20 inch wide by 30-36 inches long with metal inventory of about 1/2 inch depth. A hearth of this general configuration is capable of refining 350 to 450 pounds of

VIM input quality, nickel base alloy, per hour, using a total of 120 to 150 kW for melting, refining (including surface sweeping) opening the pour lips and hot topping the inqots. This estimate is based on a dual strand caster.

Larger furnaces for superalloy forging ingots may require larger hearths, ingot molds and higher power EB guns, but mega watt power is not part of the future of superalloy refining. At the power levels described above the chromium losses for IN-718 are typically 2% to 3% during EB refining that equates to change from 19.5% input to 19.0% output. Hf, Al, Ti, Zr, B, Cb, Y and V are unchanged during EB processing.

The E.B. melting of titanium and titanium alloys is carried out at pressures of 50 to 100 microns, this is due to the higher levels of contained gases and water vapors from sponge and cleaned machine chips added to the melt. These are low density materials which are fed into the melt. The combined problems of low density, poor coupling, high surface area, feed stocks require large amounts of electric power to melt.

Ingot production rates in the mega watt range EB titanium furnaces are in the 1100 to 1500 pound per hour range depending upon ingot size, shape and alloy grade. Aluminum and Chromium are preferentially evaporated, rather unevenly from the titanium alloys in which they are contained because of the high beam power densities used.

The plasma arc melting (PAM) and electron-beam melting (EBM) are both cold hearth processes are currently being studied.

Titanium alloys produced by Electron Beam Melting (EBM) (EBCHR) and Plasma Arc Melting (PAM), (PACHR) is underway by several aircraft engine builders funded in part by the USAF.

These two processes obviously compliment one and other and their greatest value will be realized when the are joined. The capacity of the plasma torch to operate at 1 atmosphere and pour an unrelenting blast of heat, on to the melt stock, when molten allow the metal to pass to a vacuum chamber for EB refining and on to an ingot casting/solidification station with continuous electron-beam hot topping.

There is much design and equipment building work to be done to satisfy these growing markets, each with specific production/application needs.

We would like to share with you, some ideas we have for specific furnace designs.