Hot Isostatic Pressing Offers Greater Flexibility in Component Design, Alloy Choice, Achievement of Mechanical Properties

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More and more, designers and purchasers of metal castings find themselves in a battle between lower cost and higher performance. Maintaining a balance between the two sometimes requires sacrificing one asset for another. Strength, weight, service life, and/or other considerations may be forfeited to minimize cost.

Hot isostatic pressing (HIP), however, is providing an alternative solution to this dilemma. By incorporating HIP as a part of the manufacturing process, casting manufacturers and end users are experiencing greater freedom in producing their products.

The HIP process, developed in the mid 1950s, subjects components to the simultaneous application of heat and high pressure in an inert gas medium. The pressure is uniform on all directions or isostatic. Components are placed in a pressure furnace with inert gas and heated to high temperatures. Using "hot isostatic pressure," the part is heated to a "plastic state" which collapses the voids. The clean surfaces of the voids bond together, making components or parts stronger. In most cases, the voids that were collapsed do not change or alter the shape of the parts or components.

The HIP process began being used for casting densification in the early 1970s. Since that time, HIPing costs have dropped as more efficient methods have been adopted and larger and larger capacity units have entered the market. Turnaround times have also been drastically reduced.

Currently, the process is universally recognized in and used in the aerospace, commercial, military, medical, automotive and recreational industries.

The major activity is in the consolidation of powder metals, the densification of high-performance castings, diffusion bonding of similar and dissimilar metals, and rejuvenation of fatigue-damaged parts.

More and more applications of HIP are expected in the future as designers identify areas where the technical or cost advantages might be realized.

Mold design can be simplified to save material formerly used in complex gating. The placement of chills becomes less critical when HIPing is designed into the process.

Alloys once considered uncastable can be reconsidered by using HIP. A concept of cast-to-fill and HIP-to-density can be developed to take full advantage of more exotic materials.

HIP reduces rejection due to casting defects such as porosity and improves mechanical properties.

Reasonable control of defects in cast alloys, such as shrinkage, inclusion and alloy segregation is possible by proper mold design and good foundry practice. However, the complete elimination of all defects from cast shapes is not possible without applying some external force to accomplish deformation necessary to close voids and porosity. HIP provides the ideal mechanism for the application of this force, combining heat and pressure to collapse voids and porosity of creep mechanisms and to "heal" the material by diffusion bonding the material together. The isostatic nature of the applied pressure is well suited to healing the defects in castings. Void closure is accomplished with a usually immeasurable, dimensional distortion resulting in improved reliability of the casting. Pieces of extremely complex geometry can be treated without the use of expensive tooling.

The effects of HIP on mechanical properties include higher strength, higher toughness, longer fatigue resistance and longer creep life. The greatest significance of the HIP process is the marked reduction in the statistical spread or scatter usually associated with cast material. The result is improved efficiency of the material utilization in the casting, and the ability to use castings for applications formerly requiring wrought or forged parts to meet specifications

In many engineering applications, the response to a fatigue environment is critical to the materials and processing route selections. Any increase in porosity content reduces fatigue capability. Since HIP eliminates the porosity, it improves fatigue life and tensile properties.

HIP can be cost effective in even the smallest of foundries.

While the full extent of HIP application is yet to be discovered, the demonstrated benefits of HIP make it important to identify areas where technical or cost advantages might be realized. Research and development departments will continue to seek solutions with hot isostatic precessing. As we enter the 21st century, HIP will enable us to fabricate exotic materials into better products for a changing environment.

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