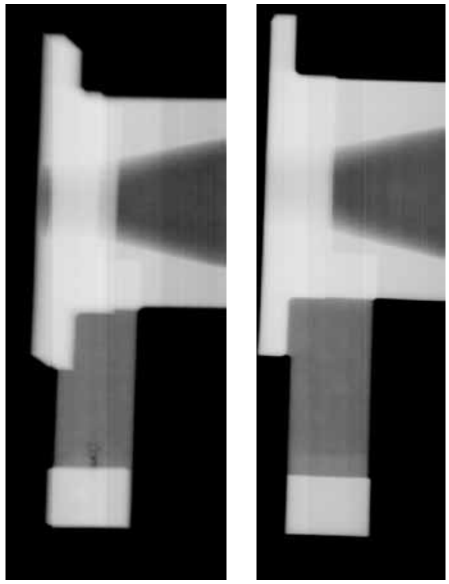
An Introduction to Hot Isostatic Pressing for Investment Casters

Castings, the introduction of liquid metal into a suitably shaped mold and then allowing it to solidify, is a way to produce net-shape metal components. Unfortunately, the liquid to solid phase change at the heart of the process is accompanied by a change in volume, which is at the root of all the problems commonly associated with the casting process. In the extreme cases, this volume change on solidifications gives rise to gross shrinkage cavities or hot tears within the casting; this phenomenon is a problem for the foundry, but is well understood and can be corrected by a competent metalcaster, so that the end user of the casting need not usually take this problem into consideration.

The traditional methods of gating and feeding castings are the foundryman's response to the volume change on solidification and represent an attempt to arrange for a liquid/solid interface to move through the metal in the mold cavity in such a way that defects in the casting are minimized, all the gross effects occurring within the gating and feeding systems which is then removed from the finished casting. Usually, micro-shrinkage still exists within the casting, weakening the material from within, but these age-old techniques result in a product adequate, and indeed often highly satisfactory for the applications in which castings are traditionally specified, structural and critical applications where a large safety factor can be designed into the component.

Premium Quality Castings

The logical next stage to widen the application of castings is the removal of this residual micro-shrinkage. The approaches used involve the narrowing of the liquid/solid interface and controlling the grain growth of the metal. Both techniques reduce micro-shrinkage by minimizing the restrictions within the solidifying casting. The ultimate narrowing of the liquid/solid interface occurs in directional solidification and single-crystal technology, but this makes for extremely expensive castings, and traces of shrinkage can still occur between dendrite arms within the metal crystal as the last metal solidifies.



LEFT: Component before HIP
RIGHT: Component after HIP
Photo compliments of Kovatch Castings.

The last metal to solidify is surrounded by solid material, so that it cannot be fed from elsewhere, giving rise to shrinkage in the grain boundaries, and also to some extent, between dendrite arms within the grains. This micro-shrinkage, expressed as a percentage of casting volume, may be minute (less than .01%), but its effect on physical properties will be disproportionately high, because each tiny cavity is sharp-edged and often located in high energy areas of the casting.

To compound the problem for the casting user, the feeding of the casting at this level represents a complex set of problems changing the level of hydrostatic pressure within an environment (intergranular and ultimately interdendritic). The net result is that the variation in properties between apparently identical castings may be high, so that a safety factor must be applied.

Thus, all castings may be said to have defects inherent in the process, and also to be inherently inconsistent in quality. This is the reason for the aircraft industry's "Casting Factor," requiring an overdesign (after other safety factors have been applied) for castings in airborne applications.

Upgrading the Casting

Pressure can be used to close internal defects in metal components, as in forging. However, mechanical pressing is not practical for the complex shapes of most castings. Hot Isostatic Pressing (HIP), on the other hand, involves gas pressure applied to the heated components. It can be applied with no change to the cast configuration, and when the pressure exceeds the yield point, the internal shrinkage cavities will be forced closed and the metal will then diffusion bond, thus "healing" the casting.

HIP is a well-established process for the improvement of a variety of materials such as titanium, cobalt-chrome, steel aluminum and superalloys for complex cast parts. Rotating cast parts in aircraft engines, critical titanium castings and prostheses are examples of parts frequently processed by HIP. The closure of internal voids tends to improve mechanical properties, especially the notch-sensitive properties such as fatigue resistance and impact resistance. Defects visible by radiographic techniques can be eliminated. Most important, HIP processing makes the castings much more consistent in quality because the lower limit of the properties scatter band is raised.

HIP involves batch processing in specialized expensive equipment, but the use of a HIP service provider removes the need for capital investment, and using the process can yield significant savings in production costs. For instance, the engineer designing the gating systems can concentrate on filling the mold with the simpler gating system, improving the casting yield and maximizing the number of castings to a mold. This in turn leads to lower finishing costs. Finally, the necessity for radiographic inspection can be reduced or eliminated, resulting in even further savings.

Hot Isostatic Pressing is unique in that it is the only known process which improves casting quality after the fact, in a predictable manner.

Benefits of HIP of Castings

1. Improvement of mechanical properties, particularly fatigue life.
2. Allowing reduced gating and feeding. reduces casting costs by improving yield per mold as well as yield per pound of metal melted.
3. The ability to produce more consistent castings should open up new markets, enabling metal casters to compete with other manufacturing processes such forging or hogouts.
4. Allowing the use of super-fine grain casting techniques. Several techniques are available for producing castings with extremely fine grain size, but the castings are unusually difficult to feed. After HIP, the full advantage of the fine gained structure can be realized.
5. Inspection costs can be reduced, again due to the improved consistency.
6. Enable the salvage of rejected parts

This article offered by Pressure Technology with input from Kovatch Castings..

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