Moly is HIP

Improving the safety and efficiency of technologies and minimizing their environmental impact often depends directly on the development of better materials. Hot isostatic pressing (HIP) technology has been at the forefront of this area for decades. Recent advances improve the productivity of making HIPed parts and reduce their cost. Molybdenum metal components are crucial to HIP furnace performance.

A hot isostatic press, or HIP, is essentially a furnace built inside a pressure vessel. Originally developed in the 1950s in the quest to make man-made diamonds from graphite, HIPs are now used in a range of critical, high-performance applications. They can produce temperatures up to 2000°C and pressures twice those at the deepest part of the ocean, to process parts and materials. Holding a work piece under pressure, at 80 to 90% of its melting temperature, closes any internal pores and cracks and homogenizes the microstructure.

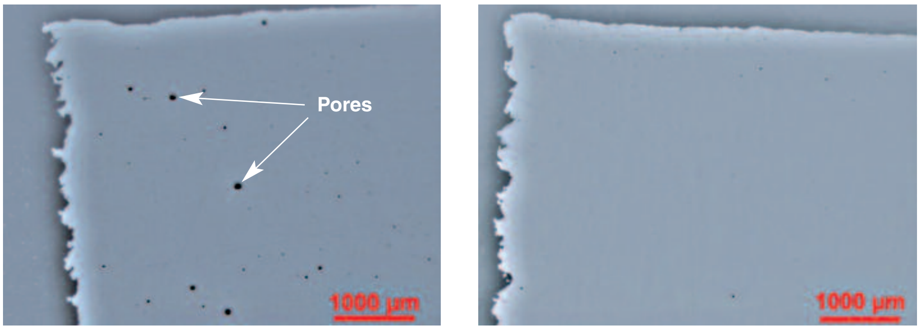
Traditional HIP applications

Most metallic parts are fabricated from standardized bar, plate or sheet products. They are then hot or cold formed, welded, machined or undergo a combination of these processes to create the final component. This approach works well for the vast majority of applications, but there are cases where it is not economical or even possible. They include materials that are not weldable or machinable, are expensive, or cannot be produced with traditional processes and components with complex geometry. For these examples, specialized production methods such as casting, Powder Metallurgy (PM) and Additive Manufacturing (AM), also called 3D printing, have been developed. These processes skip most or all of the conventional steps and produce what is called a near-net shape (NNS) part from the start.

HIP is traditionally used to reduce porosity of castings, press-sintered and metal-injection-molded PM parts, and more recently, of AM parts. It is an essential processing step in consolidating PM powders to create fully-dense NNS components. It can also be used to join different materials through diffusion bonding, such as cladding a thin layer of a high-cost, high-performance material onto a lower-cost base material.

HIP is a cost-effective technology to improve material properties such as toughness and fatigue life. HIPing thereby increases the safety and reliability of materials and components, extending their service life and reducing ❯

Cast components being lowered into a HIP vessel. © Bodycote



NNS parts often have to cope with internal voids, pores and cracks as a result of the process. These defects reduce a material's strength, ductility, and impact toughness, as well as its fatigue and creep resistance. Closing them through HIPing significantly improves material properties. The pictures show an AM part before (left) and after (right) HIPing. © Quintus Technologies

the danger of failure during operation. It can even 'heal' parts that have been in service and have some internal damage. For example, turbine blades that have formed pores in operation can be rejuvenated by closing those pores through HIPing, and returned to service.

Traditionally, large HIPs have been operated by a few specialized service providers around the world. They are used in many industries, including aerospace, oil and gas, automotive, tooling, electronics, power generation and medicine. Examples of parts that are HIPed include medical implants, high strength cutting tools and critical components in gas turbines.

HIP/Heat-treating combo

HIPing used to be a relatively slow process, not only because of the procedure itself, but because the vessel (and the HIPed parts in it) can take hours to cool down. Unfortunately, many materials require rapid cooling or quenching after annealing, often followed by further heat treatments to achieve the desired properties. These steps are usually outsourced, adding to lead times and cost.

Engineers at a long-established company, now known as Quintus, were able to overcome this constraint through an innovative wire-wound design in the HIP vessel which was originally introduced in the 1950s. It permitted thin-walled pressure vessels which were strong enough to contain the high operating pressures and were extremely safe. The reduced mass of wire-wound vessels enables rapid cooling and even quenching from the operating temperature, vastly expanding their usefulness.

Modern HIP units combine the benefits of HIPing and heat-treating, including controlled cooling in one vessel, reducing cycle time and increasing productivity of making HIPed parts that also require heat treatment. For example, the high-strength, corrosion-resistant nickel-base superalloy IN718 used for jet turbine parts is hardened by the precipitation of secondary phases within the metal matrix. After HIPing, parts require solution annealing at around 1000°C,

The inside of a typical HIP furnace. Molybdenum is used for the heating elements encircling the 'hot zone', the structure that supports the elements, 'furniture' that supports the furnace load, and thermal shielding that surrounds the hot zone. © Quintus Technologies

followed by rapid cooling. The material is then aged in two steps to precipitate the hard particles in a controlled fashion.

Processing this material directly in the HIP can reduce handling and shipping time for outsourced heat treatment as well as related transportation expenses, delay times awaiting furnace availability, and inventory costs needed to protect against such delays and extra steps.

These developments may be a key to the success of the rapidly growing additive manufacturing (AM) technology, where HIP has become a standard process used to heal internal defects. For example, one AM manufacturer is able to perform all heat treatment in the in-house HIP unit in hours rather than weeks, keeping the entire process within the walls of the AM center.

Why is Moly HIP?

Molybdenum's high melting point of 2623°C, its high strength at elevated temperatures, and its low cost compared to alternative choices have made it the preferred material for HIP furnaces since their inception. The heating elements, thermal shields, furnace racks and other internal furniture, are all made predominantly of molybdenum alloys.

The new HIP furnaces which feature heat treatments and rapid cooling use thermal cycles that stress components in ways never before seen due to thermal expansion related stresses on heating elements and other internal parts. Molybdenum's low thermal expansion coefficient and high thermal conductivity combine to minimize thermal-cycling stresses, allowing the long service expected of these sophisticated furnaces.

Small and medium HIP units for metal AM are the fastest growing market for HIPs. Both Original Equipment Manufacturers (OEMs) with in-house AM centers and independent AM processors, who produce 3D printed parts for third parties, are purchasing systems. As AM technology grows and as companies shift from prototyping to production › mode, they are realizing the economic and intellectual property benefits of operating their own in-house HIP. Such a setup permits optimization for their specific products' performance.

With the dramatically growing demand for HIP services and faster turnaround times, heat treating companies are also getting into the business. They are expanding their offerings by adding a HIP vessel to become a one-stop shop for all AM heat treating, simplifying their customers' logistics. Smaller vessels are more flexible, can run with faster turnaround times and tailored heat treatment cycles. However, as AM evolves to produce more parts simultaneously, it is expected that a need for larger vessels with high pressure heat treatment capability will arise in the future. Molybdenum has been there to support the growth of HIP technology and will continue to be there as the industry evolves. (JS, JAS)

A modern HIP unit. The molybdenum furnace is found in the pressure vessel at the center of the picture. The vessel is contained within the dark arched frame. © Quintus Technologies