Hot Isostatic Pressing of Near Net Shaped Parts

a service offered by the Hempel Special Metals Group
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Introduction

- What is hot isostatic pressing of near net shaped parts?
- Which are the technologies needed?
- What are the alternatives?
- Which are the comparative advantages?
- For which alloys and geometries is HIP an option?
What is hot isostatic pressing of near net shaped parts?

It is a modern manufacturing method for shaped parts with a weight in the range between 10 kg and 15 tons. The method bases on powder metallurgy and combines some of the advantages of casting technology with those of forging technology.
Which are the technologies needed?

- manufacturing of alloy powder by gas atomisation
- powder consolidation by hot isostatic pressing
- near net shaped product
What are the alternatives?

raw material | master-alloys | metal powder | billets | plates bars
---|---|---|---|---
MANUFACTURING METHOD | CASTING | COMPACTION (SINTERING) | FORGING | MACHINING / JOINING
Which are the comparative advantages?

<table>
<thead>
<tr>
<th></th>
<th>casting</th>
<th>HIP</th>
<th>forging / machining</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>metallurgical quality</strong></td>
<td>bad</td>
<td>good</td>
<td>good</td>
</tr>
<tr>
<td><strong>material losses</strong></td>
<td>low</td>
<td>low</td>
<td>low / high*</td>
</tr>
<tr>
<td><strong>processing effort</strong></td>
<td>low</td>
<td>low</td>
<td>low / high**</td>
</tr>
</tbody>
</table>

* for complex shaped parts (i.e. valve bodies…)
** for complex shaped and / or big parts
For which alloys and geometries is HIP an option?

- Nickel & cobalt based alloys
- Super-austenitics & duplex SS
- Stainless steels
- Potential HIP regime
- Classical forging regime
- Discs
- Drums & hollow bars
- Valve bodies & manifolds
- Increasing material value
- Increasing shape complexity

HIP is favoured where material costs & metallurgical requirements are high and/or where the total processing effort is high.
Description of Method

- How does hot isostatic pressing work?
- How is a HIP - part produced?
- How is the container manufactured?
- How does a HIP - furnace function?
- How does a HIP’d part look like and how is it finished?
How does hot isostatic pressing work?

HIP is a method for the densification of metallic or ceramic material by application of a high isotropic pressure at temperatures below the melting point of the material.

HIP can be used for:

1. elimination of closed porosities in castings or sintered parts

2. consolidation of a metal powder within a closed and evacuated metal container
How does hot isostatic pressing work?

1) densification of materials containing closed porosities

![Diagram showing pressure, temperature, and material with closed porosity]
How does hot isostatic pressing work?

2) consolidation of metal powders

HIP-furnace (gas filled)

container (must be completely evacuated!)

powder particles

merge by formation of...

...sinter necks
How is a HIP - part produced (next slide)?

(1) a container with the shape of the desired product is designed and produced
(2) the container is filled with a powder of the desired alloy
(3) filled container is evacuated
(4) the container is put into a hot isostatic press
(5) the alloy powder is consolidated at elevated temperatures with the help of a big pressure by a sintering mechanism
(6) pressed canister is cooled down
(7) container material on the surface is removed by machining
processing sequence

1) weld a container with an intake
2) fill container with metal powder
3) evacuate and close container
4) press container in a HIP
5) remove container material by machining
How is the container produced?

- Container is manufactured by welding of steel sheets, tubes and pipes.
- Weld design and integrity is critical.
- Weld seam can be examined with respect to leakages using He detectors.
How does a HIP - furnace function?

- HIP is filled with an inert gas (Ar) at room temperature
- closed HIP is heated up and gas expands
- at high temperatures the powder within the canister consolidates by a sintering mechanism with the help of argon pressure all-round
How does a HIP’d part look like and how is it finished?

- as-hipped part with canister & with fill tubes
- machined & annealed drum

Canister material is perfectly bound to the base material by diffusion bonding. It can be removed by machining (simple shape) or by acid leaching (complex shape).
Supply Chain Aspects and Quality Management

- How does the overall value chain looks like?
- Which are the main quality drivers within the value chain?
- How is the part certified?
How does the overall value chain looks like?

P/M route

- alloy melting and atomisation
- design and fabrication of a container
- HIP and heat treatment of part
- container removal & finishing to tolerance
- validation & certification of product

forging route

- alloy melting and casting
- forging a billet
- forging and heat treatment of part
- finishing to tolerance
- validation & certification of product

P/M - HIP can also be used for manufacturing of forging billets
What are the main quality drivers in the value chain?

- Alloy melting and atomisation
- Design and fabrication of container
- HIP and heat treatment of part
- Finishing to tolerance
- Validation & certification of product

**Control measures**

<table>
<thead>
<tr>
<th>chemical composition</th>
<th>weld compactness</th>
<th>shrinkage</th>
<th>dimensions</th>
<th>yield-strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>oxygen content</td>
<td>(leakage testing)</td>
<td>density</td>
<td>tolerances</td>
<td>tensile-strength</td>
</tr>
<tr>
<td>inclusion content</td>
<td>porosities</td>
<td></td>
<td></td>
<td>elongation</td>
</tr>
<tr>
<td></td>
<td>grain size</td>
<td></td>
<td></td>
<td>impact energy</td>
</tr>
<tr>
<td></td>
<td>homogeneity</td>
<td></td>
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</tr>
</tbody>
</table>
How is the material certified?

- for any part a certificate according to EN 10 204 3.1 can be issued

- this certificate gives information about alloy composition, (annealing) condition & mechanical properties

- further information like grain size, purity content and ultrasonic examination results can be added on demand

- for applications with special requirements, as for example pressure vessel applications, the parts can be released by means of a expert's (TüV) report
Applications

- Where is HIP already being used for critical applications?
- Which questions have to be raised when considering HIP?
Where is HIP already being used for critical applications?

- **off-shore industry**
  - shaped parts made of nickel based alloys and duplex stainless steels

- **aero industry**
  - gas turbine discs made of high temperature nickel based alloys

- **medical industry**
  - billets for forged and hot-rolled bars made of a cobalt based alloy are currently being produced by powder metallurgy; these bars are used for the manufacturing of implants by forging or machining
Which questions have to be asked when considering HIP?

- Are there economic gains by using powder metallurgy (P/M) and hot isostatic pressing (HIP) instead of forging: costs, quality, raw material availability, throughput time...

- Can we select alloys that are difficult or even impossible to forge or cast: fine grained complex alloys / structures, alloys with enhanced precipitation hardenability, oxide dispersion strengthened alloys...

- Are there possible quality gains provided by HIP alone: densification of casting porosities, densification of MIM - parts, densification of sintered ceramics...

- Are there new opportunities for the design of high temperature components: bimetallic compounds, internal cooling systems....
near net shape manufacturing of valuable alloys

manufacturing of a HIP’d drum from a nickel alloy to save material and machining costs
use of powder metallurgy for customisation of alloys

manufacturing of a HIP’d disc for an impeller made of a customer specific nickel based alloy, which is not available on the raw material market
improved material performance realised by PM & HIP

HIP enables to adjust fine, isotropic microstructures in duplex stainless steels, which is fundamental to attain high strength - high toughness combinations
increased flexibility in design and material selection

Valve bodies and manifolds for oilfield uses can be produced by hot isostatic pressing of duplex stainless steel powder.
bi-metallic components manufactured by HIP

Hot isostatic pressing enables to produce bi-metallic compounds by powder-powder or by powder-solid body bonding.

The method is successfully applied for cladding of more or less complex shaped parts like valve bodies.

sub-component A / alloy A (AISI 304)

sub-component B / alloy B (Ni-base)
realisation of internal cooling passages by diffusion bonding

Hot isostatic pressing enables to produce **hollow structures** by HIP’ing of a pipe or tube system with a metal powder. The realisation of internal cooling passages is a typical example.
Interested?

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