Isostatic Pressing

To Create Unique Engineered Materials

MPIF - HIP Council
John C. Hebeisen
What is Isostatic Pressing?

- The use of fluid pressure to modify materials
  - Fluid may be a liquid (water, oil) or a gas (Ar)
  - Process may be done hot (HIP) or cold (CIP)
- We will discuss 3 commercial processes
  - HIP casting densification
  - HIP powder metal (PM) consolidation
  - CIP powder metal (PM) consolidation
What is Unique About Isostatic Pressing?

- The fluid pressure acts uniformly in all directions.
- Can densify castings without distortion of complex casting features.
- No die friction forces for PM parts
  - 100% densification is possible
  - No size constraints - very large parts are possible
- No die to control shape
  - Must understand shrinkage relationships
Isostatic Vs Uniaxial

Isostatic Pressing

Uniaxial Pressing
Isostatic Pressure Distr.

Object under pressure

Atoms or molecules of gas colliding with the surface.

Compressed gas in container.
Isostatic Shape Change

Initial envelope in specific shape.

Envelope after hot isostatic pressing (exaggerated size reduction).

Pressurized gas in container.
HIP Casting Densification

- Heal internal porosity in cast materials without distortion
  - Improve x-ray results
  - Improve mechanical properties
  - Improve fatigue life
  - Yield smooth polished surfaces
Commonly HIP’d Castings

- Turbine engine components
  - Structural castings
  - Blades
  - Vanes
Commonly HIP’d Castings

- Orthopedic implants
Airframe Castings

- Aluminum and Titanium alloys
- Replace machined slabs and fabrications
Cast Steel Wrench

- Forging replaced by investment casting
- Porosity limited strength properties
- HIP solved the problem
- 80,000 pcs recovered

Micros at 25X
Commonly HIP’d Castings

- Commercial castings (Al, Steel, Stainless)
  - Turbocharger wheels
  - Pump bodies
  - Valve components
  - Gun parts
  - Sterile enclosures
  - High vacuum materials
Improved Microstructure

- Al turbocharger wheel with pores in blade tips and hub
- Pores removed by HIP
- Ductility and HCF life significantly improved

Before HIP | After HIP
---|---
**HIP Improved Properties**

**Cast A356 Aluminum**

<table>
<thead>
<tr>
<th>Condition</th>
<th>Tensile</th>
<th>Fatigue</th>
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<tbody>
<tr>
<td></td>
<td>UTS (Mpa/ksi)</td>
<td>YS (Mpa/ksi)</td>
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<tr>
<td>Cast + HT</td>
<td>258/37.4</td>
<td>211/30.6</td>
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<tr>
<td>Densal + HT</td>
<td>275/39.9</td>
<td>215/31.2</td>
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Typical HIP PM Process

- Gas atomized powder
- Welded steel container
- Powder - vibration packed into container
- Container - outgassed and sealed
- HIP consolidation
- Container removal
Good HIP Powder

Gas Atomized

PREP
HIP Preforms

- Simple shapes
  - Bars, billets, slabs, hollow bars
- Optional finishing steps
  - Forging, rolling, sawing, machining
- Container fabrication
  - Pie, tubing, plate, sheet, etc.
- Part size
  - Large - up to 25,000lb/pc
HIP Container Fabrication

- Steel components
- Weld design is critical
- Weld integrity is critical
Powder Loading

- Air quality and dust control are important
- Inert loading for some grades
- Vibration to settle powder
- Maximum and uniform packing density is important
Hot Outgassing

- Evacuate to remove air
- Heat to remove moisture (RT-800F)
- Seal stem by hot crimping and welding
- Pressure-tight container is critical
HIP Billet Consolidation

- HIP pressure on can consolidates powder at temperature.
- Dimensions reduce predictably as density approaches 100%
Typical HIP PM Billets
HIP PM Hollow Bar

- 25,000lb duplex stainless steel hollow
- After HIP at left, before Hip on right
- Pulp de-watering roll application
Advantages HIP PM HSS

HIP PM T15

Conventional T15
Advantages HIP PM HSS

- 100% dense
- Fine, uniform microstructure (carbides)
- Compared against conv. high speed steel
  - Equivalent wear
  - Improved grindability
  - Improved response to heat treatment
  - Improved toughness
  - No size constraints
HIP PM Near Net Shapes

- Simple to complex shapes
- Machining envelope - typical
- Can fabrication (steel is typical)
  - Spinning, stamping, hydroforming, etc.
  - Internal detail is possible
- Part sizes
  - Large - up to 25,000lb
HIP PM NNS Container

- CAD/FEA container designs
- Complex shapes are possible
- Internal detail can be included
- Weld integrity is critical
HIP PM Valve Body

- Duplex stainless steel for oilfield use
- Greater detail inside and out than forged
- 100% dense with properties equivalent or better than forged
HIP PM Manifold

- Net shape on ID and OD surfaces
- Only machined on mating faces
- Welded into 40ft assemblies
- Lighter in weight than comparable wrought components
HIP PM Steam Chest

- The can at top shows complex inner detail
- The finished part at bottom is machined only on mating faces
- 12% Cr steel
Advantages of HIP PM

- Fine structure, isotropic properties
- Mechanical properties equal to or better than wrought
- Reduced material input
- Reduced machining costs
- Faster delivery
The PM material has a finer, more uniform microstructure than forged material.
### 254-SMO 16” Flexible Coupling - Destructive test results

<table>
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<th>POSITION</th>
<th>DIRECTION</th>
<th>YS(ksi)</th>
<th>UTS(ksi)</th>
<th>EL(%)</th>
<th>RA(%)</th>
<th>IMPACT(ft.lbs)*</th>
<th>HARD(BHN)</th>
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<tr>
<td>Flange</td>
<td>Longitudinal</td>
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<td>108</td>
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<td>ASTM</td>
<td>A182-F44</td>
<td>44min.</td>
<td>94min</td>
<td>35min</td>
<td>50min</td>
<td>-</td>
<td>-</td>
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* impact test at -20C
The CIP PM Process

- Elastomeric bag with metal mandrel
- CIP+Sinter Preform
- HIP to improve density (optional)
- Finish machined part (Ti-6Al-6v-2Sn missile warhead body)
Good CIP Powder

Water Atomized  Hydride-Dehydride
CIP Bag Manufacture

RTV Injection

Bag Removal
CIP Part Manufacturing

Powder Loading

CIP Consolidation
CIP Part Manufacture

Vacuum Sinter

Load for HIP
CIP - Shape Capability

- Intermediate size - typically 2” - 16”
- Fairly intricate shapes
- Typical tolerances
  - Bag-formed features ±.030”
  - Mandrel formed features ±.015”
CIP - Typical Materials

- Titanium alloys
- Tool steels
  - Cutting tools
- Stainless steels
  - Porous filters
- Refractory metals
- Composite materials
  - Macro composites (Ti/W warheads)
  - Micro composites (Ti/TiB₂, Ti/TiC)
HIP Clad Composites

- Powder/powder, powder/solid, solid/solid
- Perfect diffusion bonds are possible
  - Interlayers to control
    - Reactions
    - Differential expansion
- Put expensive material only on the working face
WC-Coated Valve Lifters

The problem:
- Furnace brazed lifters - inconsistent bond
- High scrap rate - 15-17%
- High rate of field failure
- High repair cost
- Lengthening warranty periods
HIP Clad Valve Lifters
Characteristics of HIP Clad Lifters

- Interlayer thickness reduced: .030 to .005"
- Shear strength and thermal fatigue life were improved
- 100% dense bond
- Rejection level reduced: 15 to < 0.5%
- Over 3 million produced without failure
- Total cost cut substantially
Plastic Extrusion Barrels

- Engineered alloys for corrosion and wear liners
- HIP bonded for improved properties
Hot Rolls
HIP Clad Railroad Wheels

- Objective: 4-10 x life “million mile wheel”
- Dyno test on 34” wheel complete
- Alpha wheels on maint. vehicles
- Locomotive test planned

Courtesy: Ultraclad, Inc.
Summary

- Isostatic pressing of unique engineering materials
  - CI P
    - preforming intricate PM shapes
    - sinter or sinter + HIP
  - HIP
    - Casting densification
    - PM billet fabrication
    - PM near net shapes manufacture
    - Clad composite fabrication