The Benefits of HIP and Heat Treatment for Metal Additive Manufacturing

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Bodycote today

- The world’s leading provider of thermal processing services
- Over 170 locations in 21 countries
- 2015 revenue: approx. US$802m
- Listed on London Stock Exchange (BOY)
What does Bodycote do?

World’s largest supplier of HIP and Heat Treating services

Classical Heat Treatment

Bodycote’s Classical Heat Treatments describe a group of mature processes and treatments such as nitriding, carburizing, annealing, tempering and many more. Working to very exacting quality specifications, heat treatment uses precisely controlled furnaces to process a huge variety of metals and alloys, improving their mechanical properties.

HIP Services

- Uses simultaneous application of heat and pressure to eliminate internal porosity from cast components.
- Improves fatigue strength, tensile ductility and fracture toughness.
- The perfect partner for Additive Layer Manufactured (ALM) parts.
A Component Journey - Metal AM

1. Grow part on 3D metal printer
2. Stress Relieve on the build plate
3. Remove the parts from the build plate
4. Hot Isostatic Pressing (HIP)
5. Final Heat Treat
6. NDT + Testing
A Component Journey - Metal AM

Why Stress Relieve?

Grow part on 3D metal printer

Stress Relieve on the build plate

Standard vacuum furnaces cycles

Why Stress Relieve?
Why Stress Relieve?

- Huge thermal stresses are built up with each micro weld interval
- The build plate helps maintain dimension during stress relieve
- Minimize the distortion before more cost goes into the build
- More predictable dimensional control for later operations
A Component Journey - Metal AM

- Grow part on 3D metal printer
- Stress Relieve on the build plate
- Remove the parts from the build plate

- Parts are handled individually for next processing
- Saves volume for following operations
A Component Journey - Metal AM

1. Grow part on 3D metal printer
2. Stress Relieve on the build plate
3. Standard vacuum furnaces cycles
4. Remove the parts from the build plate
5. Hot Isostatic Pressing (HIP)

What is HIP?
**Hot Isostatic Pressing**

Parts are subjected to high temperature (typical of forging temperatures) while also subjected to extreme pressure using inert gas (argon).

**Results:**
- Material densification
- Microstructure grain recrystallization and refinement
- Improved ductility and fatigue properties
- Improved consistency in properties

**HIP is not a toy!!!**
A one-inch hole was machined into two stainless steel block halves, which were then welded together along their edges to simulate an internal pore. After HIP, the block was cut in half to reveal fully dense material.
AM parts typically contain a small amount of porosity

- Scanning calibration mismatch (a)
- Key-hole beam-weld interaction (b)
- Gas (can be internal to individual powder particles) (c)
- Shrinkage as previous layers solidify
- Micro cracks

(a), (b) GE Aviation; (c) Arcam
Effect of surface-connected porosity on HIPability of AM parts

As deposited

Open porosity

Post- HIP

Courtesy of Mercury Centre, University of Sheffield
Elimination of porosity by HIP - titanium

Courtesy of MOROKOSHI, et al.
A Component Journey - Metal AM

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Final Heat Treat
A Component Journey - Metal AM

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Final Heat Treat

- Creates best possible mechanical properties for parts
- Approaches wrought properties
Effect of HIP on microstructure
Titanium 6AL-4V

As built:
Typical martensitic structure of Ti 6AL-4V rapidly cooled from beta phase field

HIP and age:
Grain boundary of alpha and intergranular coarse alpha plates

Fig. 7 — Microstructure of DMD-built Ti6Al4V before and after HIP’ing. Courtesy of DM3D Technology.
Tensile and yield strengths tend to reduce slightly with HIP.

The benefit: increased ductility without significant strength decrease.
Fatigue performance of different manufacturing routes for same alloy part

Improved fatigue life approaches that of wrought material (pink)
Rotating beam fatigue performance of EBM Ti-6Al-4V

[Run-out = \(10^7\) cycles]
A Component Journey - Metal AM

Grow part on 3D metal printer → Stress Relieve on the build plate → Remove the parts from the build plate

Hot Isostatic Pressing (HIP) → Final Heat Treat → NDT + Testing
A Component Journey - Metal AM

- Grow part on 3D metal printer
- Stress Relieve on the build plate
- Remove the parts from the build plate
- Hot Isostatic Pressing (HIP)
- Final Heat Treat
- NDT + Testing

- Validates build properties
- Confirms acceptance to standards
- CT scanning and metallography – lots of debate on how to apply technology
- Other NDT techniques - UT
Bodycote provides a comprehensive service model for metal AM
Service Model Regions: North America

Service Centers

Northeast
- Berlin, CT

Upper Midwest & Ohio
- Cincinnati, OH

Southeast
- Greenville, SC

Texas & Central
- Fort Worth, TX

California & Southwest
- Rancho Dominguez, CA
Service Model Regions: Europe

Service Centers

UK
- Derby, UK

Belgium, Germany & Northern Europe
- Sint-Niklaas, Belgium

France, Italy & Southern Europe
- Magny-Cours, France
Thank You! Questions?

Improving the mechanical properties of AM components with HIP and heat treat