SOLAR ATMOSPHERES

HTS Heat Treating Society ASM INTERNATIONAL

Vacuum Furnaces Were Made For Additive Manufacturing

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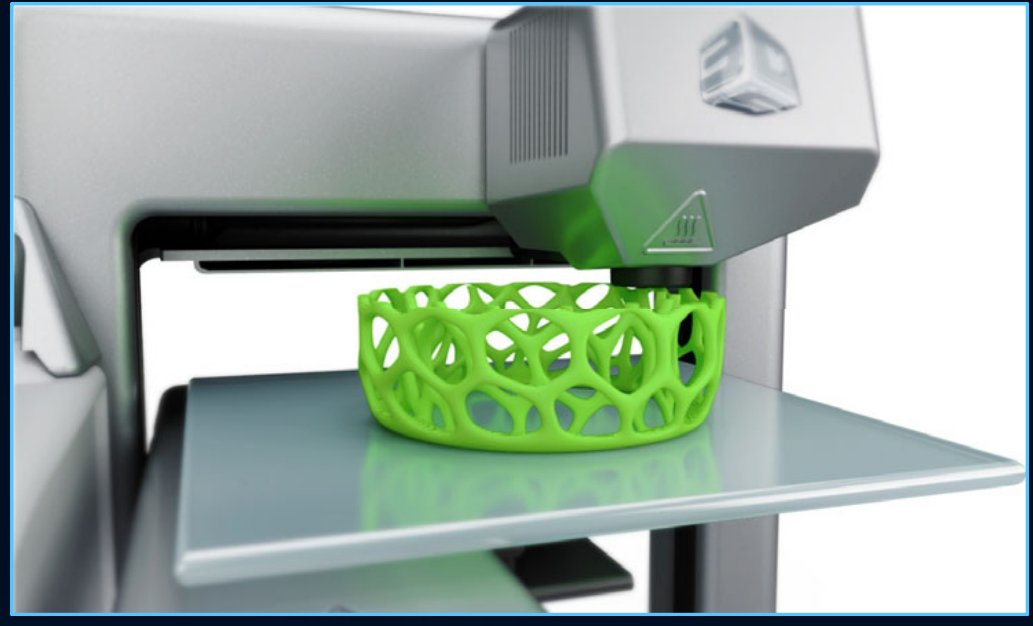
October 20, 2015
10:30am Room 250A

Transforming Technologies that have Changed the World



What is Additive Manufacturing?

- Additive Manufacturing is a process where a digital model is converted into a component layer by layer versus "subtracting" material from a larger piece of material as in machining

Video courtesy of GE Aviation, http://www.geaviation.com/company/additive-manufacturing.html

Advantages of Additive Manufactured Components

- Less input material required equals less waste
- Zero design constraints
- Brings product to the market faster
- Reduce or eliminate supply chains / production lines
- Reduce inventories
- Designs will move around the world as digital files, not as products
- Foreign production could be re-shored locally
- Carbon footprint reduced dramatically

Disadvantages of Additive Manufactured Components

- Printing machines are expensive
- Feed stock materials are expensive
- 3D Printing lacks industry-wide standards
- Due to the metallurgy, new qualification and verification standards need to be developed
- New quality assurance techniques need to be quantified
- Slow build rates – today not conducive to high production
- Limited component size due to limited printer size

Vacuum Heat Treating AM Parts Utilizing Three Methods of Printing

Direct Metal Laser Sintering (DMLS)

- Within an inert chamber a focused laser melts the surface of the target material forming a pool of molten metal
- Metal powder is delivered into the molten pool forming a deposit

(continued)

Vacuum Heat Treating AM Parts Utilizing Three Methods of Printing

Direct Metal Laser Sintering (DMLS)

- Process has a low rate of deposition however result in a finer detailed product
- Materials used with this method are titanium, inconel, and cobalt chrome alloys

Vacuum Heat Treating AM Parts Utilizing Three Methods of Printing

Electron Beam Additive Manufacturing (EBAM)

- Within an inert chamber a multi-kilowatt electron beam is used to selectively fuse wire onto a backer plate of similar material
- Multiple layers of wire are deposited forming the rough shape
- Process has a high rate of deposit forming a less detailed part

(continued)

Vacuum Heat Treating AM Parts Utilizing Three Methods of Printing

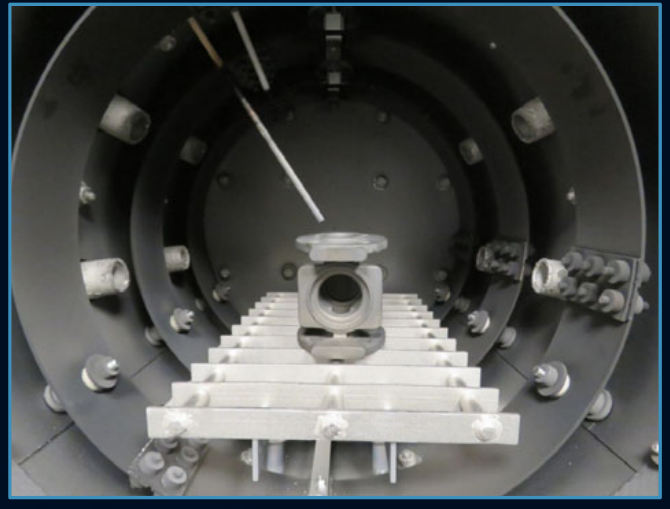
Electron Beam Additive Manufacturing (EBAM)

- Most common material is $Ti6Al_4V$
- Often the backer plate warps and vacuum stress relieving and creep flattening is required

Vacuum Heat Treating AM Parts Utilizing Three Methods of Printing

Binder Jet Process (BJP)

- A liquid binder is sprayed onto a bed of powder at ambient temperature
- Conglomeration of binder and powder is solidified by a low heat source, similar to a heat lamp
- After each layer solidifies, the platform lowers until the 3D part is complete



2436°F (±2°F)

(continued)

Vacuum Heat Treating AM Parts Utilizing Three Methods of Printing

Binder Jet Process (BJP)

- The lowest cost method of the three methods discussed
- Deposition is slow, however details of the part can be fine
- Most common materials are Titanium and Nickel Based Alloys

Why is the Vacuum Furnace made for AM Parts?

- All surfaces are near net shaped, therefore zero tolerance for contaminated surfaces
- Critical temperature control (±2°F) is a must
- Sintering temperatures can approach 2500°F
- Ability to directly thermocouple the work pieces
- Hydrogen partial pressure in certain processes improves mechanical properties

(continued)

Why is the Vacuum Furnace made for AM Parts?

- Slow ramp rates with lower intermediate holds are utilized to evaporate residual binders after de-lube post printing
- Graphite fixturing and crucibles are imperative and can only be used in vacuum furnaces
- Vacuum levels of 10^{-5} and 10^{-6} Torr ranges are required

Is Additive Manufacturing Going to Change Our Heat Treating Industry?

- Aerospace Heat Treating
- Medical Device Heat Treating

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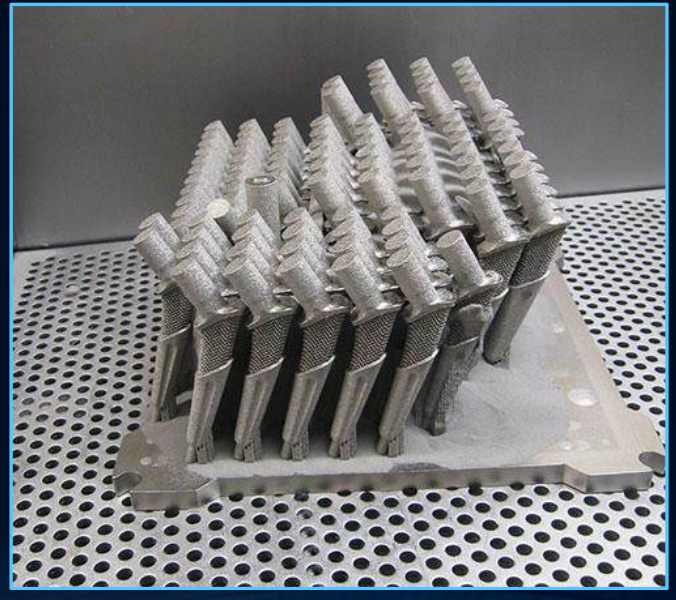

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Is Additive Manufacturing Going to Change the World?

Facts:

- GE and Lockheed are driving additive manufactured parts into their new aircraft designs
- Airbus plans to 3D print 30 tons of metal parts monthly by 2018
- Additive manufactured parts are already flying on commercial aircraft

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Is Additive Manufacturing Going to Change the World?

Facts:

- SAE Additive Manufacturing Committee held their first meeting in July 2015. The goal of this committee is to generate aerospace industry specifications.
- In 2014, additive manufacturing was a $4.1 Billion business [1]
- Currently there are 49 system manufacturers in 13 countries producing 12,850 industrial printing machines [1]

1 – Wholer's Report 2014 in cooperation with SME

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My Predictions

- Brazing Services may be changing
  - E.g. – GE Fuel Nozzle - previously made of 18 components brazed into one
    - Printed part is 5x more durable
    - Printed part is 25% lighter
    - Printed part has a better fuel flow geometry
    - With 19 printed high efficient and lighter fuel nozzles in every LEAP engine, fuel savings over the life of an airplane will equal $1.5 billion
- HIP'ing may become more prevalent for parts made of powder
- Heat treat pricing structure will vary
- Heat treating less raw materials and processing more near-net finished parts
- Vacuum Furnaces will be used more than atmospheric furnaces

Mechanical Testing Is Critical

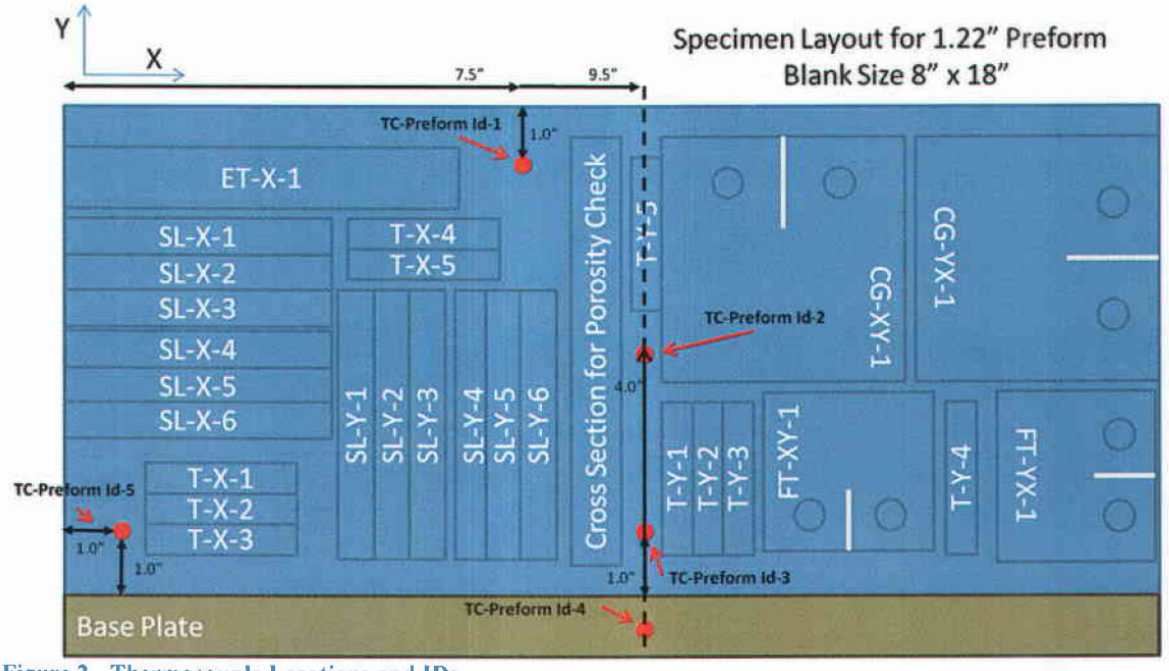
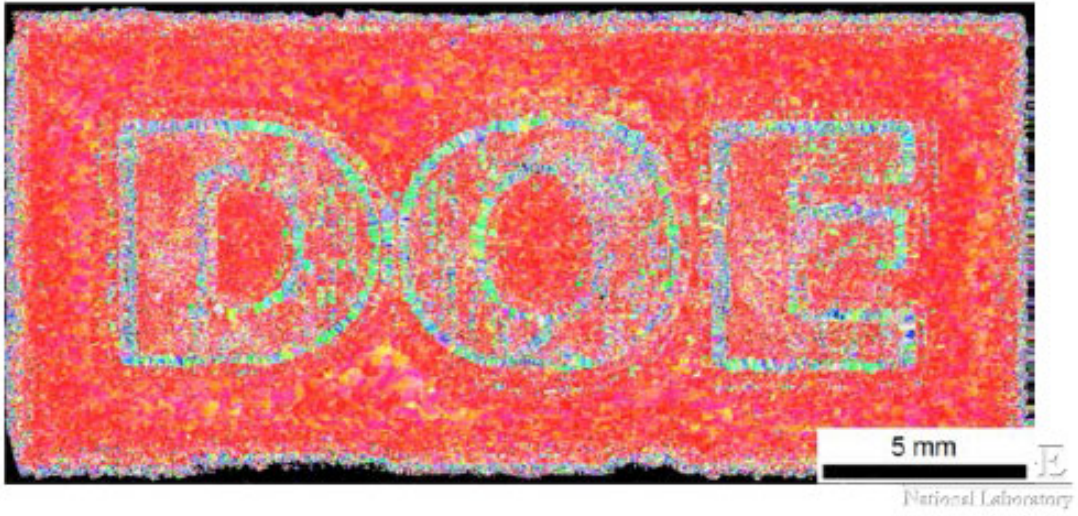


Figure 2 - Thermocouple Locations and IDs

Controlling Energy Is The Holy Grail of Additive Manufacturing



International Titanium Association 2015
Dr. Ryan Dehoff ORNL

Today's Heat Treating Customer

Tomorrow's Heat Treating Customer?

Is Additive Manufacturing Going to Change Our Heat Treating Industry?

THE PESSIMIST

COMPLAINS ABOUT THE WIND;

THE OPTIMIST

EXPECTS IT TO CHANGE;

THE REALIST

ADJUSTS THE SAILS.

WILLIAM A. WARD

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Thank you for your time!

Questions?

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Presentation is accessible on our website under Technical Documents