



# Finishing for Parts Made by Additive Manufacturing Part II

## Plating and Additive: Perfect Together

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# Agenda

- **Problem Statement**
- **Additive Manufacturing 101**
- **Combining Post Processing and Plating with AM for Superior Repairs**
- **Summary**
- **Questions**

# Problem Statement

- **1. SCRAP PARTS**
- **2. OBSOLESCENCE**
- **The ability to repair, rather than scrap and replace, these components offers significant schedule and cost benefits**

# Additive Manufacturing 101

What is AM? Any process that can make three dimensional (3D) solid objects from a digital model, or build-up controlled 3D features onto an existing object, typically layer by layer.

## Benefits

- Low quantity requirements (no tooling)
- Can repair / fabricate complex-shaped parts/features (conformal passages, etc.)
- Fast delivery (when compared to ordering parts made by traditional production methods)
- Excellent for doing “what if” scenarios, prototypes, research, testing, etc.
- Excellent for “one off” solutions, like the medical/dental industry (crowns, hip joints, skull/bone attachments)

## Challenges

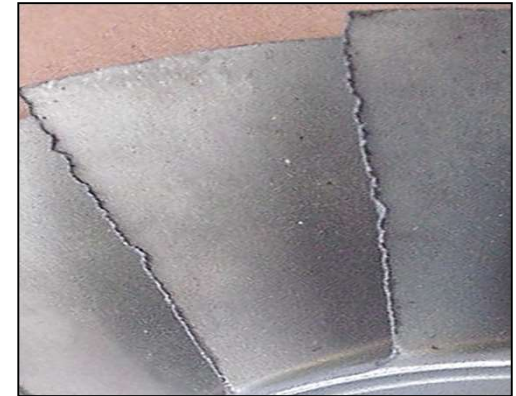
- Qualifying process and production systems
- Consistent properties among diverse parts
- Determine when to use AM (cost & logistics)
- New thought process in designing for AM
- Post processing: heat treating, finishing, hot isostatic pressing, etc.
- Real-time feedback
- Machine-to-machine consistency
- Price of metal AM machines and materials



# Example: AM Solutions for DoD

- Objective: Evaluate concept of using laser powder feed deposition / coatings for repair of gas turbine engine (GTE) parts
  - Team:  
CTC, AFRL/RXMP, AFRL/RXMS, OC-ALC
  - POP: February 2011 – June 2012
  - Recommendation: Further investigate viability of using laser-based repair process (OC-ALC)
    - Repair of blades
    - Repair of blisks
    - Replacement of dabber welding (legacy engines)

**FROM THIS:** Damaged airfoils, showing leading edge erosion



**TO THIS:** Airfoils repaired, ready for machining to correct shape

# Most AM Parts Require Post-Processing for Superior Repairs



Stainless Steel Wingnut, As Printed



Titanium Bracket, As Printed

- Rough surfaces
- Matted appearance
- Might have internal porosity (depending on the process and parameters)
- Performance characteristics generally not optimized



# Combining Post-Processing and Plating with AM for Superior Repairs

- Plating and Coating
  - Electrolytic and electroless plating
    - Copper
    - Nickel
    - Gold
    - Silver
    - Chrome
  - Improves appearance
  - Provides wear and corrosion resistance for metallic components
  - Provides increased strength for plastic-based AM parts (standard POP processes typically used)
  - Surface-connected porosity and surface roughness may need to be considered

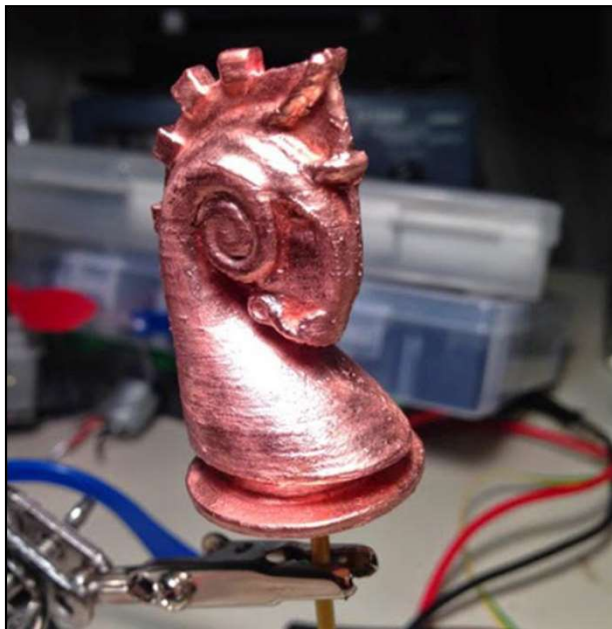


Strength of AM-fabricated plastic, plated vs. unplated

(SOURCE: [www.youtube.com/watch?v=d-heV79vRWY](https://www.youtube.com/watch?v=d-heV79vRWY))

# Combining Post-Processing and Plating with AM for Superior Repairs

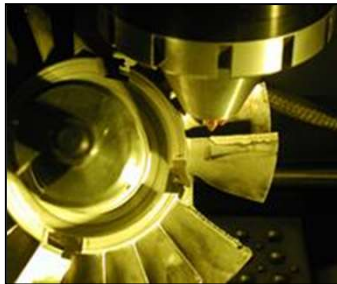
- Plating and Coating – Examples (decorative)





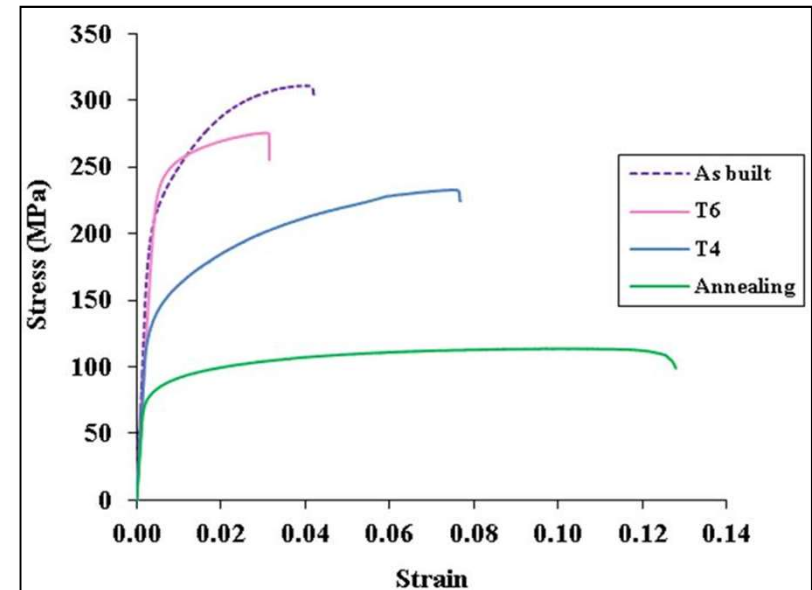
# Combining Post-Processing and Plating with AM for Superior Repairs

- Possible Repair Process Flow using AM and Plating
  1. Machine defect area on part to remove debris, oxides, etc.
  2. Build area back using AM
  3. Heat treatment as needed
  4. Machine to within tolerance
  5. Apply plating for corrosion resistance, wear resistance, appearance, etc.
  6. Return part to service



# Combining Post-Processing and Plating with AM for Superior Repairs

- Heat Treatment
  - Metals-based processes
  - Usually required to obtain desired properties and relieve residual stresses
  - Improves hardness, tensile and fatigue properties
  - Homogenizes chemistry and microstructures
  - Alloy and application dependent
  - Response to HT may be different for AM materials than wrought materials



Stress vs strain curve for aluminum alloy specimens, as built vs after heat treatment

(SOURCE: D. Manfredi et al, "Additive Manufacturing of Al Alloys and Aluminum Matrix Composites")

# Combining Post-Processing and Plating with AM for Superior Repairs

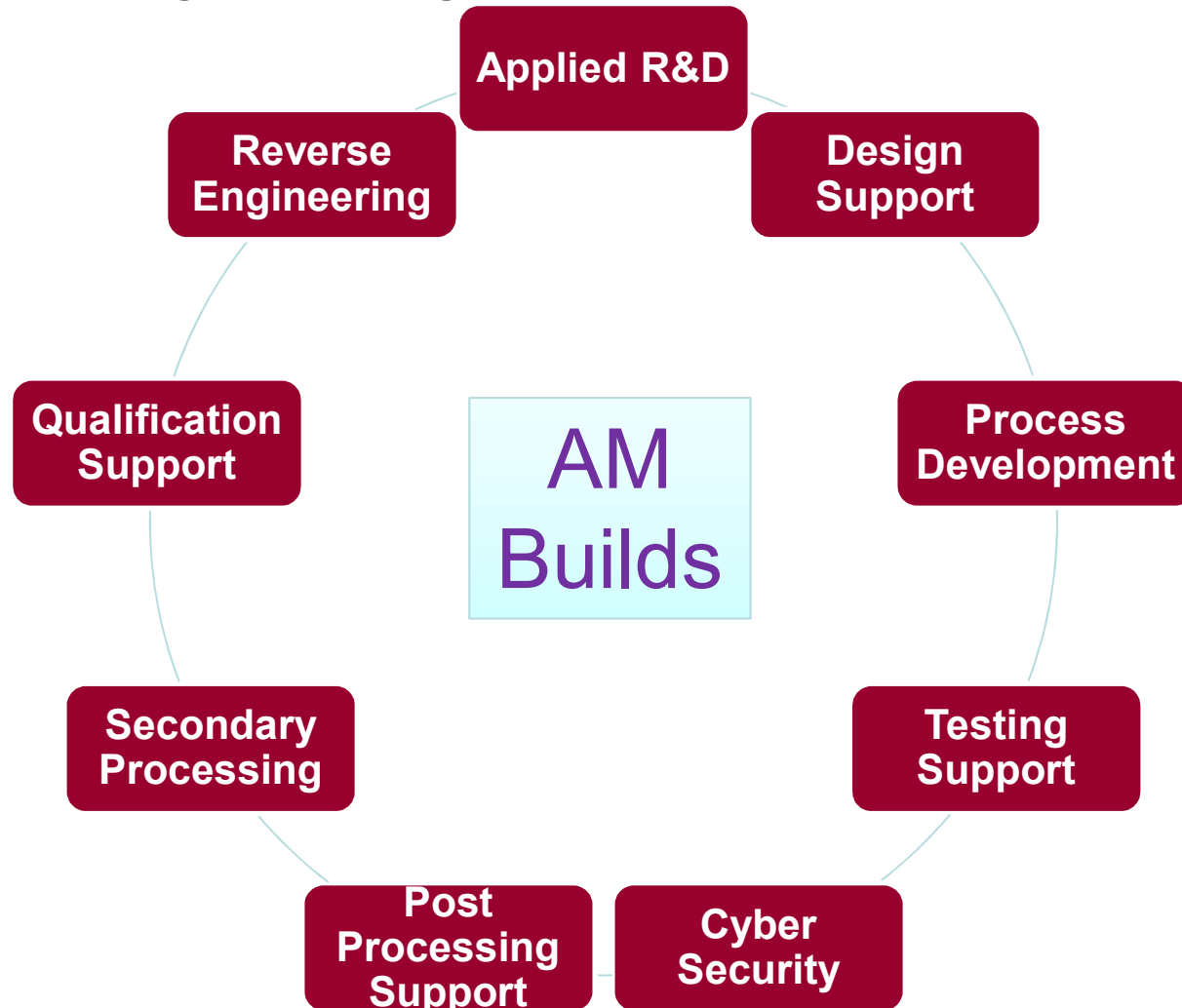
- Hot Isostatic Press (HIP) - high-pressure, high-temperature gas
  - Increases density of AM parts
  - Improves elongation and fatigue properties
  - Removes non-surface connected voids
- Machining
  - AM parts can be machined like wrought materials
  - Process and application dependent
    - Standard CNC machining used to make mechanical test specimens
  - Tight tolerances, sharp detail, inexpensive
  - Removes imperfections, eliminates heavy plastic deformation layers, improves finish

# Combining Post-Processing and Plating with AM for Superior Repairs

- Material Removal
  - Needed for many plastic AM parts and those systems that use binders and supports
- Particle Infiltration
  - Reduces porosity, improves part density
  - Used for SLS and other plastic/composite processes
- Other Surface Treatments
  - Sanding
- Welding
  - Dependent upon chemistry and microstructure in AM builds
- ***For all of these, a holistic approach is necessary***

# CTC Approach to AM

It's not "just building (or repairing) parts"



# Summary

- AM is a growing technical field, finding applicability in all areas of manufacturing
- Particular interest for the repair of metal components that cannot be repaired effectively by conventional means
- AM can be combined with surface treatment and plating processes to recap and repair both scrap parts and obsolete parts



# Data Call – For Those In Attendance

1. Do you have excessive scrap parts that could be repaired with AM and plating?
2. Are you aware of critical parts that are becoming obsolete?
3. If so, what are the materials? Can you provide drawings?
4. Is there a cost benefit?



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# Backup Slides



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# Common AM Processes

- Metal Processes

- Powder bed sintering (Laser)
- Powder bed sintering (Electron Beam)
- Binder jetting
- Directed Energy Deposition
  - Laser powder injection
  - Wire fed electron beam
- Ultrasonic welding of foils
- Inkjet
- Cold Spray

- Plastic Processes

- Selective laser sintering
- Fused deposition modeling
- Stereo lithography
- Material jetting



Laser-based Powder Bed AM Machine



Hybrid AM Machine with Directed Energy Deposition