EAG LABORATORIES | Eurofins Materials Science

Additive Manufacturing (3D Printing): Metallurgical and Material Services

INTRODUCTION

The progressive field of additive manufacturing (AM), also known as 3D printing, is transforming how products and parts are manufactured. AM is proving to be a more cost-effective solution than "traditional" subtractive manufacturing for applications where low production volumes, short turnaround times, complex part geometries, and/or high value materials are used.

IMPORTANCE OF METALLURGY DURING AM PART DEVELOPMENT

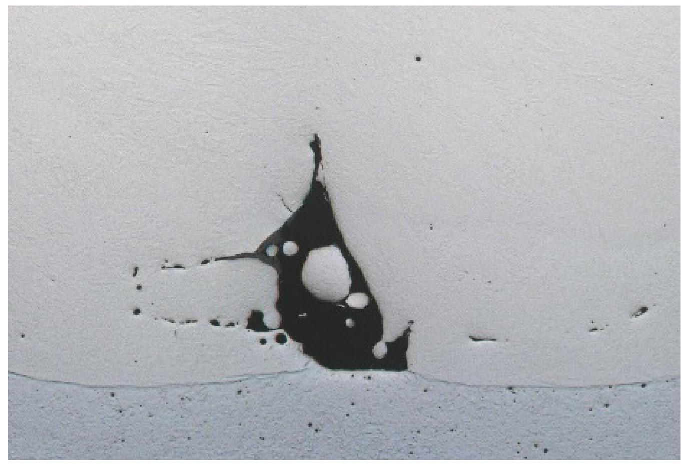
In order to achieve the desired mechanical properties with AM, the chemistry, microstructure and defects should be controlled. Process inputs such as feedstock quality, build chamber environment, scan strategy, part geometry and AM hardware all affect the thermal and physics interactions to determine the extent, size, and shape of defects and microstructure. These thermal and physics interactions can be explained similarly to welding process variables such as power, speed, beam interactions, heat transfer, and process temperature that determines solidification kinetics and subsequently phase distribution and grain morphology.

EAG can help determine what caused the defect or why the AM part does not meet the mechanical requirements. For example, in Laser Directed Energy Deposition (L-DED), it is known that porosity defects are related to flow rate of the fill gas and the path of the gas flow. Additionally, solidification rate and heat extraction influence residual stress leading to cracks in the L-DED parts. The scan strategy is known to highly influence the grain structure in the various types of Direct Energy Deposition (DED). Laser Powder Bed Fusion (L-PBF) is most sensitive and best at controlling microstructural evolution but keyhole porosity is a common defect. Some Electron Beam-Powder Bed Fusion (EB-PBF) systems can preheat the build volume to a high enough temperature for recrystallization, whereas L-PBF system may not have the capability. Post AM heat treatment is common to help optimize microstructure and thereby mechanical properties. Understanding the effects of the AM process and the inputs is vital to creating a quality part.

IMPORTANCE OF FEEDSTOCK ANALYSIS

Knowing the composition of the feedstock for AM is important for achieving the desired part. For AM powders, understanding the particle size analysis, shape, and purity can further enhance the integrity of the desired part let alone mitigate potential manufacturing problems.

EAG offers metallurgical services to assist in the analysis, testing, and optimization of AM products and parts, as well as years of consulting experience assisting our clients in creating the highest quality parts in a cost-effective, optimized process.



Printing defects- Incomplete melting and insufficient overlap

METALLURGICAL AND MATERIAL SERVICE

1. **Microscopy:**
   - Defects
     - o Surface inconsistencies – surface patterns, drooping, roughness
     - o Cracking
     - o Distortion/Shrinkage/Warping/Swelling
     - o Delamination
     - o Design accuracy/Loss of net shape
     - o Satellites particles
     - o Porosity
     - o Cold laps
     - o Lack of fusion
     - o Cracks
     - o Delamination
     - o Inclusions
     - o Incomplete melting
   - Microstructure
     - o Grain size analysis
     - o Microstructural characterization

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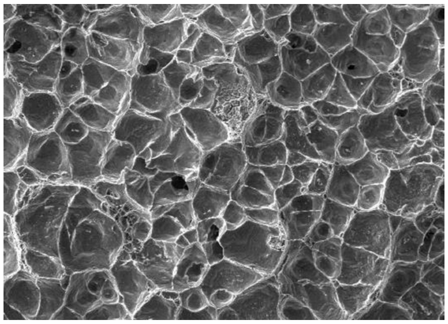
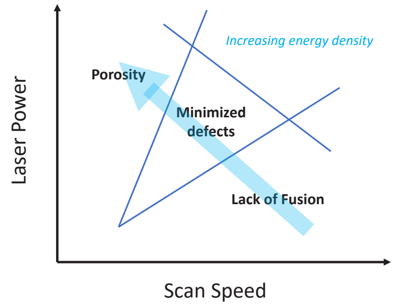
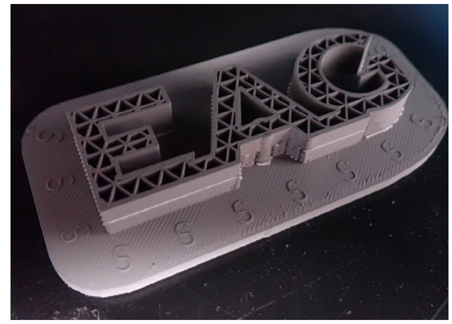

Fracture surface-Dimples





  - o Primary solidification structure determination
  - o Approximate cooling rate determination
  - o Diffusion and dilution effects of multi-alloy printing
- Hardness testing
  - o Hardness – Rockwell, Superficial Rockwell, Brinell
  - o Microhardness – Knoop, Vickers (hardness profile through as-solidified and reheated metal)
  - o Nanoindentation
- Processing parameter
  - o Penetration depth
  - o Bead width
  - o Bead height
  - o Bead morphology
  - o Bead area
  - o Macrophotographs – Montage of transverse and longitudinal cross sections

2. SEM
- Fractography - fracture mode
- Defect chemistry evaluation
- Diffusion and dilution effects
- Residual porosity in atomized powder
- Higher magnification than LOM
- Powder Characteristics - Shape

3. Surface Analysis – XPS and AES
- Surface analysis
- Surface corrosion resistance
- Surface contamination

4. Electron Backscatter Diffraction (EBSD) and X-ray Diffraction (XRD)
- Grain size distribution
- Grain boundary characterization
- Texture analysis
- Phase analysis
- Coincidence Site Lattice (CSL) boundary characterization
- Orientation and misorientation analysis between grains / phases
- Local strain

5. Chemistry (ICP-OES, ICP-MS, IGA/RGA, GDMS, XRF, EDS)
- Feedstock
- AM part

6. Density
- AM Part: ASTM B962 Standard Test methods for Density of Compacted or Sintered Powder Metallurgy (PM) Products Using Archimedes' Principle
- Feedstock powder: ASTM D7481 Standard Test Methods for Determining Loose and Tapped Bulk Densities of Powders Using a Graduate Cylinder

NON-DESTRUCTIVE SERVICES

7. 3D Computed Tomography
- Feature recognition - 0.1µm (0.3µm above 10W)
- Maximum L x W x H – 50.8 mm x 50.8 mm x 25.4 mm (2" x 2" x 1")
- Maximum weight – 0.45g (1lbs)
- 3D model reconstruction
- Image rendering – 2D planar slices and virtual cross section images (JPG or TIFF)
- Movie Clips of the 3D model (AVI or WMV)

8. 2D X-Ray Technology
- Feature recognition – 0.1 to 0.5 µm
- Maximum L x W x H - 508 mm x 444.5 mm x 254 mm (20" x 17.5" x 10") and 457 mm x 355 mm x 190 mm (18" x 14" x 7.5")
- Maximum weight – 2.28g (5lbs) to 10kg (22lbs)
- 2D images from various angles