Gorham PMA and DER Conference 2015

Additive Manufacturing

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Date: **March 24, 2015**

Outline

- **Current situation**
- **Background**
  - What is Additive Manufacturing (AM)?
  - Traditional Manufacturing versus AM
- **Issues and concerns**
- **FAA Activities (AM National Team)**

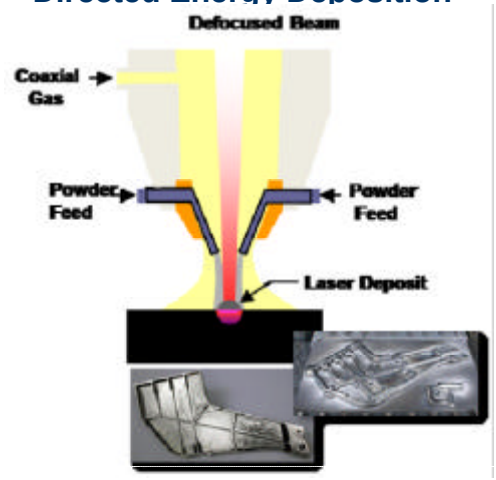
What Is Additive Manufacturing (AM)

- **Commonly know as “3D-Printing”**
- **Aerospace industry has been pursing AM in last 7-10 years (R&D 15-20 yrs.).**
- **US government and major US aerospace companies are promoting research and use of AM.**
  - ✓ Government invested over $100M in AM Technology.
- **AM technology is expected to rapidly proliferate due to various potential benefits, i.e., reduction in material cost, fewer part to fabricate, and ability to produce more complex designs.**

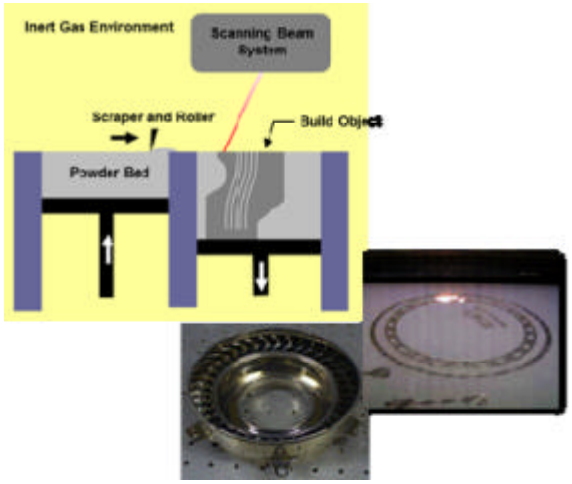
What Is Additive Manufacturing (AM) (Cont'd)

Metal AM Technologies

Directed Energy Deposition



Powder Bed Fusion

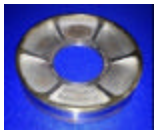


Processes for AM of Metallic Materials

- Primary additive manufacturing processes for metallic materials may be grouped into two categories:
  - directing a beam of energy to sequentially melt material that is added, which may be in powder or wire form (directed energy deposition processes) or
  - sequential scanning of the beam onto a pre-deposited powder bed (powder bed fusion processes)
- Laser and electron beams are used in both categories
- In most instances, the energy is used to fully melt the material followed by solidification and cooling

Benefits

Potential Advantages for Utilizing Additive Manufacturing



- **Additive manufacturing may be used to reduce cost:**
  - reduced use of expensive material
  - decreased machining time
  - reduction of parts for assembly
- **Additive manufacturing may enhance product performance:**
  - ability to economically create features that are difficult or impossible to produce using traditional methods
- **and, it may greatly influence the future supply chain:**
  - enables a high degree of customization
  - further enhances distributed design, validation, and manufacturing models

Additive Manufacturing
Perceived application

- **Areas where AM will likely will be first introduced**
  - **Small complicated part to be machined such engine/turbo engine**
  - **Repair Station seeking to replace or/and repair damaged parts**
  - **Small manufacturers (not OEMs) seeking to produce low production rate parts (replacement parts and repairs)**
    - **Part Manufactures Approvals (PMA)**

Issues and Concerns

- **AM has a number of technical risk factors.**
- **Government agencies, Industry, and other engineering organizations activities.**
- **Commercial off-the-shelf AM equipment is available to the public and industry ***

*** For instance, AM could potentially open the flood gate for secondary market and replacement part (PMA)**

“Traditional Fabrication” vs “Additive Manufacturing”

- **AM is fundamentally different from traditional “subtractive” processes:**
  - ***Traditional*** **Fabrication Process (subtractive processes) removes portions of preexisting material during part fabrication**
    - ✓ Long history and understanding of the effects of machining, heat treat, casting and forging processes on material properties, including damage tolerance and fatigue

“Traditional Fabrication” vs “Additive Manufacturing”

- ***Additive* Manufacturing process actually *creates the material as a part is being fabricated***
  - ✓ “Additive Manufacturing Process” is used to describe a range of processes, (i.e. Laser, electronic beam, powder bed, wire feed, etc..) each of which have their own unique sources of variations which need to be identified and controlled.
  - ✓ All the mechanical behavior of the material is dependent on the process itself.
  - ✓ Studies have identified ***120 variables*** that may need to be controlled for ***a given AM machine*** to produce stable and repeatable parts.

"Traditional Fabrication"

vs

"Additive Manufacturing"

Common **Industry Understanding or Acceptance of:**	**Al 2014 Cast** *(common airframe alloy)*	**IN 718 Wrought** *(common engine alloy)*	**AM Alloy** *(airframe or engine alloy)*
Material and process specs	Yes	Yes	No / WIP
Design allowables	Yes	Yes	No / WIP
Capable NDI methods	Yes	Yes	No / WIP
Characterization of material defect / anomalies types	Yes	Yes	No / WIP
Key manufacturing process control parameters and acceptable ranges	Yes	Yes	No / WIP
Effect of process parameters on microstructure and mechanical properties	Yes	Yes	No / WIP
Qualification / certification criteria	Yes	Yes	No / WIP

WIP = Work In Progress

Note: Some OEMs may have more advanced understanding of AM technology than indicated in the table

FAA concerns with AM Material Specifications

- **§ 2X.603 (Materials)**
  - The suitability and durability of materials used for parts, failure of which will adversely affect safety, must:
    - ✓ Be established by experience or test
    - ✓ Conform to approved specifications
    - ✓ Take into account the effects of environmental conditions

- **FAA acceptable material specifications for AM have not been developed at this time.** **These specifications are needed to support inclusion of these materials in MMPDS and FAA regulation**

FAA Concerns with AM Process Specifications

- § 2X.605 (Fabrication methods)
  - The methods of fabrications used must produce a consistently sound structure
    - ✓ If a fabrication process requires close control to reach this objective, the process must be performed under an approved process specification
    - ✓ Each new aircraft fabrication method must be substantiated by a test program.
- Each manufacturer will need to develop process specifications for their specific fabrication method.

FAA Concerns for AM Material Design Properties

- **§ 2X.613 (Material strength properties and material design values)**
  - Strength properties must be based on testing of materials meeting approved specifications to establish design values on a statistical basis
    - ✓ Design values must be chosen to minimize the probability of structural failure.
      - o Single load path structures must meet a 99% probability with 95% confidence statistics
      - o Redundant load path structures must meet a 90% probability with 95% confidence statistics

FAA Concerns for AM Material Design Properties (Cont'd)

- **Need to develop MMPDS procedures which would allow individual manufacturer to demonstrate that mechanical properties of parts being produced by AM in their facilities is "equivalent" to the properties of values published in MMPDS.**
  - ✓ **Note: Similar approached being used in CMH-17 for composite materials**
- **Fatigue and damage tolerance properties need to be discussed separately**

FAA AM National Team

- **Directorates**
  - ✓ Mark Freisthler (TAD)
  - ✓ Dan Kerman (E&PD)
  - ✓ Mark James (SAD)
  - ✓ Bob Grant (RD)
  - ✓ Tim Mouzakis (E&PD)
- **Headquarters**
  - ✓ Jim Kabbara (Team Lead)
  - ✓ Robert Cook
- **CSTAs**
  - ✓ Michael Gorelik (F&DT)
  - ✓ Terry Khaled (Metallurgy)
- **Flight standards**
  - ✓ Rusty Jones
- **Tech Center**
  - ✓ John Bakuckas
  - ✓ Kevin Stonaker
  - ✓ Dave Gallela

FAA AM National Team's Charter

- **Participate in government sponsored initiatives to provide guidance on issues pertaining to certification and continued airworthiness**
- **Assess current FAA policy and guidance to insure the safe implementation of these technologies into the commercial fleet.**
- **Develop policy and guidance as needed to prepare *ACOs/MIDOs/FISDOs* for the expected expansion in the use of AM parts**

FAA AM National Team (Cont'd)

- **AM is tip of the iceberg…**
- **Stayed tune…**
- **More information will be available…**

Questions?

Information Slides

Basic Material Types

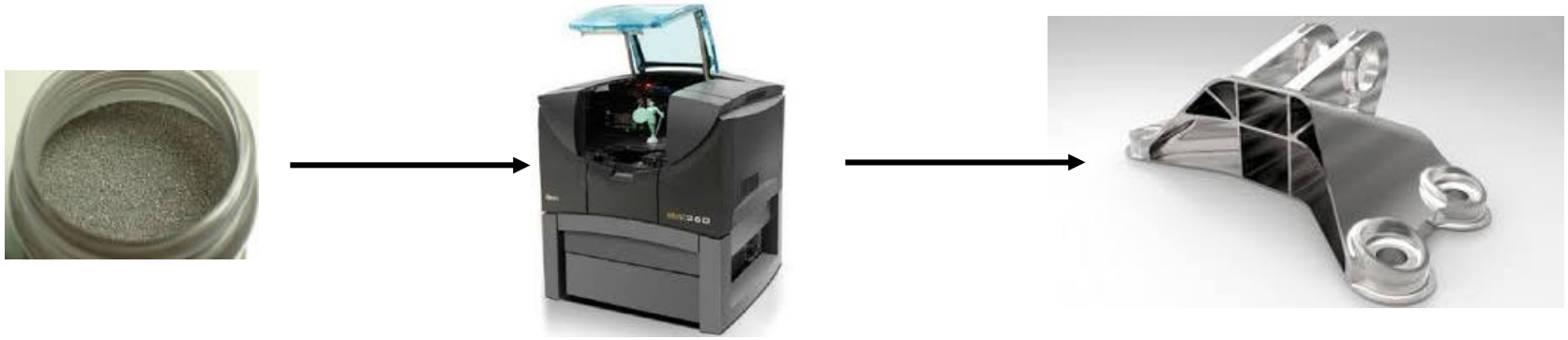
- **Materials may be divided into three basic types:**
  - **Stock Materials**

    Refers to materials whose basic mechanical behavior are not severely impacted by the manufacturing process (or at lest the impacts of manufacturing steps such as heat treatment are well understood). (Sheet, Plate, Bar, etc.)
  - **Externally Engineered Materials**

    Refers to materials whose mechanical behavior is highly dependent on the manufacturing processes prior to being purchased. (castings, forgings, extrusions etc.)
  - **Internally Engineered Materials**

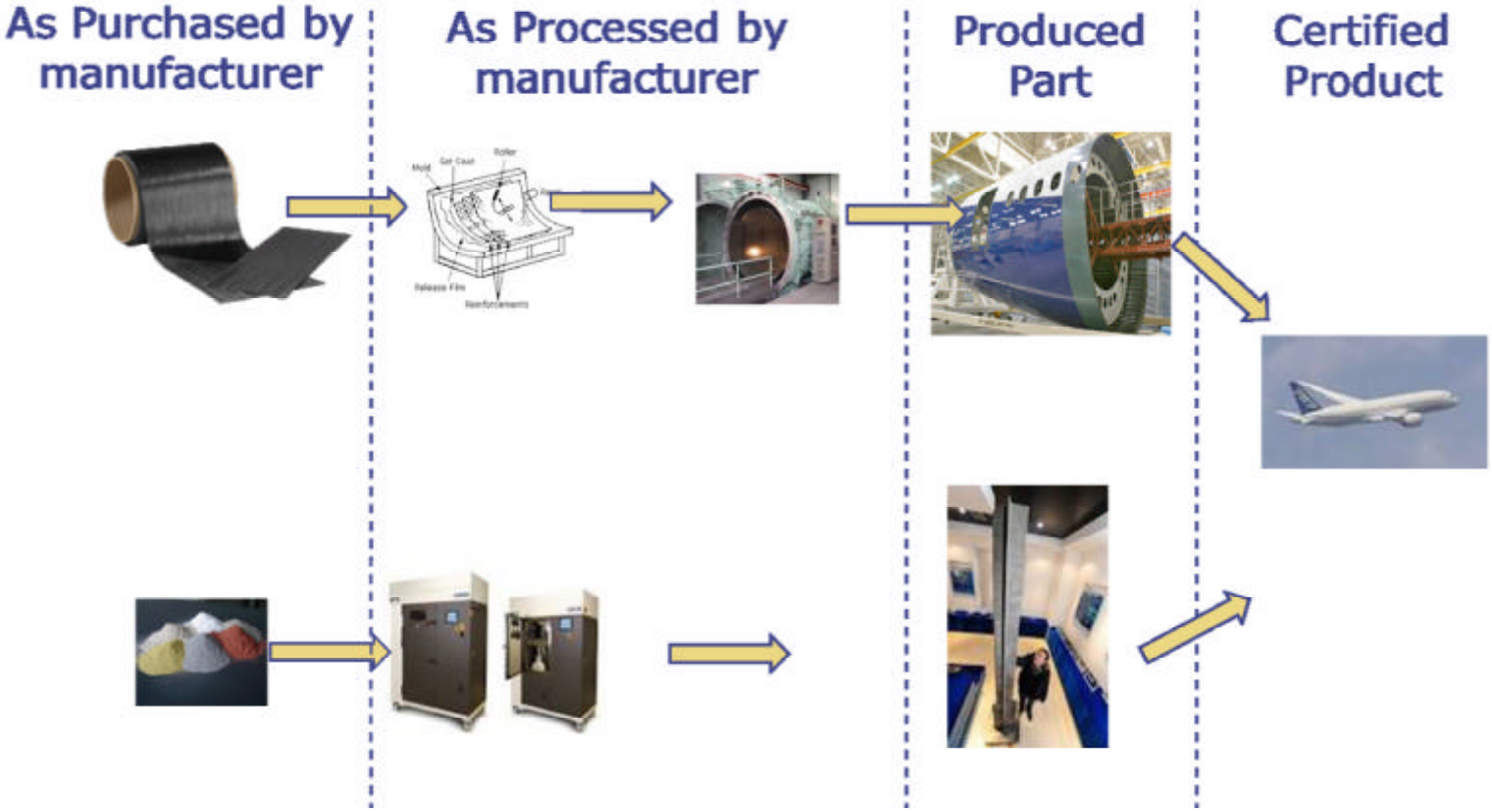
    Refers to materials whose mechanical properties are dependent on post *processing of raw material purchased.* (Composites/ Additive Materials)

Internally Engineered Materials
Additive Materials

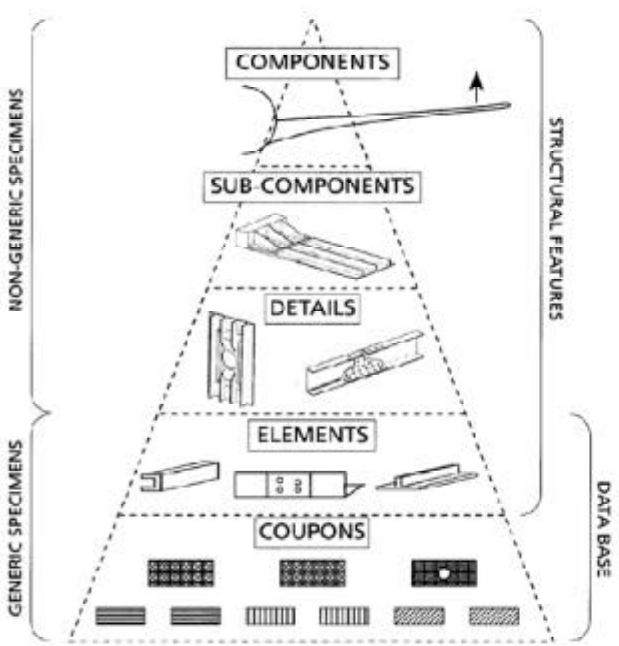


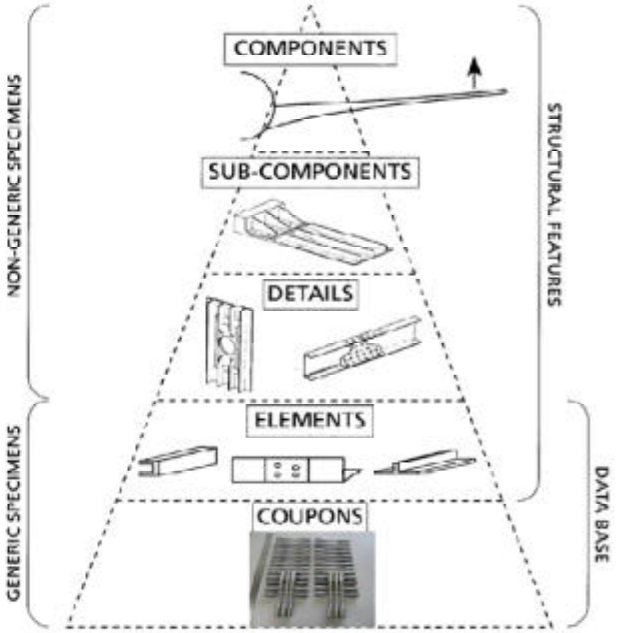
- Material is actually created during part fabrication.
- Material Specifications controls raw material being purchased, not the material in it's final state.
- The key design properties are dependent on the fabrication process used to produce the product.
- Design Values are tied to both the materials as purchased by an approved specifications and the approved documented fabrications process used to fabricate parts.

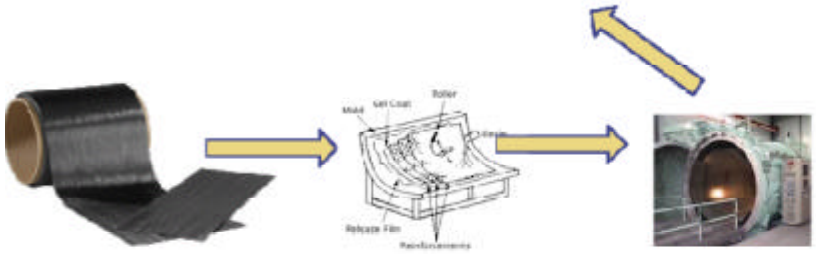
Composites & Metallic Additive Manufacturing Materials Have Similar Production Requirements

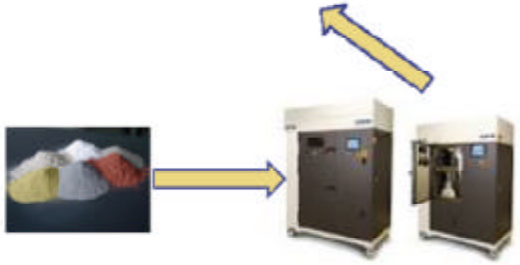


SIMILARITIES Between Composites & Metallic Additive Manufacturing BBA Requirements









- **While AM is an U.S. came up with the concept, most the technical developments are occurring outside the USA**
- **AM activities sponsored by both legislative and executive initiatives are meant to bring the USA back to a predominate position in this technology**
- **Initiatives seeks to promote early applications of AM in many fields, including commercial aerospace applications.**

EASA already working on policies to approve AM application…How FAA plans to deal with EASA approved articles?

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