Gorham Conference - 2016

FAA Program Update on Additive Manufacturing

By: Robert Grant
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Outline

- **State of Additive Manufacturing (AM)**
- **What Is Additive Manufacturing**
- **AM Challenges To Be Addressed**
  - *Examples* of Risk Factors for AM
  - Sources of Variability
- **Regulatory Requirements**
- **Recent FAA Activities involving AM**
- **Summary**

State of Additive Manufacturing (AM)

- **Commonly known as “3D-Printing”**
- **AM use is rapidly expanding and is being introduced into service through TC programs and design changes**
  - Many major OEM’s have announced publically that their new aviation products will have some AM parts (metallic)
  - Thermoplastic AM parts have been utilized for years in multiple aircraft
  - Vision is that AM will be widely used within the next 5-10 years.

State of Additive Manufacturing, 'cont'

"Additive manufacturing is the new frontier. It has taken the shackles off the engineering community, and gives them a clean canvas…"

Mr. David Joyce, GE Aviation President and CEO

"Metal parts from some AM systems are *already on par with their cast or wrought counterparts*. As organizations qualify and certify these and other materials and processes, the industry will grow very large…

Source: Wohlers Report 2012

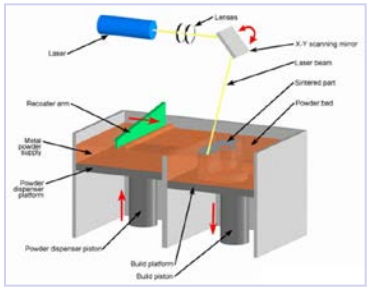
"We are on the cusp of a step-change in weight reduction and efficiency – producing aircraft parts which weight 30 to 55 %, while reducing raw material used by 90 % …"

Mr. Peter Sander, Airbus

"3D printing opens up new possibilities, new design space… Through the 3D printing process, you're not constrained [by] having to get a tool in to create a shape. You can create any shape you like."

Dr. Henner Wapenhans, Rolls-Royce Head of Technology Strategy

What Is Additive Manufacturing (AM)



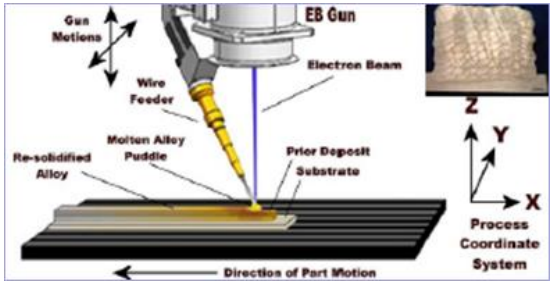
Additive Manufacturing (AM) --

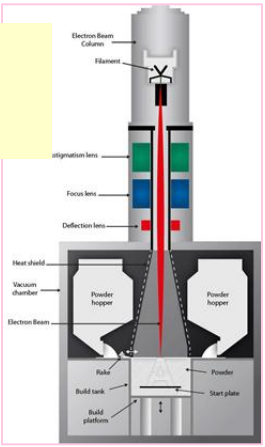
A process of joining materials to make objects from 3D model data, usually layer upon layer, as opposed to *subtractive manufacturing* methodologies

(***Ref: ASTM F2792 – 12a***)

By Source of Material:
Powder vs. Wire

By Source of Energy:
Laser vs. E-Beam





AM Challenges To Be Addressed

"top five"

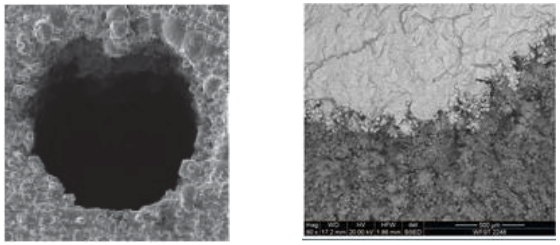
- **Limited understanding of acceptable ranges of variation for key manufacturing parameters**
- **Limited understanding of key failure mechanisms and material anomalies**
- **Lack of industry databases / allowables**
- **Development of NDI procedures with accept/reject criteria**
- **Lack of industry specs and standards**

Additional level of complexity – these areas are not independent…

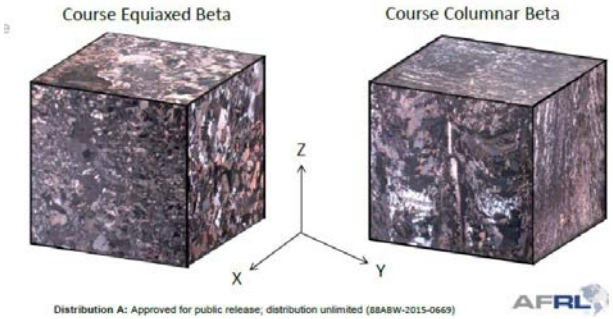
Other considerations

- ***OEM-proprietary vs. commodity type technology path***
- ***Low barrier to entry for new (inexperienced?) suppliers***

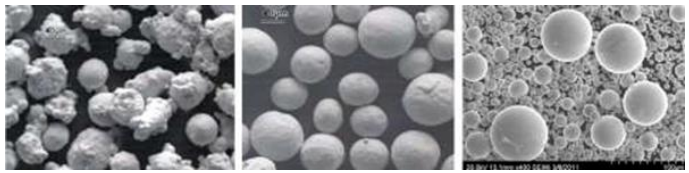
Examples of Risk Factors for AM



Surface Quality



Microstructure Variability

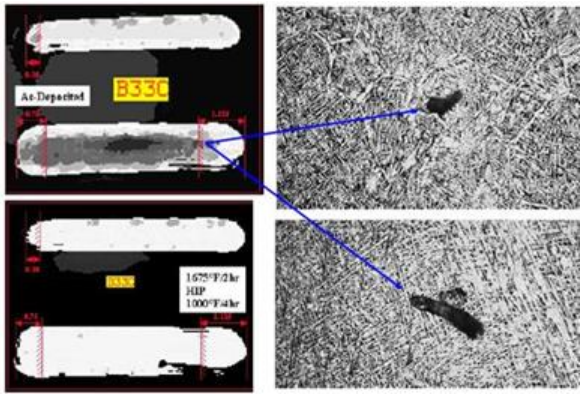


Powder Control

Powder feed rate (g/min)
Laser Power (W)
Scan speed (in/min)
Laser spot size (in)
Substrate temp (°F)
Hatch spacing (% of calculated)

over 100 process parameters identified

Process Controls



HIP Effectiveness

Many More Identified by Experts…

Source of Variability - Examples

- ✓ Powder/Wire specification
- ✓ Powder Blending and/or recycling
- ✓ Parts in a Build
- ✓ Specimens built with parts
- ✓ Part Feature Orientation
- ✓ Machine software version
- ✓ Machine Process Parameters
- ✓ Surface finish
- ✓ Layer Thickness
- ✓ Post build operations
- ✓ Material characterization

Federal Regulations

- **The Federal Aviation Regulations are:**
  - Part of Title 14 of the Code of Federal Regulations (CFR).
  - Prescribed by the Federal Aviation Administration (FAA) governing all aviation activities in the United States.
- **Regulations that apply to the certification of specific products (aircraft, engines and propellers):**
  - Part 21 – Certification Procedures for Products and Parts
  - Part 23 – Airworthiness Standards: Normal, Utility, Acrobatic and Commuter Airplanes
  - Part 25 – Airworthiness Standards: Transport Category Airplanes
  - Part 27 – Airworthiness Standards: Normal Category Rotorcraft
  - Part 29 – Airworthiness Standards: Transport Category Rotorcraft
  - Part 33 – Airworthiness Standards: Aircraft Engines
  - Part 35 – Airworthiness Standards: Propellers

FAA Regulations

§ 2X.603 Materials.

The suitability and durability of materials used for parts, failure of which could adversely affect safety, must:

- Be established on the basis of experience or tests
- Meet approved specifications that ensure their having the strength and other properties assumed in the design data; and
- Take into account the effects of environmental conditions, such as temperature and humidity, expected in service.

FAA Regulations, 'cont'

§ 2X.605 Fabrication methods.

- The methods of fabrication used must produce a consistently sound structure.
- If a fabrication process requires close control to reach this objective, the process must be performed according to an approved process specification.
- Each new aircraft fabrication method must be substantiated by a test program.

Publically available AM material and process specifications have not been used in FAA approved metallic AM parts.

- ✓ Company-developed proprietary specifications

FAA Regulations, 'cont'

§ 2X.613 Material strength properties and design values.

- Material strength properties must be based on enough tests of materials meeting specifications to establish design values on a statistical basis.
- Design values must be chosen to minimize the probability of structural failure due to material variability. Design values must assure material strength with the following probability:
  - Single load paths, where failure would result in loss of structural integrity of the component , 99% probability with 95% confidence.
  - Redundant load path, 90% probability with 95% confidence statistics

Recent FAA Activities in AM

- AMNT (Additive Manufacturing National Team) chartered by FAA management (Oct 2015).
  - Includes representatives of four Directorates, Flight Standards, Tech Center, MIDO, Chief Scientists, and HQ
  - Development of agency's AM Roadmap
- AM Memo (FAA Internal – Jun 2015)
- AM Issue Papers (Directorates)
- Joint FAA-USAF Workshop (CSTA Workshop) on AM held in September 2015
- Benchmarking of OEMs in progress

Recent FAA Activities in AM, 'cont'

- We are working with other government agencies, standards organizations, academia, and industry including:
  - SAE, ASTM
  - AIA (Kick-off meeting held last month)
  - FAA Chief Scientist supporting America Makes
- Developing policy for AM parts with failure consequence of minor and below.
- Developing AM checklists for use by FAA certification engineers and inspectors.

Summary

- **The use of AM in aviation is rapidly expanding.**
- **As industry gains experience with AM, the level of part criticality is expected to increase.**
- **Key AM considerations include:**
  - Identification and characterization of key failure modes and anomalies
  - Control of Significant process variables for AM by process specifications to ensure that sound structure can be consistently produced.
  - Creation of public specifications for AM materials and processes
  - Development of design values
  - QA, Process Monitoring and NDI methods
- **The FAA AM National Team will continue to engage with other government agencies, standards organizations, academia, and industry to ensure the safe introduction of AM parts into service.**

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Information Slides

FAA Policy for AM parts with failure consequence of minor and below

Minor Failure Conditions: For the purposes of this policy, minor failure conditions do not significantly reduce aircraft or engine safety and involve crew actions that are well within crew capabilities. Minor failure conditions may include a slight reduction in safety margins or functional capabilities, a slight increase in crew workload (e.g. routine flight plan changes), or some physical discomfort to occupants (e.g. passengers and flight crew).

PMA / TSOA

Applicants may receive Production Approval (PMA), Authorization to build TSO parts (TSOA).

- **PMA (Part 21, Subpart K)**

  Is a combined design and production approval for modification and replacement articles. It allows a manufacturer to produce and sell these articles for installation on type certificated products.

- **TSOA (Part 21, Subpart O)**

  It allows a manufacturer to produce and sell these articles that meet minimum performance set by Technical Standard Order (TSO).

  - ✓ **Applicant still must show that PMA/TSO component meets the TC requirements prior to installation**

FAA Regulations, 'cont'

§ 33.15 Materials.

The suitability and durability of materials used in the engine must:

- Be established on the basis of experience or tests, and
- Conform to approved specifications that ensure their having the strength and other properties assumed in the design data.

FAA Regulations, 'cont'

§ 35.17 Materials and manufacturing methods.

- The suitability and durability of materials used in the propeller must:
  - ✓ Be established on the basis of experience, test or both; and
  - ✓ Account for environmental conditions expected in service.
- All materials and manufacturing methods must conform to specifications acceptable to the Administration.
- The design values of properties of materials must be suitably related to the most adverse properties stated in the material specification for applicable conditions expected in service.