ADDITIVE MANUFACTURING REGULATORY PERSPECTIVE: SHOWING COMPLIANCE WITH MATERIALS AND PROCESSES STANDARDS

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PRESENTATION OUTLINE

- Presentation Objective
- Additive Manufacturing
- Existing Materials and Processes Standards
- Authorities Approach
- ASTM Standards Development
- Conclusion

OBJECTIVE

Transport Canada Expectations for certification of Additive Manufacturing (AM)

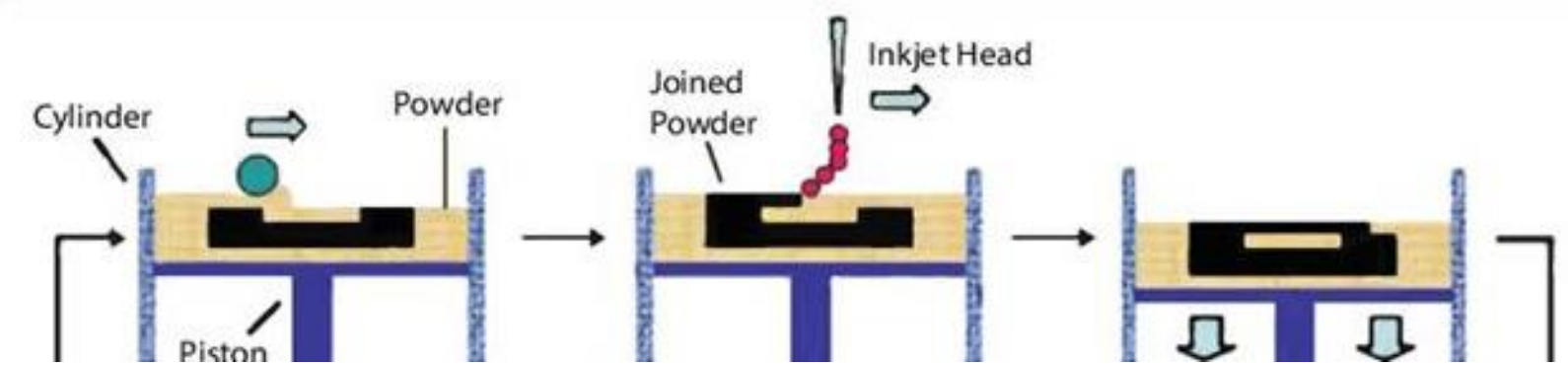
WHAT IS AM?

- **A**dditive **M**anufacturing (**AM**) is a name to describe the technologies that build 3D objects by ***adding*** layer-upon-layer of material.

- AM uses computer 3D modeling software tools (Computer Aided Design or CAD). Once a CAD model is produced, the AM machine reads in data from the CAD file and adds successive layer-upon-layer of material to fabricate a 3D object.

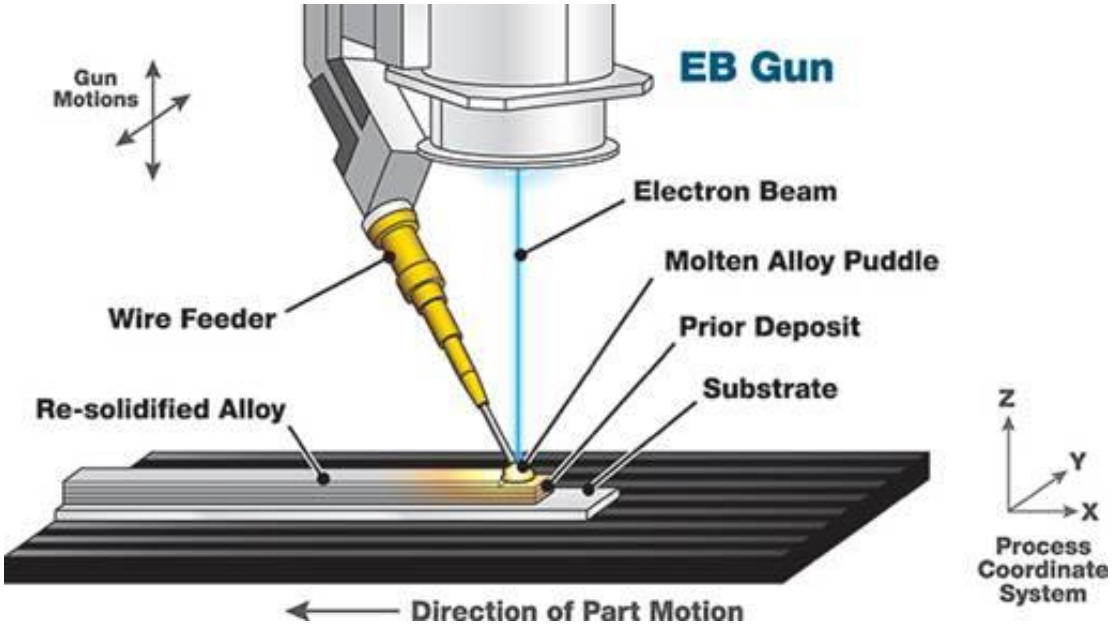
AM TECHNOLOGIES

- Powder Bed Fusion
  - Selective Laser Sintering / Select Laser Melting



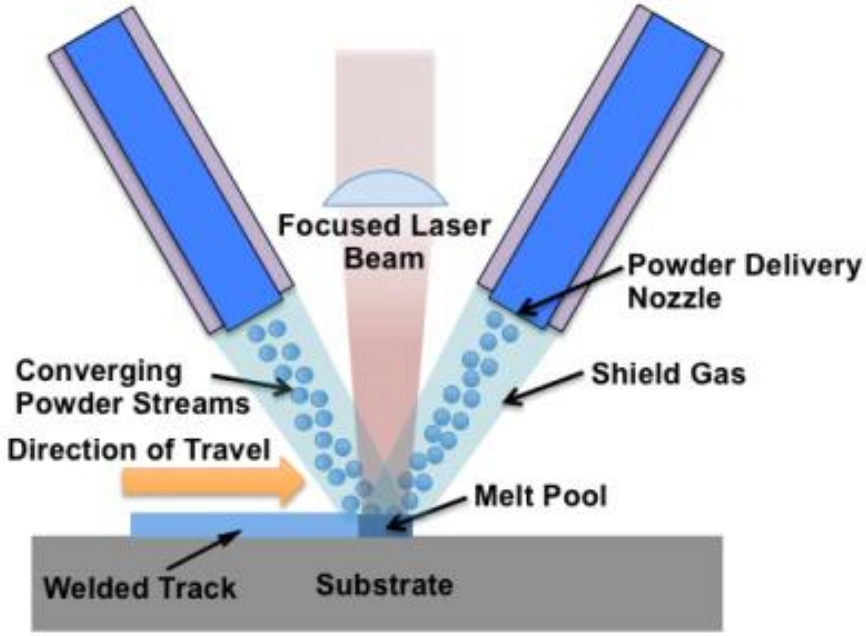
AM TECHNOLOGIES

- Electron Beam Melting



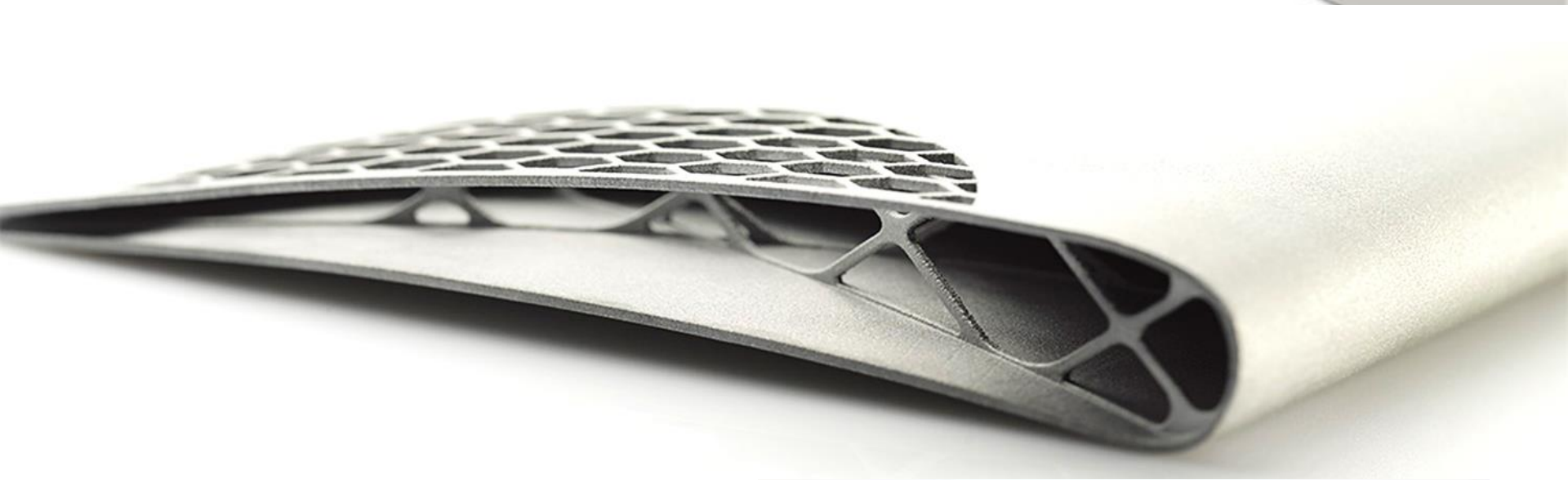
AM TECHNOLOGIES

- Directed Energy Deposition
  - Laser engineered net shaping, directed light fabrication, direct metal deposition, 3D laser cladding



KNOWN BENEFITS

- Shorter Lead Times
- Less Material used
- Ability to produce complex parts (Reduction in Parts Count)
- Ability to produce parts on demand
- Design driven manufacturing processes



EOS V/Tail Plain Bracket ***EADS Prototype for Airbus***

GE LEAP FUEL NOZZLE

20 parts replaced by 1

25% weight reduction

5 times more durable

CHALLENGES

- Equipment, processes, source material (powders, gas):

  No standardization

- Manufacturing parameters:

  Increased number of parameters with acceptable tolerances unknown

- Part strength relationship to process or material anomaly:

  Unknown

CHALLENGES

- Industry databases:

  None

- Inspection techniques:

  Traditional NDI techniques might not work

- Skilled labour force:

  Limited

MATERIAL AND PROCESSES STANDARDS (M&P)

Showing compliance with existing M&P standards

- 52X.603 Materials
- 52X.605 Fabrication Methods
- 52X.613 Material Strength Properties and Material Design Values

AM properties impacted by the as-purchased raw material and the manufacturing processes

52X.603 MATERIALS

Any part whose failure may affect safety must comply with AWM 52X.603

- Material specification based on test data
- Operating environment

Safety - the condition of being protected from danger, risk, or injury

52X.605 FABRICATION METHODS

All new manufacturing processes, regardless of the consequences of failure must comply with AWM 52X.605

- Process specification
- Test program to substantiate the manufacturing process to produce consistently sound structure

52X.605 FABRICATION METHODS

Process specification

- Machine type and settings
- Build environment
- Number of specimens and specimen orientation
- Dimensional control
- Monitoring during manufacturing
- Post processing such as heat treatment
- Final part inspection

Note: This is not an exhaustive list.

52X.613 MATERIAL STRENGTH PROPERTIES AND MATERIAL DESIGN VALUES DESIGN VALUES

Strength and design values used to compute margins of safety must comply with AWM 52X.613

- All values must be statistically derived from testing (A, B, S basis)
- Design values must account for process variability
- Operating environment

AUTHORITIES APPROACH

FAA

AIR100-16-130-GM18 Engineering Considerations for Powder Bed Fusion Additively Manufactured Parts

DOT/FAA/TC-16/15 Summary Report: Joint Federal Aviation Administration–Air Force Workshop on Qualification/Certification of Additively Manufactured Parts

Transport Airplane Issues List: Additive Manufacturing Design & Construction (Materials, Fabrication Methods)

FAA AC 33.15-5 Draft - **Open for comments**

AUTHORITIES APPROACH

EASA

CM-S-08 Additive Manufacturing

EASA Workshop on Additive Manufacturing:

https://www.easa.europa.eu/newsroom-and-events/events/easa-workshop-additive-manufacturing

AUTHORITIES APPROACH

TCCA

On project by project basis

Certification Memo Additive Manufacturing - Project Specific

FAA and/or EASA guidance as applicable

ASTM STANDARDS DEVELOPMENT

- Materials and Processes
  - F2924 – 14 Standard Specification for Additive Manufacturing Titanium-6 Aluminum-4 Vanadium with Powder Bed Fusion
  - ASTM F3001 – 14 Standard Specification for Additive Manufacturing Titanium-6 Aluminum-4 Vanadium ELI (Extra Low Interstitial) with Powder Bed Fusion
  - F3049 – 14 Standard Guide for Characterizing Properties of Metal Powders Used for Additive Manufacturing Processes
  - F3055 - 14a Standard Specification for Additive Manufacturing Nickel Alloy (UNS N07718) with Powder Bed Fusion
  - F3056 - 14e1 Standard Specification for Additive Manufacturing Nickel Alloy (UNS N06625) with Powder Bed Fusion
  - F3091 / F3091M – 14 Standard Specification for Powder Bed Fusion of Plastic Materials
  - F3184 – 16 Standard Specification for Additive Manufacturing Stainless Steel Alloy (UNS S31603) with Powder Bed Fusion
  - F3187 – 16 Standard Guide for Directed Energy Deposition of Metals
  - ISO / ASTM52901 – 16 Standard Guide for Additive Manufacturing – General Principles – Requirements for Purchased AM Parts

ASTM STANDARDS DEVELOPMENT

- Design
  - ISO / ASTM52915 – 16 Standard Specification for Additive Manufacturing File Format (AMF) Version 1.2
  - ISO / ASTM52910 – 17 Standard Guidelines for Design for Additive Manufacturing
- Terminology
  - ISO / ASTM52900 – 15 Standard Terminology for Additive Manufacturing – General Principles – Terminology
- Test Methods
  - F2971 – 13 Standard Practice for Reporting Data for Test Specimens Prepared by Additive Manufacturing
  - F3122 – 14 Standard Guide for Evaluating Mechanical Properties of Metal Materials Made via Additive Manufacturing Processes
  - ISO / ASTM52921 – 13 Standard Terminology for Additive Manufacturing-Coordinate Systems and Test Methodologies

CONCLUSION

- Applicant to consult with TCCA when c*onsidering* introduction of AM parts
- Existing Materials and Processes standards apply to these novel processes
- FAA and EASA Guidance Material can be used
- Certification Memo likely to be issued on a case by case basis

THANK YOU FOR YOUR ATTENTION

National Aircraft Certification

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Canada

525.603 *Materials*

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

(a) Be established on the basis of experience or tests;

(b) Conform to approved specifications (such as industry or military specifications, or Technical Standard Orders) that ensure their having the strength and other properties assumed in the design data; and

(c) Take into account the effects of environmental conditions, such as temperature and humidity, expected in service.

525.605 *Fabrication Methods*

(a) The methods of fabrication used must produce a consistently sound structure. If a fabrication process (such as gluing, spot welding, or heat treating) requires close control to reach this objective, the process must be performed under an approved process specification.

(b) Each new aircraft fabrication method must be substantiated by a test program.

525.611 *Accessibility Provisions*

(a) Means must be provided to allow inspection (including inspection of principal structural elements and control systems), replacement of parts normally requiring replacement, adjustment, and lubrication as necessary for continued airworthiness. The inspection means for each item must be practicable for the inspection interval for the item. Non-destructive inspection aids may be used to inspect structural elements where it is impracticable to provide means for direct visual inspection if it is shown that the inspection is effective and the inspection procedures are specified in the maintenance manual required by 525.1529. (amended 2009/05/11)

(b) EWIS must meet the accessibility requirements of 525.1719. (amended 2009/05/11)

525.613 ***Material Strength Properties and Material Design Values*** (amended 2003/11/26)

(a) Material strength properties shall be based on enough tests of material meeting approved specifications to establish design values on a statistical basis. (amended 2003/11/26)

(b) Material design values shall be chosen to minimise the probability of structural failures due to material variability. Except as provided in paragraph *(e)* and *(f)* of this section, compliance with this paragraph shall be demonstrated by selecting material design values which assure material strength with the following probability: (amended 2003/11/26)

(1) Where applied loads are eventually distributed through a single member within an assembly, the failure of which would result in loss of structural integrity of the component, 99 percent probability with 95 percent confidence.

(2) For redundant structure, in which the failure of individual elements would result in applied loads being safely distributed to other load carrying members, 90 percent probability with 95 percent confidence.

(c) The effects of environmental conditions, such as temperature and moisture, on material design values used in an essential component or structure shall be considered where these effects are significant within the aeroplane operating envelope. (amended 2003/11/26)

(d) Reserved (amended 2003/11/26)

(e) Greater material design values may be used if a “premium selection” of the material is made in which a specimen of each individual item is tested before use to determine that the actual strength properties of that particular item will equal or exceed those used in design. (amended 2003/11/26)

(f) Other material design values may be used if approved by the Minister. (amended 2003/11/26)

(Change 525-3 (91-11-01))