NDT for Additive Manufactured (AM) / 3D-Printed Parts
What does this mean for MRO?

A4A NDT Workshop 2016, San Diego, US
Content

△ Introduction to AM

△ AM Approach for Service

△ Quality & Inspection Aspects
  – Powder Quality
  – Dimensional Measurements
  – NDT Techniques

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Introduction to Additive Manufacturing (AM) for Metals
What is AM?

Wikipedia:

- **Additive manufacturing (AM)**, refers to processes used to synthesize a **three-dimensional** object in which successive layers of material are formed under **computer control** to create an object.

- **Additive Manufacturing = Industrial 3-D Printing**

- **AM for metals is a welding/sintering process**

- **Several different processes for metals are existing, e.g.**
  - Powder Bed: Selective Laser Melting (SLM)
  - Electron Beam Melting (EBM)
Selective Laser Melting (SLM)

- Used for Titanium and Aluminum Parts
- Most promising technology for Aerospace
- Mainly used in Aerospace and Orthopedics
- Layers between 0,020 and 0,100 mm are produced

Source: IQ-Evalution
Post Processing

⚠️ Surface of AM parts very rough
  – Post treatment partial necessary, especially in case of need for inspection (e.g. Penetrant Testing)
  – Mechanical or chemical milling might be applied

⚠️ For high load parts a Hot Isostatic Pressing (HIP) is mandatory.
  – HIP is used to eliminate pores and remove defects, i.e. nitrides, oxides and carbides and to dramatically increase the material properties.
Quality related Topics

- Pre-delivery check of powder

Powder Quality Assurance

AM Parts

NDT Inspection

- Computed Tomography (CT)
- Radiography (film and digital) (RT)
- Non contact NDE metrology
- Penetrant testing (PT)
- Eddy Current (ET)

DT Inspection

- Tensile tests
- Compression tests
- Shear tests
- Metallography
- Hardness tests
- Fatigue tests
- Fracture toughness tests
- …

Standardiz.

- ISO
- ASTM
- AIMS
- AITM
- …

NDT Training

- Basic method trainings
- Special application Trainings
AM Approach for Service
Justification

Manufacturing

⚠️ Implementation of AM in Manufacturing ongoing
⚠️ First Titanium Parts (Class 2.3 – non fatigue critical) approved by EASA (Airbus A400M)
⚠️ Future Focus on Class 1 and 2.1 parts (fatigue critical)

Service

⚠️ Need for availability of spare parts
  = production in-situ = reduce down-time
⚠️ Special parts for repairs
  = production in-situ = improve repair solutions
Expected Benefits for OEM / MRO

△ Reduction of Warehousing costs by production on demand

△ Complex parts can be manufactured at nearly no extra costs

△ Quicker than several conventional manufacturing processes

△ Avoid long lasting AOG
Challenges (Quality related)

- Ensure quality of the powder during the printing process
- Having metal printing process under control
- Different materials can not be printed on one machines (today status)
- Dimensional measurement of complex parts to be done
- NDT technologies & tools to be available
- Inspectors trained to perform NDT on AM parts
Quality & Inspection Aspects
Quality and Inspection Aspects

- NDT Inspection
- AM Services
- DT Inspection
- Powder Quality Assurance
- Standardiz. Expertise
- NDT Training
Quality and Inspection Aspects

AM Services

- NDT Inspection
- Powder Quality Assurance
- DT Inspection
- Standardiz. Expertise
- NDT Training
Powder Quality Assurance
Powder Quality Assurance

Challenges

⚠️ AM process require high quality of powder
  – No contamination
  – Nearly no moisture
  – Size of powder particles
  – Shape of the powder particles

⚠️ No mix of powder charges

⚠️ Closed circuit has to be ensured

⚠️ Re-use of remaining powder
Dimensional Measurement
Dimensional Measurement

Usually all parts have to be measured, but for AM parts it is even more of relevance:

⚠️ Printing process could lead to unexpected deformation caused by the melting process

⚠️ Removing of the supporting structure could lead to unexpected deformation (usually taken into account during the design)

⚠️ Tolerances of printing process today not as accurate as e.g milling
Example: Measurement with CT

⚠️ Nominal/actual comparison

CT-measurement (actual geometry)

CAD-part (nominal geometry)

Visualized nominal/actual deviation
Inspection Methods for AM Parts
Potential NDT Technologies

Main, currently envisaged NDT methods:
- Visual Testing (VT)
- Computed Tomography (CT)
- Digital X-Ray / Non-Film (RT-NF)
- Penetrant Testing (PT)

Additional, potential technologies
- Eddy Current (ET)
- Infrared Thermography (IRT)
- Leak Testing for complex structures (LT)
- Pressure Testing
- ………and more to come

Starting point: NDT applied as for castings
Most Promissing Technology - CT

Technical data
Voltage     < 225 kV
Current     < 1000 µA
Focal spot  > 2 µm
Voxel size  > 2 µm

→ FlyBy acquisition (duration ~ 15 minutes)
→ Dual Energy CT

Some quantitative characterization methods
(depending on the material)

Porosity     | Structure      | Undulation    | Shape       | Damage     | Material
--------------|----------------|---------------|-------------|------------|---------
26,98         | 13             |
AM-Part NDT/CT Inspection

⚠️ Overview- and detail measurements

Detail C

Detail A

Detail D

Detail B

~150 mm
AM-Part NDT/CT Inspection

Porosity determination

- Defect volume [mm³]
- xy-slice

~13 mm

0.90 mm

0.06 mm
AM-Part NDT/CT Inspection

⚠️ Powder residues
Analysis of pores using detail measurements

<table>
<thead>
<tr>
<th>Diameter [mm]</th>
<th>Volume [mm³]</th>
<th>Voxel</th>
<th>Surface [mm²]</th>
<th>SizeX [mm]</th>
<th>SizeY [mm]</th>
<th>SizeZ [mm]</th>
<th>PX [mm²]</th>
<th>PY [mm²]</th>
<th>PZ [mm²]</th>
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<td>0.01</td>
<td></td>
<td></td>
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<td>0.44</td>
<td>0.32</td>
<td>0.09</td>
<td>0.08</td>
</tr>
</tbody>
</table>

Detail A

Censored
AM-Part NDT/CT Inspection

Crack analysis
Digital X-Ray
Digital / Non-Film X-Ray

⚠️ Standard Technique for castings and other parts

⚠️ Complete X-Ray Systems for automated post-printing inspection under development

⚠️ Software for automated X-Ray image analysis under development within Airbus Group (ULTIS)

Source: GE
Conclusion
Conclusion

- AM could revolutionize spare part manufacturing & availability

- Challenges (Quality related)
  - Complex parts difficult to inspect
  - Powder quality essential
  - Capabilities for NDT of printed parts

- OEM to prepare basic requirements and standards

- Opportunities for service companies (print & inspect)
NDT – the view under the skin!

Thank you very much for your attention!
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