Additive Manufacturing Specifications and Standards

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in lieu of Carrie Davis, JDMTP Metal Subpanel Chair

Significant Area of Mutual Interest: Qualification and Certification

Joint Defense ManTech Panel

The Issue

- How do we qualify materials, processes and certify products for a manufacturing method that can deliver a unique part, with nearly an infinite combination of material compositions and process variations under nontraditional processing conditions?

The Solution

- Develop an approach for process qualification that is reliable, repeatable and credible for customers that are familiar with traditional materials and process specifications, but does not limit the potential and flexibility the process provides
- Traditional methods rely upon quantitative analysis through a combination of destructive and non-destructive evaluation (NDE)
- Advanced approaches include:
  - Materials and process modeling that provides pedigree and predicts performance
  - Less destructive evaluation and post-process evaluation through predictive modeling
  - Sharing of qualification property data between services and companies is important rather than continue to retain data as proprietary
  - Then follow up with application certification.

Navy Perspective

Goal

- Ability to acquire AM parts using competitive sourcing from a Technical Data Package (TDP) enabled by common standards
  - Usable across machines, processes, and companies employing a neutral build file
  - High confidence that parts produced by AM using the TDP will meet performance and safety requirements

Impediments

- Lack of sufficient AM standards and understanding in key areas:
  - Technical data package (TDP)
  - Neutral build file
  - Engineering design guidelines
  - Pedigreed materials properties
  - Process controls
  - Post-processing
  - Process qualification & part certification
  - Machine qualification & calibration

Air Force Perspective

The Air Force (AF) relies on different standards organizations for different applications:

- Feedstock materials: SAE AMS (Society of Aerospace Engineers Aerospace Material Specification)
- Process: AWS (American Welding Society)
- Testing: ASTM (American Society for Testing and Materials)

The AF approves for its use only those standards that meet its requirements, *(i.e., those published standards that do not meet AF requirements are not included in the AF standards database)*

For AM structural components, because they are highly process sensitive, a handbook allowables approach is not preferred. A more appropriate approach to standards for AM is that used for welding, not materials.

The AF expects that the standards approach for polymer/composite structural materials will be similar to that for metals. More work, however, needs to be accomplished to understand the effects of defects, etc.

Army Perspective

Applications

- Armor
- Explosives
- Repair (high demand area)

Repair

- Army is not using the military standard for laser repair (Mil-Std 3049), but they want to work it in to their practices
- Need for defined test requirements for repaired parts so that AM repairs can be tested to those requirements
- Understand unique loading or fatigue properties to specify for AM
- Design and material changes are ok as long as the part still works

Defense Logistics Agency

DLA has agree to other services comments and has no additional comments

Common Threads

Common Needs

- Materials (Material Property Database)
- Processes
- Inspection
- Certification

- Testing – both physical and virtual (M&S)
- Design Guidelines
- Common Terminology

- Strategic Plan and Investment Strategy

Summary of Proposed Outline for Navy AM Standards

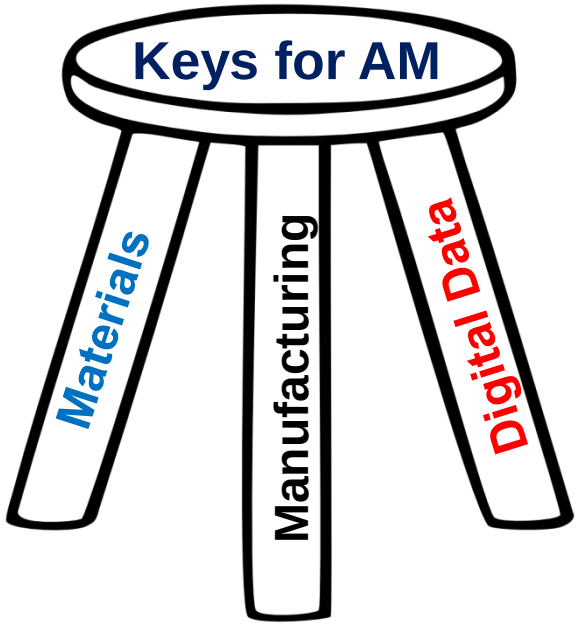
Scope	• Tailoring Existing Procurement Specs for AM	
References	• Common Terminology for AM	

Requirements	• Neutral Build Package Format
	  • Portability Validation (machine equivalence)
	• Design and CAD Model
	• Material Specs
	  • Input Materials (Virgin and Recycled) Characterization/Certification
	  • Material Properties/Directional Properties
		• Manufacturing and Fabrication Process Stds
		• Machine Type/Model/Series (T/M/S) Qualification, Calibration & Operation
		  • Metrology
		• Operator Qualification/Certification
		• Post-processing
		• Safety (environmental, human)

Verification	• Testing • Inspection • Non-Destructive Evaluation (NDE)	• Quality Assurance (material, in-process, and post process inspection plans) • Statistical Process Controls (SPC) • Parts Qualification/Certification
Packaging	• Packaging, Storage and Reuse of Powders	
Govt Action	• Part Build TDP • System Design TDP • Modeling and Simulation (i.e., FEA) • Performance Criticality	• Digital Thread (Configuration and data management through the part life cycle) • Cybersecurity • Education/Training

***Near-term priority topics (0-2 year need) are in red**

Issues and Common Threads



Materials

- Raw stock and pedigree info
- Metals, polymers, ceramics, hybrids
- Characterization
- Handling and storage
- Testing

Manufacturing

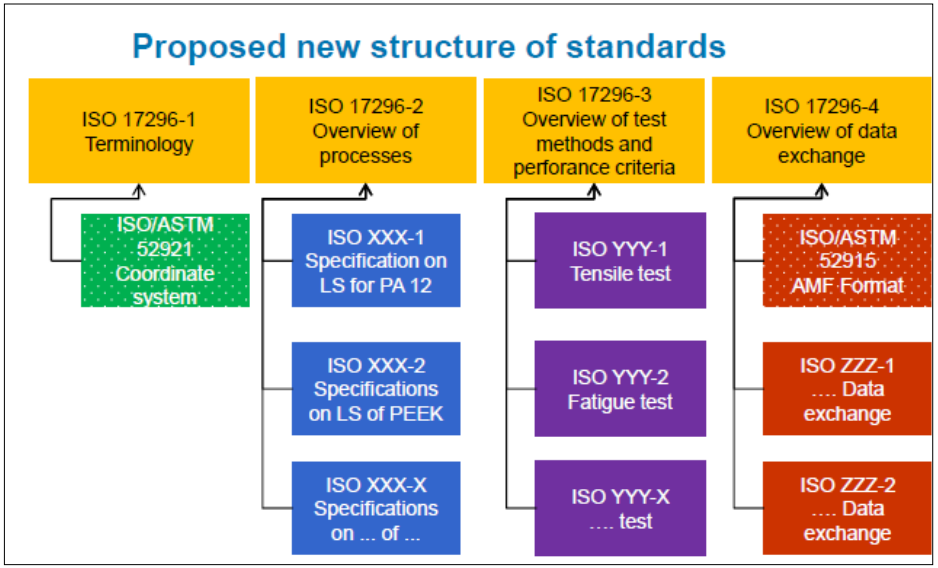
- Process parameter & controls
- Sensors, security
- Equipment pedigree info
- Producibility and repeatability
- Inspection

Digital Data

- Model quality, data formats
- Information Technology (IT) infrastructure and data management
- Validation, Verification, Certification
- Cyber Security
- Integrated Computational Materials Engineering (ICME)

Expertise in Standard Developing Organizations

ISO 17296/ASTM F42



AWS D20 committee on AM

D20A/TG1 on General Requirements
D20B/TG2 on Material Characteristics
D20C/TG3 on Prequalification
D20E/TG5 on Fabrication
D20F/TG6 on Inspection

ASME: 14.46, 14.41.1

SAE's: AMS & AS standards

Others: SME, ASNT, IEEE, ASM, DoD MIL STD & DTLs, NAVSEA Tech Pubs, Industries (Primes) etc..

Some Print Formats:

AMF, STL, 3MF, STEP(ISO-10303)

What about Safety/ Regulations Stds?

Summary

- AM is already being used in the DoD for process enabling, intermediate, and finals parts.
- For final parts, AM is being approved on a case by case basis across the services.
- For intermediate and process enabling parts where AM is used to enable the final part build and design, such as tools, dies, and consumables, AM parts are used as a drop-in substitute for the current process.
- The majority of AM parts are for repair items where the original supply chain no longer exists.
- For new parts, the business case for using AM revolves around long lead time items and parts with increased complexity.

Questions?

Navy Perspectives

- As we look at the list of standards we need to develop our requirements to enable DOD/Industry to increase our use of AM and reduce the "proprietary" standards for qualification and certification, we need to focus the standards committees on our priority applications of AM.
- We talked about a prioritized list of top level DOD needs to focus the standards:
  - AM for metal aerospace components - including safety critical items
  - New materials standards to address fire/smoke/toxicity for expeditionary/shipboard use of AM (metal and polymer)
  - Maintenance plan for AM standards across multiple standards organizations (ASTM, ASME, DWG)
  - Data/analysis repository to accelerate and support standards development

Navy has some unique requirements for AM based on the various platforms in construction and in sustainment which may require MIL SPECS or STD.

ONR Additive Manufacturing S&T

Vision

Exploit the flexibility and opportunities afforded by Additive Manufacturing (AM) to provide the warfighter with high-performance systems that could not otherwise be produced, and technologies that enhance operational fleet readiness, improve energy efficiency, and reduce total ownership cost

Approach

Make strategic S&T investments that enable full exploitation of AM:

- Push the limits of AM length scales, material selection and complexity of material and design
- Develop the understanding and tools to rapidly and confidently certify lots of one
- Actively assess and leverage partner services, agencies, industry and academia activities (e.g. DARPA Open Manufacturing, America Makes, Oak Ridge National Laboratory, etc.)

Examples

- Direct Digital Manufacturing (DDM) Accelerated Certification Technology – develops in a heuristic technique for rapid qualification/certification
- Disruptive Technologies in Direct Digital Manufacturing – demonstrates the repair of single crystal turbine blades, closed-loop process control and micro/nano DDM
- Cyber-enabled Manufacturing Systems – improves closed-loop feedback control for real-time shape compensation
- Advanced Integrated Computational Materials Engineering (ICME) and Additive Manufacturing (AM) Methods for Improved Performance, Reduced Cost Heat Exchanger – provides opportunity for material design, processing and rapid prototyping with tailored microstructural topology- Including FY17 FNC “Quality Made”