What’s New with ASTM F42 On Additive Manufacturing

July 13, Virtual

Shane Collins, Head AM Advisory Services
Shane Collins

- **Head of Additive Manufacturing Advisory Services – ASTM Center of Excellence**

- 20-year veteran of the AM Industry
  - Operations, product management, business development for metal and polymer additive manufacturing

- Produced production class parts to specifications from:
  - Experience includes CalRAM – First organisation to achieve Nadcap for L-PBF and EB-PBF

- ASTM F42 Fellow
  - Chair of the ASTM F42.07 on additive manufacturing Applications
  - Formerly for 10 years, Chair of F42.05 on Materials and Process
  - ASTM Robert F. Painter Memorial Award in 2017, the ASTM Award of Merit in 2018
ASTM Additive Manufacturing Footprint

- **Established:** 2009 (Oldest, largest committee on AM)
- **Current Membership:** 1000+ members (Over 30% outside the US)
- **Standards:** 30+ approved, 45+ in development (Jointly with ISO)
- **Global Representation:** 35+ countries involved

**Collaboration:**
- Partnership with ISO TC261 (& CEN TC438)
- Strategic Relationships – America Makes, NIST, NASA, FAA, FDA, DOD, MMPDS, CMH17 ASTM F4, ASTM E07
Evolution of AM Part Qualification

Past two years

Part Qualification
Standards and Specifications
Design Allowable Data

Historical Perspective

Metal AM Production Anomalies

In situ monitoring
Fixed M&P Controls
Post-print NDE and final inspection
Design Practice

Certification Path
Part Criticality
Business Case
Tech Maturity

Diagram credit Charles Park @ Boeing
How do we show parts are Safe?

**Defect Free**
- No defects above a certain size
- Strict process controls and inspection to avoid defects
- Assessment approaches based on fatigue life (crack initiation)
- Safe operating life is up to the point of initiation of an engineering defect.
- Analysis route is relatively simple
- Problematic where inspection is difficult or risk of initial defects not negligible

**Defect Tolerant**
- Accept defects exist in the structure
- Critical defect sizes (resulting in fracture) are calculated
- Safe life based on the time for an initial defect to grow to the critical size
- Analysis based on engineering fracture mechanics and fatigue crack growth
- Inspection used to limit the initial defect size
- Inspection and process requirements lower
- Analysis route potentially more complex and may require more data

Ref: Dr Simon Lewis, Norton-Straw Consultancy, “Cost Effective Characterisation of Defect Populations in AM Materials” ICAM 2020
Part Qualification Can Only Evolve with a Robust Party Classification System

F42.07.01 Aviation Part Classification Matrix (May 2021 Draft)

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<tr>
<td>Class A Part that contributes significantly to the safety of flight, ground, or personal injury or loss of life. Category 6 Flight Parts/Components that Pass a Safety Impact Test: C3b. Category IV: Part consequence of failure: High. Category 3 Part shows a serious risk of damage to other equipment or personnel (e.g., C5a). Category 1 A part that, if it fails, will cause serious or catastrophic failure of the aircraft. Part failure would result in a loss of life. This Standard Guideline will ballot as WK77559.</td>
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<td>Class B Part whose failure could affect the integrity of the airplane. The failure of the part may have an operational impact due to the loss of function when the part has safety or operational criticality to the occupants and the integrity of the airplane. Category 5 Flight Parts/Components that Pass an Operational Impact Test: Safety Impact Category 4 Flight Parts/Components with a Readiness impact, but no Safety or Operational impact. Category III Part consequence of failure: Medium. Category II Part consequence of failure: Low. Category I Part consequence of failure: Negligible.</td>
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<td>Class C Part that does not significantly affect the safety or operational impact. Category 3 Flight Parts/Components with a Safety, Operation, or Readiness impact. Normal-Central Part: Structural component that is not mission critical and satisfies the requirements of the airworthiness regulations. Category I Flight Parts/Components that Pass an Operational Impact Test: Safety Impact Category 4 Flight Parts/Components with a Readiness impact, but no Safety or Operational impact. Category II Part consequence of failure: Negligible. Category I Part consequence of failure: Non Structural.</td>
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| Class D Negligible to no effect on operational capabilities, safety, or operational impact. Category 3 Avionics Ground Support Equipment, Category 1 Flight Parts, Flight, Drop, Roll, and Testing. Example: Part consequence of failure: Negligible. No mission critical impact. Non Structural. No loss of readiness impact. No risk of injury to personnel. Category 0 Part shows no risk of damage to other equipment or personnel (e.g., non mission critical, non structural, no mission critical impact). Non Structural. No loss of readiness impact. No risk of injury to personnel. Category 0 A part that shows no risk of damage to other equipment or personnel (e.g., non mission critical, non structural, no mission critical impact). Non Structural. No loss of readiness impact. No risk of injury to personnel. Category 0 Low Critical Application: No significant changes in higher structural classifications. Non Safety Effect: No effect on operational capabilities or safety, and not affect on occupants or flight crew. Category 0 Non Critical Application: A component whose failure would not affect the operation of the system or endanger personnel. Category 0 Non Critical Application: No significant changes in higher structural classifications. Non Safety Effect: No effect on operational capabilities or safety, and not affect on occupants or flight crew. Category 0 Non Critical Application: A component whose failure would not affect the operation of the system or endanger personnel. Category 0 Non Critical Application: No significant changes in higher structural classifications. Non Safety Effect: No effect on operational capabilities or safety, and not affect on occupants or flight crew. Category 0 Non Critical Application: A component whose failure would not affect the operation of the system or endanger personnel. Category 0 Non Critical Application: No significant changes in higher structural classifications. Non Safety Effect: No effect on operational capabilities or safety, and not affect on occupants or flight crew. Category 0 Non Critical Application: A component whose failure would not affect the operation of the system or endanger personnel. Category 0 Non Critical Application: No significant changes in higher structural classifications. Non Safety Effect: No effect on operational capabilities or safety, and not affect on occupants or flight crew. Category 0 Non Critical Application: A component whose failure would not affect the operation of the system or endanger personnel. Category 0 Non Critical Application: No significant changes in higher structural classifications. Non Safety Effect: No effect on operational capabilities or safety, and not affect on occupants or flight crew. Category 0 Non Critical Application: A component whose failure would not affect the operation of the system or endanger personnel. Category 0 Non Critical Application: No significant changes in higher structural classifications. Non Safety Effect: No effect on operational capabilities or safety, and not affect on occupants or flight crew.
This standard is issued under the fixed designation FXXX; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

INTRODUCTION

Part classification is required to provide a consistent metric for aviation parts based on a part’s consequence of failure. Without carefully defined part classes, the ability to accurately gauge the consequence of failure associated with AM aviation parts within and across programs, projects, and suppliers becomes exceedingly difficult, resulting in mitigations that are either not commensurate or consistent. This classification system does not affect a part’s functional requirements, but rather is used to group AM Aviation parts into classifications which can be used as a metric to ensure, to within a level of confidence, varied by the classification, the acceptable level that defects are permitted. Consequently, this classification system can be used in material and process specifications to determine the appropriate levels of process control, thermal post processing, qualification, and inspection to ensure AM aviation parts meet their required application. This classification does not identify a level of defects permitted, nor does it specify how the classification is used in any downstream processes. The use of the classification shall be left to the downstream documents which reference this standard.
An example Quality System Leveraging ASTM/ISO Standards

Credit: Shane Collins, F42

Note: Not inclusive of all Standards. Note also that some Standards are not issued yet; please check ISO/ASTM websites for latest information.
Using Standards as part of your Quality System drives ‘best practices’ into your organisation

Reduce workload – you don’t have to reinvent the wheel

https://www.iso.org/committee/629086/x/catalogue/p/0/u/1/w/0/d/0
Forthcoming ISO Standards

Ref David Hardacre, Lloyds Register
ISO/ASTM 52941

Additive manufacturing — System performance and reliability — Acceptance tests for laser metal powder-bed fusion machines for metallic materials for aerospace application

This standard is highlighted to demonstrate the detail required when considering Quality Assurance for AM Machines, as well as some of the fundamentals required in a facility to enable the machine use

- Can be used for FAT/SAT & calibration
ISO/ASTM 52941 Establishes Machine Fitness
ISO/ASTM 52941

- This standard for additive manufacturing will enable users to maintain operation within the process window - realizing the process window is much more than energy density.
Key Standards for Critical Applications

- **ISO/ASTM 52901**: Standard Guide for AM – General Principles – Requirements for Purchased AM Parts
  - Provides requirements for purchased parts from AM. Includes part ordering information, part geometry, tolerances, repair methods allowed, and other requirements to be considered.

- **ISO/ASTM 52904**: Practice for Metal Powder Bed Fusion Process to Meet Critical Applications
  - Provides requirements applicable for critical components and mechanical test specimens using powder bed fusion (PBF) with both laser and electron beams.

- **ISO/ASTM 52941**: System Performance and Reliability – Acceptance Tests for Laser Metal PBF Machine for Metallic Materials for Aerospace
  - Specifies requirements & test methods for qual & re-qual of Laser PBF machines. Can be used to verify machine features during inspection, or after maintenance & repair.

- **ISO/ASTM 52942**: Qualifying Machine Operators of Laser Metal Powder Bed Machines and Equipment used in Aerospace Applications
  - Specifies requirements for operators of Laser Metal Powder Bed Machine and equipment for AM in Aerospace applications. Qualification tests to include theory & practical tests, and evidence of visual acuity.

- **ASTM F3434**: This guide addresses IQ, OQ, and PQ issues directly related to the AM machine and connected equipment. Physical facility, personnel, process and material issues are included to the extent necessary to support machine qualification.

**Forthcoming ASTM Qualification Program**

**Machine**

**Operators**

**Installation, Operation, and Performance - PRODUCTION**
Development of the Common Data Dictionary (F42.08)
- Means to exchange AM data between stakeholders

Essential for AM Data-System developers
- To meet requirements
- Standard definitions of data element, data types, and allowable values

Neutral definitions for essential AM data terms
- Can be mapped to Proprietary data systems

These concepts can be used to develop a common data model and a common data-exchange format.

This enables seamless data integration via both exporting from, and importing to, the original native formats.
## Key Standards in Development

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<th>NDT/In-Process Monitoring</th>
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<tr>
<td>WK62190</td>
<td>WK75901</td>
<td>WK62181</td>
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<td>WK66030</td>
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### Feedstock Materials
- Technical Specifications on Metal Powder
- Documentation & traceability, sampling, particle size & distribution, chemical composition, characteristics, density, morphology, flowability, contamination, packaging and storage

### Test
- New Guide for Quality Assessment of Metal Powder Feedstock Characterization Data for Additive Manufacturing
- Additive Manufacturing – Test Artifacts – Miniature Tension Testing of Metallic Materials
- Miniature rectangular cross-section tension test specimens with gauge length 10-15mm for metallic materials. Comparable tensile results to 25mm gauge length

### NDT/In-Process Monitoring
- Standard Guide for In-Situ Monitoring of Metal AM Aerospace Parts
- Guide to ensure that parts/products meet the stipulated In-Process Quality Assurance. Will consider multiple techniques, such as Infrared Thermography, Laser Ultrasonic Testing, Melt-pool, Acoustic Microscopy
- Provides supplier and customer NDT acceptance criteria for products used in aviation and space application. This practice provides a part quality level, acceptance criteria and identifies some applicable NDT methods

This standard is issued under the fixed designation F; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers additive manufacturing of parts manufactured via laser beam powder bed fusion (PBF-LB) processing of niobium-hafnium alloy used in spaceflight applications. Parts made using this processing method are typically used in applications that require mechanical properties similar to wrought products. Products built to this specification may require additional post-processing in the form of machining, polishing etc. to meet necessary surface finish and dimensional tolerances.

1.2 This specification is intended for the use of purchasers or producers, or both, of PBF-LB R04295 parts for defining the requirements based on classification methodology.

1.3 Users are advised to use this specification as a basis for obtaining parts that will meet the minimum acceptance requirements established and revised by consensus of committee members.

1.4 User requirements considered more stringent may be met by the addition to the purchase order.

1.5 Units—The values stated in SI units are to be regarded as the standard. Other units are included only for informational purposes.

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1. Scope

1.1 This specification covers additive manufacturing of parts manufactured via laser beam powder bed fusion (PBF-LB) processing of 4340 alloy used in transportation applications, including automotive applications. Parts made using this processing method require heat treatment to achieve maximum strength and are typically used in applications that require mechanical properties similar to wrought 4340 products. Products built to this specification may require additional post-processing in the form of machining, polishing, etc. to meet necessary surface finish and dimensional tolerances.

1.2 This specification is intended for the use of purchasers or producers, or both, of PBF-LB G43400 parts for defining the requirements based on classification methodology.

1.3 Users are advised to use this specification as a basis for obtaining parts that will meet the minimum acceptance requirements established and revised by consensus of committee members.

1.4 User requirements considered more stringent may be met by the addition to the purchase order.

1.5 Units—The values stated in SI units are to be regarded as the standard. Other units are included only for informational purposes.
Standard Specification for
Manufactured Polymeric Ultraviolet (UV)-Cured Structures for
Residential Construction¹

WK74302

This standard is issued under the fixed designation X XXXX; the number immediately following the designation indicates the year of
original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A
superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification is intended to apply to structures for residential construction manufactured
with a three-dimensional (3D) printing process with polymeric ultraviolet (UV)-cured materials
in which the structures can be buildings components or complete modules of the construction
building. The manufactured UV-cured structures that comply with this specification are intended