NISTIR 8005

Applicability of Existing Materials Testing Standards for Additive Manufacturing Materials

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INTRODUCTION

This NIST Internal Report (NISTIR) is the third in a series of reports from the National Institute of Standards and Technology (NIST) Engineering Laboratory's project on Additive Manufacturing Materials. This project provides the measurement science for the additive manufacturing (AM) industry to measure material properties of additive manufacturing materials in a standardized way. Currently there are no additive manufacturing-specific consensus-based standards in this area. This project, in conjunction with the NIST Engineering Laboratory's other additive manufacturing projects, will provide the technical foundation and documentary standards development necessary to develop new consensus-based standards for AM materials, AM processes, and AM part qualification. This will be done via ASTM-International's (hereafter referred to as 'ASTM-I') Committee F42 on Additive Manufacturing Technologies and the newly formed International Organization for Standardization (ISO) TC261 committee on Additive Manufacturing.

Determining the properties of the powder used for metal-based additive manufacturing, as well as the properties of the resulting bulk metal material, is a necessary condition for AM users to be able to confidently select powder and produce consistent parts with known and predictable properties. Standardized methods for characterizing the properties of metal powders and metal parts already exist. Summaries of these existing methods were published in NISTIR 7847 [1], for bulk metal materials properties, and NISTIR 7873 [2], for metal powder properties. While many of these existing standards are applicable for AM powders and parts, others are not, while still others are applicable with some additional modifications or guidance to the existing standards. This report summarizes an assessment of the applicability of the standards described in NISTIR 7847 and NISTIR 7873 for use on metal AM powders and parts.

The applicability assessment presented here is based on our knowledge and experiences of the various test methods, as well as our experiences and knowledge on the capabilities of metal powder-bed AM systems. For each of the ASTM and ISO standards presented here, a qualitative judgment on the degree of applicability of the standard for AM metal powders and parts is presented. This is shown in tabular form in the next section. A description of each applicability classification is described at the beginning of the table.

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APPLICABILITY ASSESSMENT

In this chart, each standard is given one of the following classifications in determining if it is applicable for additive manufacturing. Some standards have additional pertinent text in the NOTES column.

- YES – The standard should be applicable for additive manufacturing without any modifications.
- YES WITH GUIDANCE – The standard should be generally applicable for additive manufacturing, but there may be limits on its applicability, or additional considerations. These include:
    - Limits on some ranges of test specimens, especially thin sheets and wires that may not be easily realized via metals-based commercial additive manufacturing systems; however some specimens can be readily built via AM.
    - Required post-processing such that specimens built via additive manufacturing meet the requirements of the standard; this typically includes surface finish or dimensional requirements.
    - Material isotropy requirements. AM specimens usually have some inherent anisotropy. The measurement methods that specify applicability for isotropic materials may still work, but the measured results may have larger uncertainties.
    - Application specific considerations, such as elevated testing temperatures.
- NOT A TEST METHOD – These standards may have useful auxiliary information, such as terminology, but they are not by themselves a test method.
- NO – The standard either requires specimens that certainly cannot be built via AM, or the measurement simply is not applicable.

This analysis does not address any measurement-specific safety issues, such as those that may be encountered while manipulating raw AM powder, which may require additional modifications and/or considerations.

MECHANICAL TESTING OF METAL PARTS

Standard Designation	Standard Name	Applicable for AM Testing?	Notes
ASTM E0006	Terminology Relating to Methods of Mechanical Testing	Not a test method	This is not a testing standard, it is a terminology document
ASTM A370	Standard Test Methods and Definitions for Mechanical Testing of Steel Products	Yes	For steel, refers to several other testing standards for basics and adds additional requirements/guidance, includes hardness, tension and impact testing
ASTM A1058	Standard Test Methods for Mechanical Testing of Steel Products—Metric	Yes	Same as ASTM A370 but in SI units

Standard Designation	Standard Name	Applicable for AM Testing?	Notes
ASTM B557	Standard Test Methods for Tension Testing Wrought and Cast Aluminum- and Magnesium-Alloy Products	Yes	ASTM B557 is for Al and Magnesium, ASTM E8 is the basic method
ASTM E8	Standard Test Methods for Tension Testing of Metallic Materials	Yes with Guidance	Basic method for tension testing at room temperature (10°C – 38°C, 50°F – 100°F). Not all specimen types can be made additively (e.g., wire and sheet). Includes requirements for powder metallurgy materials that should cover AM specimens.
ASTM E0021	Test Methods for Elevated Temperature Tension Tests of Metallic Materials	Yes with Guidance	Like ASTM E8 but at elevated temperatures (assume > 38°C/100°F). Yes with guidance that depends on application.
ASTM E0292	Test Methods for Conducting Time-for-Rupture Notch Tension Tests of Materials	Yes with Guidance	Similar to ASTM E8 but uses notched specimens. This test is done at elevated temperatures and with constant loads. Pre-test specimens need post-processing (after AM building) to achieve dimensional requirements.
ASTM E0740	Practice for Fracture Testing with Surface-Crack Tension Specimens	Yes with Guidance	Similar to ASTM E8 but for plate with an existing flaw. Possible specimen thickness limitations for AM specimens.
ASTM E1450	Test Method for Tension Testing of Structural Alloys in Liquid Helium	Yes with Guidance	Similar to ASTM E8 but done at cryogenic temperatures. May require possible application-specific guidance.
ISO 6892-1:2009	Metallic materials -- Tensile testing -- Part 1: Method of test at room temperature	Yes with Guidance	Basic ISO method similar to ASTM E8, includes additional test sample geometries (sheet, wire, etc.) that may not be appropriate for AM.
ISO 6892-2:2011	Metallic materials -- Tensile testing -- Part 2: Method of test at elevated temperature	Yes with Guidance	Similar to ISO 6892-1 and ASTM E8 but at elevated temperatures. Sheet and wire specimens may not be appropriate for AM.
ISO 15579:2000	Metallic materials -- Tensile testing at low temperature	Yes with Guidance	Similar to ISO 6892-1 and ASTM E8 but at low temperatures (between 10°C and -196°C.) Sheet and wire specimens may not be appropriate for AM, also potentially application specific.
ISO 19819:2004	Metallic materials -- Tensile testing in liquid helium	Yes with Guidance	Similar to ISO 6892-1 and ASTM E8 but at a very low temperature (-269°C or 4.2K, liquid He temperature.) Also can be done at cryogenic temperatures (less that -196°C or 77K.) Sheet and wire specimens may not be appropriate for AM, also potentially application specific.
ISO 26203-1:2010	Metallic materials -- Tensile testing at high strain rates -- Part 1: Elastic-bar-type systems	No	Similar to ISO 6892-1 but for sheet materials such as those for car bodies, and at high strain rates (> 10^2 s^{-1}).These parts cannot currently be built on commercial AM systems due to their large size.
ISO 26203-2:2011	Metallic materials -- Tensile testing at high strain rates -- Part 2: Servo-hydraulic and other test systems	No	Similar to ISO 6892-1 but for sheet materials such as those for car bodies, and at high strain rates (10^{-2} s^{-1} to 10^3 s^{-1}). These parts cannot currently be built on commercial AM systems due to their large size.

Standard Designation	Standard Name	Applicable for AM Testing?	Notes
ASTM E9	Test Methods of Compression Testing of Metallic Materials at Room Temperature	Yes with Guidance	Basic test for axial-load compression testing of metals at room temperature. Not all of the sample types (e.g., thin sheets) can be made additively.
ASTM E0209	Practice for Compression Tests of Metallic Materials at Elevated Temperatures with Conventional or Rapid Heating Rates and Strain Rates	Yes with Guidance	Similar to ASTM E9 but for specimens that are heated at a uniform temperature (up to and beyond 1000°F/538°C). Yes, depending on application.
ASTM E0238	Test Method for Pin-Type Bearing Test of Metallic Materials	Yes with Guidance	Basic and only method for pin-type bearing. The surface finish requirements and some thickness requirements are problematic for some metal-based commercial AM systems.
ASTM E0111	Test Method for Young's Modulus, Tangent Modulus, and Chord Modulus	Yes	Limited to materials, temperatures, and stresses where creep is negligible. ASTM E8 and ASTM E9 are the basic tension and compression methods; this provides additional guidance (number of trials, specimens, temperature etc.) and defines the three moduli. Provides guidance for both high and low temperatures.
ASTM E0143	Test Method for Shear Modulus at Room Temperature	Yes	Basic method for shear modulus at room temperature only.
ASTM E1875	Test Method for Dynamic Young's Modulus, Shear Modulus, and Poisson's Ratio by Sonic Resonance	Yes with Guidance	Instead of macro deformation, uses sonic resonance (which may be considered micro deformation.) This standard covers room, elevated, and very low temperatures in the range -195°C to 1200°C. Strict requirements for isotropic materials may be a problem for some AM parts/processes.
ASTM E1876	Test Method for Dynamic Young's Modulus, Shear Modulus, and Poisson's Ratio by Impulse Excitation of Vibration	Yes with Guidance	Similar to ASTM E1875 but with an impulse instead of a body resonance. This might be considered micro-scale deformation. States that can be performed at non-room temperatures. Strict requirements for isotropic materials may be a problem for some AM parts/processes.
ASTM E0466	Practice for Conducting Force Controlled Constant Amplitude Axial Fatigue Tests of Metallic Materials	Yes with Guidance	Basic method; fatigue testing of axial un-notched and notched specimens subjected to constant amplitude periodic forcing function in air at room temp. Used to test effect of variations in material, geometry, surface condition, etc. Test is finished when it fails or a certain number of cycles are reached. Samples will require post-processing to achieve recommended surface roughness and notch geometry.
ASTM E0467	Practice for Verification of Constant Amplitude Dynamic Forces in an Axial Fatigue Testing System	Not a test method	A “method for testing the tests.” This is not a test method.
ASTM E0468	Practice for Presentation of Constant Amplitude Fatigue Test Results for Metallic Materials	Not a test method	Not a method, it’s about what to report.
ASTM E0606	Practice for Strain-Controlled Fatigue Testing	Yes	Similar to ISO 1099; strain-controlled instead of force-controlled fatigue. Uniqueness is that it yields the determination of cyclic stresses and strains at any time during the tests.

Standard Designation	Standard Name	Applicable for AM Testing?	Notes
ASTM E0647	Test Method for Measurement of Fatigue Crack Growth Rates	Yes with Guidance	Determines fatigue crack growth rates from near-threshold to Kmax controlled instability. Possible anisotropy issues.
ASTM E1049	Practices for Cycle Counting in Fatigue Analysis	Not a test method	Not a test method but still potentially useful for fatigue analysis of AM specimens.
ASTM E1823	Terminology Relating to Fatigue and Fracture Testing	Not a test method	
ASTM E1942	Guide for Evaluating Data Acquisition Systems Used in Cyclic Fatigue and Fracture Mechanics Testing	Not a test method	
ASTM E2368	Practice for Strain Controlled Thermomechanical Fatigue Testing	Yes with Guidance	Uniform temperature and strain fields over the specimen are simultaneously varied and independently controlled. AM samples would likely need post-processing.
ASTM E2714	Test Method for Creep-Fatigue Testing	Yes with Guidance	Determines deformation and crack formation or nucleation as a consequence of constant-amplitude strain-controlled tests or constant-amplitude force-controlled tests (ASTM E0606 and ASTM E0466, ISO 12106 and ISO 1099.) Typically done at elevated temperatures and involves sequential or simultaneous application of loading conditions necessary to generate cyclic deformation/damage enhanced by creep deformation/damage or vice-versa. The difference with the basic method is the long hold time.
ASTM E2760	Test Method for Creep-Fatigue Crack Growth Testing	Yes with Guidance	ASTM E2760 is to ASTM E0647 as ASTM E2709 is to ASTM E0606 or ASTM E0466. Concerns fatigue cycling with long loading/unloading rates and/or hold times to cause creep deformation at the crack tip and the creep deformation be responsible for enhancing the crack growth per loading cycle.
ASTM E2789	Guide for Fretting Fatigue Testing	Yes	ASTM E0466 is the basic method. Small amplitude motion, usually tangential, between two solid surfaces in contact.
ISO 1099:2006	Metallic materials -- Fatigue testing -- Axial force-controlled method	Yes with Guidance	Samples are similar to ASTM E0466; stress vs. cycles to failure. Can be done at high temperatures. Basic method. AM samples will require post-processing to achieve recommended surface roughness.
ISO 1143:2010	Metallic materials -- Rotating bar bending fatigue testing	Yes with Guidance	Circular cross-section samples, rotated and subjected to bending moment. Application specific, post-processing may be required.
ISO 1352:2011	Metallic materials -- Torque-controlled fatigue testing	Yes	Similar to ISO 1352 but for torque.
ISO 12106:2003	Metallic materials -- Fatigue testing -- Axial-strain-controlled method	Yes with Guidance	Similar to ISO 1099 but for low-cycle fatigue tests. Imposed constant strain rate; test starts by testing elastic region to measure modulus (checked vs nominal), test stops are failure. High and low temps mentioned. Samples will require post-processing to achieve recommended surface roughness.
ISO 12108:2002	Metallic materials -- Fatigue testing -- Fatigue crack growth	Yes with Guidance	Primarily intended for isotropic materials; variety of samples and tests.

Standard Designation	Standard Name	Applicable for AM Testing?	Notes
	method		
ISO 12111:2011	Metallic materials -- Fatigue testing -- Strain-controlled thermomechanical fatigue testing method	Yes with Guidance	Similar to ISO 12106 but with the addition of temperature cycling. Samples will require post-processing to achieve recommended surface roughness.
ASTM B645	Standard Practice for Linear-Elastic Plane-Strain Fracture Toughness Testing of Aluminum Alloys	Yes with Guidance	Fracture toughness is resistance to crack extension; Basic test method for plane-strain fracture toughness of aluminum. Supplements E399 and B646. Samples will require post-processing to achieve recommended surface roughness and dimensional tolerances.
ASTM B909	Standard Guide for Plane Strain Fracture Toughness Testing of Non-Stress Relieved Aluminum Products	Yes with Guidance	ASTM E399 or ISO 12737 is basic method. ASTM B909 provides supplemental information for plane-strain toughness testing of Al where complete stress relief is not possible. Additive manufacturing samples will require post-processing to achieve recommended surface roughness and dimensional tolerances.
ASTM B646	Standard Practice for Fracture Toughness Testing of Aluminum Alloys	Not a Test Method	Provides guidelines for test selection for fracture toughness properties of Al, particularly for quality assurance and material release purposes. Provides supplemental information on specimen size, analysis, and interpretation of results, particularly for varying thicknesses.
ASTM E0023	Test Methods for Notched Bar Impact Testing of Metallic Materials	Yes with Guidance	Notched-bar impact testing of metals by Charpy (simple-beam) and Izod (cantilever-beam) tests. Describes 4 differences between two tests (sample notches, holding mechanism, impact location, sample dimension). Additive manufacturing samples will require post-processing to achieve recommended dimensional tolerances.
ASTM E0399	Test Method for Linear-Elastic Plane-Strain Fracture Toughness KIc of Metallic Materials	Yes with Guidance	Basic method. See also ISO 12737. For metals under linear-elastic, plane-strain conditions using fatigue pre-cracked specimens subjected to a slowly increasing crack-displacement force. May require post-process machining for notch.
ASTM E1221	Test Method for Determining Plane-Strain Crack-Arrest Fracture Toughness, KIa, of Ferritic Steels	Yes with Guidance	Samples may require post-processing.
ASTM E1290	Test Method for Crack-Tip Opening Displacement (CTOD) Fracture Toughness Measurement	Yes with Guidance	Determines critical crack-tip opening displacement (CTOD) values, used to measure cleavage crack initiation toughness for materials that exhibit a change from ductile to brittle behavior with decreasing temp. Notches may require post-processing (additional machining).
ASTM E1304	Test Method for Plane-Strain (Chevron-Notch) Fracture Toughness of Metallic Materials	Yes with Guidance	Chevron-shaped-notch, notches may require post-processing (additional machining).
ASTM E1820	Test Method for Measurement of Fracture Toughness	Yes with Guidance	This also appears to be the basic ASTM method for fracture toughness. Load a fatigue pre-cracked test specimen to induce either unstable crack extension and/or stable crack extension. Need to measure force versus load-line displacement or crack mouth opening

Standard Designation	Standard Name	Applicable for AM Testing?	Notes
			displacement or both. ASTM E1921 recommended for testing ferric steels that undergo cleavage fracture in the ductile-to-brittle transition. Notches may require post-processing (additional machining).
ISO 148-1:2009	Metallic materials -- Charpy pendulum impact test -- Part 1: Test method	Yes with Guidance	Break notched test piece with a single blow from a swinging pendulum. Mention of heated or cooled tests in a liquid or gaseous medium. Notches may require post-processing (additional machining).
ISO 148-3:2008	Metallic materials -- Charpy pendulum impact test -- Part 3: Preparation and characterization of Charpy V-notch test pieces for indirect verification of pendulum impact machines	Not a Test Method.	This is about sample prep.
ISO 12135:2002	Metallic materials -- Unified method of test for the determination of quasistatic fracture toughness	Yes with Guidance	Fracture toughness (resistance to crack extension) in terms of stress intensity factor (K), crack-tip displacement (δ), loading parameter (J) and resistance curves for homogenous metallic materials. Continually increasing force applied to sample by uniaxial tension or 3-point bending. Notches may require post-processing (additional machining).
ISO 12737:2010	Metallic materials -- Determination of plane-strain fracture toughness	Yes with Guidance	Similar to ASTM E399. Determines plane-strain fracture toughness (Klc) of homogeneous metallic materials using a specimen that is notched and pre-cracked by fatigue, and slowly increasing crack displacement force. Notches may require post-processing (additional machining).
ISO 14556:2000	Steel -- Charpy V-notch pendulum impact test -- Instrumented test method	Yes with Guidance	Similar to ISO 148 but for steels. Notches may require post-processing (additional machining).
ISO 22889:2007	Metallic materials -- Method of test for the determination of resistance to stable crack extension using specimens of low constraint	Yes with Guidance	ISO 12135 is the basic method. ISO 22889 applies to samples that are very small (i.e., have size sensitivity). May require post-processing.
ISO 27306:2009	Metallic materials -- Method of constraint loss correction of CTOD fracture toughness for fracture assessment of steel components	Not a test method	Converts fracture toughness from lab specimens to equivalent toughness for structural components. This is not a test method; it is a description for how to use method.
ASTM E0740	Practice for Fracture Testing with Surface-Crack Tension Specimens	Yes with Guidance	Covers design, prep, and testing of surface-crack specimens. Test is performed with continuously increasing force and excludes cyclic and sustained loadings. Determines residual strength of a specimen with a semi-elliptical or circular-segment fatigue crack. Requires post-processing to make initial pre-crack.
ASTM E1457	Test Method for Measurement of Creep Crack Growth Times in Metals	Yes with Guidance	Determines creep crack growth in metals at elevated temps using pre-cracked specimens subjected to static or quasi-static loading conditions. Requires post-processing to make initial pre-crack.

Standard Designation	Standard Name	Applicable for AM Testing?	Notes
ASTM E1681	Test Method for Determining Threshold Stress Intensity Factor for Environment-Assisted Cracking of Metallic Materials	Yes with Guidance	Appears to be basic method, requires environmental chamber. Requires post-processing to make initial pre-crack since most metal-based AM cannot produce a test specimen with a small-enough crack.
ASTM E2472	Test Method for Determination of Resistance to Stable Crack Extension under Low-Constraint Conditions	Yes with Guidance	For low-constraint conditions (crack-length-to-thickness and un-cracked ligament-to-thickness ratios are greater than or equal to 4) and that are tested under slowly increasing remote applied displacement. Requires post-processing to make initial pre-crack.
ASTM B769	Standard Test Method for Shear Testing of Aluminum Alloys	Yes with Guidance	Double-shear loading using a tension or compression testing machine. Requires post-processing in order to meet surface finish specification.
ASTM B565	Standard Test Method for Shear Testing of Aluminum and Aluminum-Alloy Rivets and Cold-Heading Wire and Rods	No	Metal wire, rivets, and rods are difficult to make via additive manufacturing
ASTM E0010	Test Method for Brinell Hardness of Metallic Materials	Yes with Guidance	Basic method for Brinell; tests at temperatures outside of nominal (10°C to 35°C) permitted. Requires post-processing in order to meet surface finish specification.
ASTM E0018	Test Methods for Rockwell Hardness of Metallic Materials	Yes with Guidance	Basic method for Rockwell; tests at temperatures outside of nominal (10°C to 35°C) permitted. Requires post-processing in order to meet surface finish specification.
ASTM E0140	Hardness Conversion Tables for Metals Relationship Among Brinell Hardness, Vickers Hardness, Rockwell Hardness, Superficial Hardness, Knoop Hardness, and Scleroscope Hardness	Not a test method.	Tables that convert hardness values of one type of tests to other types.
ASTM E0384	Test Method for Knoop and Vickers Hardness of Materials	Yes with Guidance	Basic methods for Knoop and Vickers; tests at temperatures outside of nominal (10°C to 35°C) permitted. Post-processing likely necessary for proper specimen surface roughness.
ASTM E0448	Practice for Scleroscope Hardness Testing of Metallic Materials	Yes with Guidance	Dynamic indentation hardness (drop and bounce). This is the basic method. Requires post-processing in order to meet surface finish specification.
ASTM B647	Standard Test Method for Indentation Hardness of Aluminum Alloys by Means of a Webster Hardness Gage	Yes with Guidance	Webster gage for Al only. This is a portable handheld device useful for *in-situ* measurements; good for production/quality control purposes. Not as sensitive as Rockwell or Brinell. Requires post-processing in order to meet surface finish specification.
ASTM B648	Standard Test Method for Indentation Hardness of Aluminum Alloys by Means of a Barcol Impressor	Yes with Guidance	Barcol gage for Al only. This is a portable handheld device useful for *in-situ* measurements; good for production/quality control purposes. Not as sensitive as Rockwell or Brinell. Requires post-processing in order to meet surface finish specification.

Standard Designation	Standard Name	Applicable for AM Testing?	Notes
ASTM B724	Standard Test Method for Indentation Hardness of Aluminum Alloys by Means of a Newage, Portable, Non-Caliper-Type Instrument	Yes with Guidance	Newage gage for Al only. Good for large pieces that can't be measured with a caliper-type instrument. Requires post-processing in order to meet surface finish specification.
ISO 4545-1:2005	Metallic materials -- Knoop hardness test -- Part 1: Test method	Yes with Guidance	Basic Knoop test like ASTM E0384. Requires post-processing in order to meet surface finish specification.
ISO 6506-1:2005	Metallic materials -- Brinell hardness test -- Part 1: Test method	Yes with Guidance	Basic Brinell test like ASTM E0010. Requires post-processing in order to meet surface finish specification.
ISO 6507-1:2005	Metallic materials -- Vickers hardness test -- Part 1: Test method	Yes with Guidance	Basic Vickers test like ASTM E0384. Requires post-processing in order to meet surface finish specification.
ISO 6508	Metallic materials -- Rockwell hardness test -- Part 1: Test method (scales A, B, C, D, E, F, G, H, K, N, T)	Yes with Guidance	Basic Rockwell test like ASTM E0018. Requires post-processing in order to meet surface finish specification.
ISO 14577	Metallic materials -- Instrumented indentation test for hardness and materials parameters -- Part 1: Test method	Yes with Guidance	This test considers the force and displacement of the indentation during plastic and elastic deformation; monitoring the complete cycle of increasing and removal of test force. Requires post-processing in order to meet surface finish specification.
ISO/TR 29381:2008	Metallic materials -- Measurement of mechanical properties by an instrumented indentation test -- Indentation tensile properties	Not a Test Method	Can derive tensile properties from indentation measurements via one of three methods (representative stress-strain, inverse FEA methods, or neural networks). Not a test method.
ASTM E0132	Test Method for Poisson's Ratio at Room Temperature	Yes with Guidance	Basic method, tension tests, requires extensometers; room temp only. Requires post-processing; specimens should be stress-relieved, isotropic and homogeneous.
ASTM E0290	Test Methods for Bend Testing of Material for Ductility	Yes	Bend testing for ductility of materials
ASTM E0837	Test Method for Determining Residual Stresses by the Hole-Drilling Strain-Gage Method	Yes with Guidance	Isotropic and linearly-elastic materials only; drill hole at center of strain rosette, and measure strains. If AM materials are anisotropic then this method may not be applicable.
ASTM E0915	Test Method for Verifying the Alignment of X-Ray Diffraction Instrumentation for Residual Stress Measurement	No	This is not a materials test method, it is a method for verifying the alignment of an X-ray machine.

Standard Designation	Standard Name	Applicable for AM Testing?	Notes
ISO 7438:2005	Metallic materials -- Bend test	Yes	Like ASTM E0290.
ISO 11531:1994	Metallic materials -- Earing test	No	Metal AM systems cannot easily make samples with thicknesses of 100 μm.
ISO/TR 14936:1998	Metallic materials -- Strain analysis report	Yes with Guidance	The standard applies to sheet but the thickness requirements are not specified. AM cannot make a very thin sheet.
ASTM E0003	Guide for Preparation of Metallographic Specimens	Not a test method	Not a mechanical test method, but important for micro-structural analysis.
ASTM E0007	Terminology Relating to Metallography	Not a test method	Terminology.
ASTM B348	Standard Specification for Titanium and Titanium Alloy Bars and Billets	Not a test method	Not a mechanical test method, but does contain useful specs for various materials that could be compared to those that are made additively.
ASTM B211	Standard Specification for Aluminum and Aluminum-Alloy Bar, Rod, and Wire	Not a test method	Not a mechanical test method, but does contain useful specs for various materials that could be compared to those that are made additively.

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METAL POWDER TESTING

Standard Designation	Standard Name	Applicable for AM?	Notes
ASTM B212	Standard Test Method for Apparent Density of Free-Flowing Metal Powders Using the Hall Flowmeter Funnel	Yes	
ASTM B213	Standard Test Methods for Flow Rate of Metal Powders Using the Hall Flowmeter Funnel	Yes	
ASTM B214	Standard Test Method for Sieve Analysis of Metal Powders	Yes with Guidance	Applicable for sieves with openings from 45 μm to 1000 μm. Not suitable for powders smaller than 45 μm.
ASTM B215	Standard Practices for Sampling Metal Powders	Yes	
ASTM B243	Standard Terminology of Powder Metallurgy	Not a test method	Terminology, not a test method.
ASTM B329	Standard Test Method for Apparent Density of Metal Powders and Compounds Using the Scott Volumeter	Yes	
ASTM B417	Standard Test Method for Apparent Density of Non-Free-Flowing Metal Powders Using the Carney Funnel	No	AM powders are typically free flowing, in fact they flow exceptionally well.
ASTM B527	Standard Test Method for Determination of Tap Density of Metallic Powders and Compounds	Yes	
ASTM B703	Standard Test Method for Apparent Density of Metal Powders and Related Compounds Using the Arnold Meter	Yes	
ASTM B761	Standard Test Method for Particle Size Distribution of Metal Powders and Related Compounds by X-Ray Monitoring of Gravity Sedimentation	Yes with Guidance	Test method works best "for the analysis of elemental tungsten, tungsten carbide, molybdenum, and tantalum. Other metal powders may be analyzed using this method with caution as to significance until actual satisfactory experience is developed." It appears that this only works for particles with sizes > 25 μm (and minimum size depends on species).

Standard Designation	Standard Name	Applicable for AM?	Notes
ASTM B822	Standard Test Method for Particle Size Distribution of Metal Powders and Related Compounds by Light Scattering	Yes	
ASTM B855	Standard Test Method for Volumetric Flow Rate of Metal Powders Using the Arnold Meter and Hall Flowmeter Funnel	Yes	
ASTM B923	Standard Test Method for Metal Powder Skeletal Density by Helium or Nitrogen Pycnometry	Yes	
ASTM B964	Standard Test Methods for Flow Rate of Metal Powders Using the Carney Funnel	Yes	
ASTM C177	Standard Test Method for Steady-State Heat Flux Measurements and Thermal Transmission Properties by Means of the Guarded-Hot-Plate Apparatus	Yes with Guidance	Method uses solid specimens, applicability to powder specimens is uncertain.
ASTM E161	Standard Specification for Precision Electroformed Sieves	Not a Test Method	This standard presents the specifications for precision electroformed sieves, and is not a test method.
ASTM E1409	Standard Test Method for Determination of Oxygen and Nitrogen in Titanium and Titanium Alloys by the Inert Gas Fusion Technique	No	This method will likely not work with metal powders since as part of the method the surface of the material must first be removed, either chemically or mechanically. Given the small diameters of AM powders, this is very impractical, and may completely consume the powder under test.
ASTM E1447	Standard Test Method for Determination of Hydrogen in Titanium and Titanium Alloys by Inert Gas Fusion Thermal Conductivity - Infrared Detection Method	No	This method requires solid form specimens.
ASTM E1461	Standard Test Method for Thermal Diffusivity by the Flash Method	No	This method requires homogeneous isotropic solid disc specimens.
ASTM E1569	Standard Test Method for Determination of Oxygen in Tantalum Powder by Inert Gas Fusion Technique	No	This method is only for tantalum powders.

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Standard Designation	Standard Name	Applicable for AM?	Notes
ASTM E2792	Standard Test Method for Determination of Hydrogen in Aluminum and Aluminum Alloys by Inert Gas Fusion	No	This method does not seem to be applicable to powder samples.

DISCUSSION AND NEXT STEPS

The analysis in this report shows that AM-specific materials standards for characterizing the properties of metal powders and metal parts do not have to be developed from scratch. Decades of powder property testing (born out of powder metallurgy processes) and mechanical property testing has resulted in a suite of existing standards that can form the basis for AM-specific materials standards. This report shows that while some of these existing standards are not appropriate for AM materials, many are, either in the current form or with some additional guidance or enhancements to adequately account for the characteristics of AM materials. Standards development organizations such as ASTM-I F42 can now use this information in the development of new AM-specific materials standards, especially new standards that are largely based on the existing standards contained in this report.

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[2] Cooke, A.L., Slotwinski, J.A., "Properties of Metal Powders for Additive Manufacturing: A Review of the State of the Art of Metal Powder Property Testing," NIST IR 7873, July, 2012