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Standard Guide for Additive Manufacturing — Test Artifacts — Accelerated Build Quality Assurance for Laser Beam Powder Bed Fusion (PBF-LB)[1]

This standard is issued under the fixed designation F3626; 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 guide illustrates a test specimen geometry and testing protocol that can be used to assess the quality of a metal powder bed fusion build cycle as it could be affected by major system errors (for example, corrupted calibration, disrupted inert gas flow, laser wear) severely affecting the quality of materials fabricated by laser beam powder bed fusion (PBF-LB).

1.2 This method is designed to interrupt the manufacturing process if poor material quality is identified through go/no-go torque/angle of twist measurements of witness coupons after each fabrication.

1.3 *Units*—The values stated in SI units are to be regarded as the standard. No other units of measurement are included in this guide.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E143 Test Method for Shear Modulus at Room Temperature

E1012 Practice for Verification of Testing Frame and Specimen Alignment Under Tensile and Compressive Axial Force Application

2.2 *ISO/ASTM Standard:*[2]

ISO/ASTM 52900 Additive manufacturing — General principles — Fundamentals and vocabulary

3. Terminology

3.1 *Definitions*—Terminology relating to additive manufacturing in ISO/ASTM 52900 should apply.

4. Summary

4.1 Directly after a build cycle is completed, witness specimens in their as-built state (prior to any post-processing) are torqued to fracture. The maximum value of torque and (if necessary) angle-of-twist are recorded. Identifying measurements of torque or angle-of-twist or both outside of a specified range of variation are cause to interrupt the production cycle until the additive manufacturing (AM) machine performance and resulting material quality is further evaluated.

5. Significance and Use

5.1 This guide describes the use of torque and angle-of-twist data as a preliminary acceptance criteria for a production run utilizing a previously qualified AM process through periodical or continuous evaluation. A torsion device (for example, torque wrench, instrumented lathe with torque readout) is used to break strategically placed torque specimens within the build volume in the as-built state to provide evidence of build health. If a round of tests from a production run is determined to fall outside of some criteria (for example: 3 standard deviations from the mean or other user defined criteria), additional qualification procedures should be performed to ensure the AM machine or process health are acceptable.

NOTE 1—It is advantageous to locate the specimen at the same build height and near-critical locations of the part or component being fabricated for the evaluation to be representative of the specific region.

5.2 This guide is not intended to replace rigorous qualification procedures and should only be considered as a preliminary acceptance criterion to increase confidence that an AM machine or process has not been significantly compromised.

[1] This guide is under the jurisdiction of ASTM Committee F42 on Additive Manufacturing Technologies and is the direct responsibility of Subcommittee F42.01 on Test Methods.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

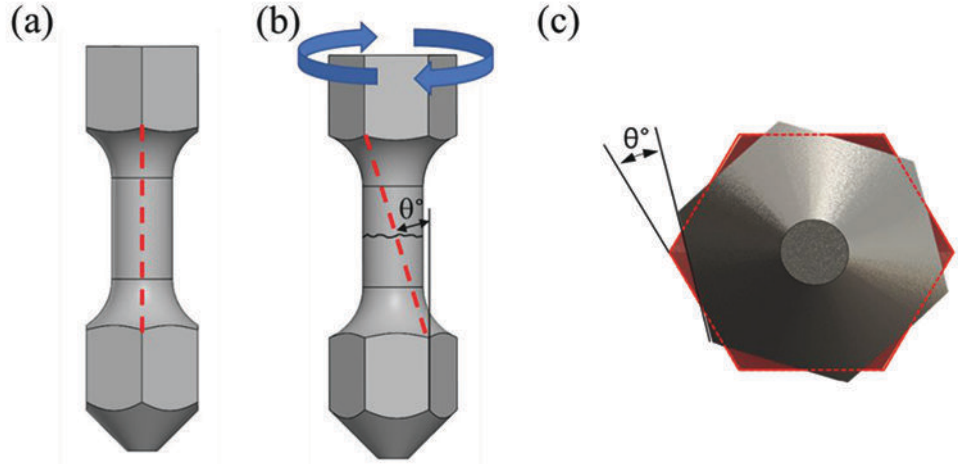

FIG. 1 Examples of Angle-of-Twist Measurements with (a) Showing a Reference Line along the Length of the Gage Section before Testing, (b) Angle-of-Twist Measurement along the Gage Section after Failure, and (c) Angle-of-twist from Top and Bottom Hex Heads after Failure

6. Procedure

6.1 *Specimen Preparation*—Test specimens should be tested in the as-built state. If angle-of-twist measurements are not provided by the torsion device, a reference line can be added in the vertical direction as shown in Fig. 1(a) to allow for the measurement of angle-of-twist after specimen failure, if required. The line may be scribed or marked using a permanent marker in a manner that allows for clear visibility after specimen fracture.

6.2 *Testing*—The use of the torsion fixture is not strictly controlled and left to the user. The torsion tool could be automated or hand driven and for both cases the torsion apparatus should be calibrated for the range of torque values appropriate for the material being tested. When performing the torsion tests, the rate of twist applied could impact the results and should be considered when utilizing the torsion device. For automated test systems the rate of twist should be established following recommendations in Test Method E143 and maintained for all tests. For hand-driven test methods where maintaining specified twist rates is not practical, the tester should attempt to apply a rate of twist that is approximately consistent between test runs. It is recommended that a minimum of 30 specimens be tested in the nominal condition to generate a distribution that subsequent test runs can be compared to.

6.3 *Alignment*—The use of a jig to maintain alignment when manually applying torque to the specimens should be used. An example of an alignment fixture for manual testing is provided in Appendix X1. Alignment of the twisting mechanism and the fixed end providing resistance to torsion should be carefully considered to minimize bending stresses.

NOTE 2—Alignment procedures are described for uniaxial loading in Practice E1012.

6.4 *Measurements*—In this test method, the measurement of maximum torque applied to failure is recorded. The angle-of-twist at fracture may also be useful as an indicator of unacceptable quality and may also be recorded if it is provided by the torsion device. If angle of twist is not provided and deemed useful, it can be measured from a reference line running along the length of the gage section as shown in Fig. 1(b). Measurement of the angle-of-twist can also be extracted from an adjacent face next to the scribed/marked reference line of the top and bottom head hex of the specimen as shown in Fig. 1(c). Another important indicator of poor build health is a change in failure mode as identified by the fracture plane. A significant change in the fracture plane angle could be indicative of a change in build health.

7. Report

7.1 *Test Specimen*—The build ID, material, specimen dimensions, and specimen orientation of the witness coupon as placed within the build volume should be recorded.

7.2 *Test Results*—The maximum torque should be recorded. If the angle of twist is measured, the maximum value should be recorded. Approximate fracture plane angle should be recorded. For automated testing where the twist rate is controlled the rate of twist applied should be recorded.

8. Interpretation of Results

8.1 The user should define failure of the inspection protocol based on the current understanding of the material quality that can be consistently measured using this method. The range of acceptable values should be determined by the user, as informed by internal production/performance requirements. Torque, angle-of-twist values, or fracture plane angles that fall outside of a specified acceptance range (for example, 3σ from the mean value, or deviating from a specified range as determined by a control chart) indicate a "failure" and trigger a pause in the production cycle until process health and material quality can be verified.

9. Keywords

9.1 additive manufacturing; quality assurance; torsion testing

APPENDIXES

(Nonmandatory Information)

X1. TEST SPECIMEN DESIGN

X1.1 Example of Test Specimen Design

X1.1.1 Geometry of the sample should incorporate characteristics that are identified as capable of providing critical process information that would indicate poor performance. Schematics of an example specimen geometry and dimensions are presented in Fig. X1.1. A smaller gage-length-to-diameter ratio required by Test Method E143 (gage length ≥ 4 diameters) is considered to minimize the specimen size to be more accommodating to sampling during production runs. The diameter of 6 mm (±0.125) is used to provide sufficient volume to be tested. Specimens can be easily stacked and removed from the build plate using an 11 mm (±0.125) box wrench near the base of the specimen.

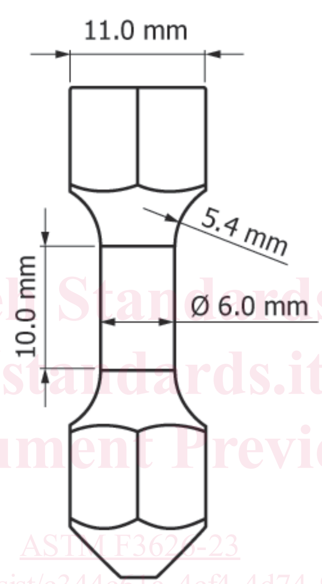

FIG. X1.1 Suggested Dimensions of the Torsion Specimen