



Material Property Characterization of Metallic Additive Manufacturing Alloys

1 Introduction

Note: Nothing in this standard supercedes applicable laws and regulations.

Note: In the event of conflict between the English and domestic language, the English language shall take precedence.

1.1 Purpose. Establish a system for material property characterization of Additively Manufactured (AM) metallic alloys, documenting the manufacturing process parameters, and providing the data required to simulate product performance in order to evaluate the suitability of a particular metallic AM material/process for a proposed application.

1.2 Applicability. This standard provides procedures for determining mechanical and thermo-physical properties of metallic alloys produced by AM methods using separately manufactured coupons within an AM build.

1.2.1 This standard provides direction on the sampling, test methods, and scope of data collected based on the intended application of that data. This standard gives general procedures and refers to specific requirements based on application Level. Generally, the levels are set to establish minimum data required for (Level 1) benchmark testing (e.g., to evaluate a new AM alloy, process, or quality standard), and/or (Level 2) Provide the data necessary for the creation of material cards for use in Computer Aided Engineering (CAE) models to simulate product performance. The tests, by application level, are described in CG6184: Additive Manufacturing Metal Material Characterization Test Matrix. Additionally, some product applications will necessitate the specification of specialty testing which will be included on a case by case basis. These categories are further defined in 3.2 and in CG6184: Additive Manufacturing Metal Material Characterization Test Matrix.

1.3 Remarks.

1.3.1 Recommended build locations for separately manufactured coupons within an AM build layout are identified. However, these locations may be modified based upon the needs of the part and the availability of adequate build volume space within an AM machine in which to fabricate test specimens with input and approval from the GM Design Release Engineer (DRE), GM Additive Manufacturing Application Engineer, and GM Product Program Materials Engineer.

1.3.2 This standard specifically applies to properties measured in coupons produced by metallic additive manufacturing processes. Use of this standard does not imply nor guarantee that the test coupon properties represent printed parts or any other region of the build layout. Some tests require further exposure prior to testing (such as high-temperature conditioning) which are known to affect mechanical properties. This exposure is required in order to simulate normal use and evaluate long term performance.

1.3.3 Process capability determination is beyond the scope of this standard.

1.3.4 Data generated under this standard does not constitute any express or implied warranty, including without limitation any warranty of merchantability or fitness for a particular purpose. Adherence to this standard does not absolve the Supplier of their responsibility to provide product that meets the part requirements as outlined in the Statement of Requirements (SOR), in the Three-Dimensional (3D) math data, on the print, or in other Engineering documents.

2 References

Note: Only the latest approved standards are applicable unless otherwise specified.

2.1 External Standards/Specifications.

IATF 16949

ISO 17025

ISO/ASTM 52921

2.2 GM Standards/Specifications.

GMW3059

GMW16705

2.3 Additional References.

- CG6184 Additive Manufacturing Metal Material Characterization Test Matrix
- CG6185 Additive Manufacturing Build Report (AM-BR)
- Statement of Development Work (SODW)
- Statement of Requirements (SOR)

3 Requirements

3.1 AM Machine Build Layout with Test Specimens.

3.1.1 The Supplier shall create a test coupon layout using AM industry standard and/or AM machine specific build preparation software for review and approval by the GM DRE, GM AM Application Engineer, GM Product Program Materials Engineer, and GM Supplier Quality Engineer (SQE) prior to fabricating the coupons. Test coupons shall be distributed throughout available AM machine build volume in order to document machine variability across buildable areas. For example, with a single laser system, Figure 1 shows nine (9) build zones in the XY plane and is further divided into three (3) Levels (A, B, C) in the Z direction. At a minimum, the coupons for each test shall be equally distributed between the center and the extremities of the buildable area. In a machine with a rectangular build area such as in Figure 1, this requires samples in the center of the build (zone 5 in Figure 1) and in each of the four (4) corners (zone 1, zone 3, zone 7, and zone 9 in Figure 1). Specific considerations for each of the data set Level 1, Level 2M, and Level 2T are included in CG6184: Additive Manufacturing Metal Material Characterization Test Matrix.

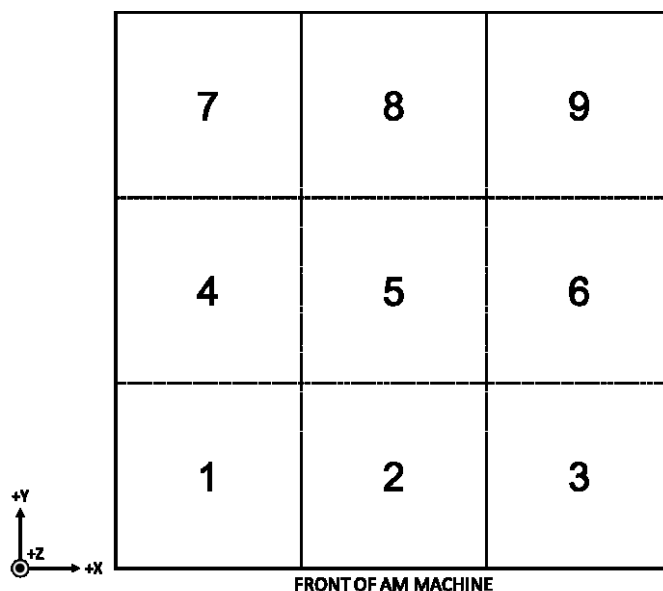


Figure 1: Top View of an AM Machine's Rectangular Build Platform, Schematically Divided into Nine (9) Equal-Sized Zones

3.1.2 For machines that use multiple lasers and have laser build overlap zones, test specimens must be distributed over the build volume just like single laser systems in 3.1.1. An additional requirement for multiple laser systems would be to include a tensile specimen built in the XY plane with the longitudinal axis of the test specimen perpendicular to the overlap zone with gage section of the tensile bar built within the overlap zone. A tensile specimen shall be printed in the XY plane to cover each laser overlap zone. Figure 2 shows an example of how to orient a tensile specimen in an overlap zone. Each machine setup and laser scan pattern is unique, the image shown in Figure 2 should be replicated across the build plate to cover each laser overlap zone at the discretions of the supplier.

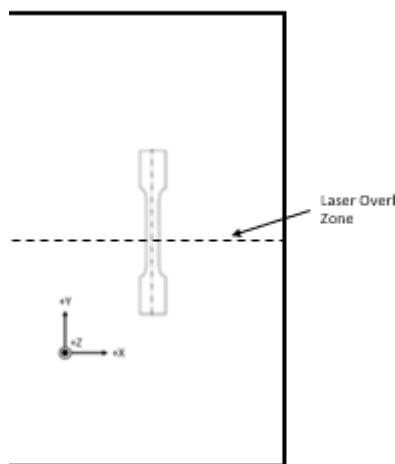


Figure 2: Example of Tensile Testing Layout in the XY Plane for Laser Overlap in Multi-Laser Systems

3.1.3 The AM Supplier shall uniquely identify each test coupon (i.e., serialize) and record the exact position of each individual coupon fabricated within the build chamber, governed by the X, Y, Z location of its Minimum Perimeter Bounding Box (L_x , W_y , H_z), its orientation (A, B, C) per ISO/ASTM 52921, and whether the sample resides in a laser overlap zone when the machine has multiple lasers. This information is to be included within CG6185: Additive Manufacturing Build Report (AM-BR) provided to the GM DRE, GM AM Application Engineer, GM Product Program Materials Engineer, and GM SQE. The AM Supplier may attach standard build layout output reports from build preparation software to the build report to meet this requirement, provided the exact same position and orientation information is provided.

3.1.4 The AM Supplier shall complete CG6185: Additive Manufacturing Build Report (AM-BR) which is required for traceability of each build to ensure data pedigree. It is critical to maintain accurate and complete records of each specimen produced to establish relationships between material, process, and properties for confidence in part performance and repeatability between consecutive/subsequent builds of identical parts.

3.1.4.1 Items required to be reported on the CG6185: Additive Manufacturing Build Report (AM-BR) include powder supplier, lot number, chemistry and properties; machine manufacturer, software version, model and serial number; complete process setting as identified by control file name version and date; build date, time and duration as well as notes as to deviations to build program noted during manufacture and post-build processing.

3.2 AM Test Specimen Requirements for Each Test Level. AM Supplier and the GM DRE, GM AM Application Engineer, GM Product Program Materials Engineer, and GM SQE shall agree to the build layout prior to the release of the PO. Suggested layouts for each level are provided in CG6184: Additive Manufacturing Metal Material Characterization Test Matrix. The proposed layout shall provide samples for each type of material property test from all of the zones within the build as near as practicable. This is required to estimate property uniformity across the entire build volume. Since the number and type of property tests to be performed will vary for the various product applications and testing levels, the build layout may not always conform to the suggested