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**Additive manufacturing of metals —
Finished part properties —
Orientation and location dependence
of mechanical properties for metal
parts**

*Fabrication additive de métaux — Propriétés des pièces finies —
Dépendance de l'orientation et de l'emplacement sur les propriétés
mécaniques pour la fusion sur lit de poudre métallique*

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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The document was prepared by Technical Committee ISO/TC 261, *Additive manufacturing*, in cooperation with ASTM Committee F42, *Additive Manufacturing Technologies*, on the basis of a partnership agreement between ISO and ASTM International with the aim to create a common set of ISO/ASTM standards on Additive Manufacturing, and in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 438, *Additive manufacturing*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

This second edition cancels and replaces the first edition (ISO/ASTM 52909:2022), of which it constitutes a minor revision.

The main changes are as follows:

- The third element of the title of the standard has been changed to "Orientation and location dependence of mechanical properties for metal parts";
- The title for [Figure A.6 b\)](#) has been corrected;
- Reference [\[12\]](#) in bibliography has been corrected.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

AM produced metallic parts are being intensively developed and used more widely today with an expected faster growth in near future. This document aims to support customers' needs to address specifics of the AM deposited parts – location and orientation dependent local properties and their variations over the part or deposition chamber.

This document provides a list of accurate terminologies and existing standards dedicated to mechanical testing of metallic materials, guidance on designation of coordinate systems and their application to AM specimens/parts designation, and recommendations on possibilities for local properties measurement.

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Additive manufacturing of metals — Finished part properties — Orientation and location dependence of mechanical properties for metal parts

1 Scope

This document covers supplementary guidelines for evaluation of mechanical properties including static/quasi-static and dynamic testing of metals made by additive manufacturing (AM) to provide guidance toward reporting when results from testing of as-built specimen or those excised from printed parts made by this technique or both.

This document is provided to leverage already existing standards. Guidelines are provided for mechanical properties measurements and reporting for additively manufactured metallic specimen as well as those excised from parts.

This document 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.

This document expands upon the nomenclature of ISO/ASTM 52900 and principles of ISO/ASTM 52921 and extends them specifically to metal additive manufacturing. The application of this document is primarily intended to provide guidance on orientation designations in cases where meaningful orientation/direction for AM cannot be obtained from available test methods.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 1099, *Metallic materials — Fatigue testing — Axial force-controlled method*

ISO 4506, *Hardmetals — Compression test*

ISO 6892-1, *Metallic materials — Tensile testing — Part 1: Method of test at room temperature*

ISO 12106, *Metallic materials — Fatigue testing — Axial-strain-controlled method*

ISO 12108, *Metallic materials — Fatigue testing — Fatigue crack growth method*

ISO 12135, *Metallic materials — Unified method of test for the determination of quasistatic fracture toughness*

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

ISO/ASTM 52921, *Standard Terminology for Additive Manufacturing—Coordinate Systems and Test Methodologies*

ASTM E8/E8M, *Standard test methods for tension testing of metallic materials*

ASTM E9, *Standard test methods of compression testing of metallic materials at room temperature*

ASTM E399, *Standard test method for linear-elastic plane-strain fracture toughness K_{Ic} of metallic materials*

ASTM E466, *Standard practice for conducting force-controlled constant amplitude axial fatigue tests of metallic materials*

ASTM E561, *Standard test method for k-r curve determination*

ASTM E606/E606M, *Standard test method for strain-controlled fatigue testing*

ASTM E647, *Standard test method for measurement of fatigue crack growth rates*

ASTM E1820, *Standard test method for measurement of fracture toughness*

ASTM E1921, *Test Method for Determination of Reference Temperature, T_o , for Ferritic Steels in the Transition Range*

ASTM E2472, *Standard Test Method For Determination Of Resistance To Stable Crack Extension Under Low-Constraint Conditions*

ASTM E2899, *Standard test method for measurement of initiation toughness in surface cracks under tension and bending*

ASTM F2971, *Practice for Reporting Data for Test Specimens Prepared by Additive Manufacturing*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO/ASTM 52900 and ISO/ASTM 52921 apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <https://www.electropedia.org/>

3.1 Definition

3.1.1

part location

location of the part/sample/specimen within the build volume

Note 1 to entry: The part location is normally specified by the x, y, z coordinates for the position of the geometric centre of the part's bounding box with respect to the build volume origin.

3.2 Abbreviations

The abbreviations used in this document, and in particular in [Figure A.1](#), are listed in [Table 1](#).

Table 1 — Abbreviations

Abbreviation	Signification	Comment
S	Start	Any base of the specimen or part that provides a surface upon which deposition starts (see Annex A).
E	End	Any area of a specimen or part that provides a surface upon which the specimen or part deposition ends (see Annex A).
M	Middle	Mid-plane of a specimen or part between start and end (see Annex A).
B	Both	Crack growth captures both start and end of build (see Annex A).
RD	Scan direction	This may or may not be the same throughout the build (see Annex A).

3.3 Acronyms

The acronyms used in this document for illustrating crack growth directions with respect to the build direction are listed in [Table 2](#) and illustrated in [Figure A.4](#).

Table 2 — Acronyms

Acronym	Signification
XY, YX, XZ, ZX, YZ, ZY	The first letter represents the direction normal to the crack plane and the second letter represents the expected direction of crack extension.
XYB	Indicates that crack growth captures both the start and end of the build in XY direction.
XZE	Indicates that the crack growth occurs from the end to the start of build in the XZ direction.
XZS	Indicates that the crack growth occurs from the start to the end of build in the XZ direction.
YXB	Indicates that crack growth captures both the start and end of the build in YX direction.
YZE	Indicates that the crack growth occurs from the end to the start of build in the YZ direction.
YZS	Indicates that the crack growth occurs from the start to the end of build in the YZ direction.
ZXM (or ZX1/2)	Indicates that crack growth occurs at the middle plane in ZX direction.

In situations in which a test specimen is created from other locations with respect to the start of the build (for example $\frac{1}{4}$, $\frac{3}{4}$, etc. distance from the start of the build) in the ZX direction, the notation used should indicate this location. For example, ZX1/4 indicates that testing was conducted in the ZX direction at a location one quarter of the way from the start of the build.

In situations where a test specimen (i.e. either a standard size or miniaturized specimen) is excised from a portion of the build volume (e.g. from an actual part) this should be noted. The terminology provided above should still be used to indicate the location of the excised sample with respect to the original build volume.

4 Summary of document

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4.1 The purpose of this document is to provide guidelines for test methods referenced in [Clause 2](#) and also use some of the terminologies defined in ISO/ASTM 52900 with metal additive manufacturing test specimens. Test specimens may be built directly to net-shape, or near net-shape, or excised from a part.

4.2 Standard geometries can be used based on the reference standards indicated in [Clause 2](#), however, direct testing of a part is a highly recommended practice for metal AM (See [A.6](#)).

4.3 In order to investigate and document orientation and location-specific mechanical properties, cut small-scale specimen from the relevant locations of the parts should be achieved. This document describes some principles to apply for the testing of various properties.

5 Significance and use

5.1 Although evaluation of mechanical properties of many additively manufactured materials can be conducted using the guidelines developed for conventional materials within existing testing standards, the coordinate systems and nomenclature specific to conventional materials testing (for example in ASTM E399, ASTM E647, ISO 12108 and ISO 12135) are not sufficient to be applicable across the full spectrum of specimens/parts produced by metal AM without causing confusion. This document is based on the nomenclature and principles of ISO/ASTM 52921 and extends them specifically to metal AM. The application of this document is primarily intended to provide guidance on orientation designations in cases in which meaningful orientation/direction for AM cannot be obtained from available test methods.

5.2 It shall be understood that the interpretations and guidelines in this document do not alter the validity requirements of test methods nor can this document be used to change the designation of “invalid” data (that is according to test methods) to a “valid” condition. This document is primarily concerned with cases in which it is not possible or practical to obtain meaningful data based on orientation/direction designations that are currently covered in standards developed for conventionally processed materials.

6 Procedure

The test procedure, analysis of test record, and calculations shall be made in accordance with [Table 3](#).

Table 3 — Standards to be applied according to test method

Test method	Referenced standards
tensile	ASTM E8/E8M, ISO 6892-1
compression	ASTM E9, ISO 4506
force controlled fatigue	ASTM E466, ISO 1099
strain-controlled fatigue	ASTM E606/606M, ISO 12106
linear elastic fracture toughness	ASTM E399
K_R curve determination	ASTM E561
non-linear fracture toughness	ASTM E1820, ASTM E1921, ASTM E2472, ASTM E2899, ISO 12135
fatigue crack growth	ASTM E647, ISO 12108

7 Report

7.1 General

The report shall include all the information required by test methods along with the location and orientation of the part or specimen, following the guidance provided in this document.

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7.2 Additional requirements

Since the scan strategy can have a significant effect on the mechanical properties of the parts, it is highly recommended that a specification of the scan strategy is included in the test report for metallic materials. There are a number of different strategies that can be used to manufacture a part. Some of the common scan strategies are included in [A.1](#). However, different types of scan strategies can be used depending on the type of AM machine used. Besides the scanning strategy, other process parameters that can have significant influence on the mechanical properties in the parts include, but are not limited to: preheating of the base plate, scanning speed, spot size, scan path overlaps and others. Because of variation in scan strategies typically used in AM, it is not possible to relate the orientation nomenclatures to the scan strategy directly. Conventional directions typically used for deformation processing have been used presently to define the axes and terminologies. Processing/post-processing parameters shall be reported in accordance with ASTM F2971.