International Standard

ISO/ASTM 52927

Additive manufacturing — General principles — Main characteristics and corresponding test methods

Fabrication additive — Principes généraux — Principales caractéristiques et méthodes d'essai correspondantes

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ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11

Email: copyright@iso.org
Website: www.iso.org

ASTM International
100 Barr Harbor Drive, PO Box C700
West Conshohocken, PA 19428-2959, USA
Phone: +610 832 9634
Fax: +610 832 9635
Email: khooper@astm.org
Website: www.astm.org

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Contents

Page

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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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This 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).

The first edition of this document cancels and replaces the first edition of ISO 17296-3:2014, which has been technically revised and merged with document ASTM F3122-14 and therefore re-designated and renamed to ISO/ASTM 52927.

The main changes are as follows:

— the main types of materials (metallic, polymers and ceramics) are separated in specific annexes following the main part containing general requirements;

— This document includes the contents of ASTM F3122-14 and merges them with (formerly) ISO 17296-3.

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

Additive manufacturing is a process of joining materials to make parts from 3D model data, usually layer upon layer, as opposed to subtractive manufacturing and formative methodologies. It is used to manufacture prototypes and production parts.

This document aims to offer recommendations and advice to machine manufacturers, feedstock suppliers, AM system users, part providers, and customers, to improve communication between these stakeholders concerning test methods.

This document has been developed within a set of consistent documents from terminology to test methods and data exchange.

Additive manufacturing processes require the selective application of thermo-physical and/or chemical mechanisms to generate the part. Thus, it is possible to produce parts with different characteristics, depending on the method and the process parameters used. However, complete testing of all characteristics for every part is neither cost-effective nor technologically feasible. Therefore, when formulating parts specifications, the nature and scope of testing is an important issue.

This document provides an overview of test methods for the characterization of the mechanical properties of metals, ceramics and polymers. It lists all the applicable standards based on specimens manufactured in a traditional process and gives the complement applicable when these specimens are manufactured by additive manufacturing.

At the time of publication of this document, the state of the art does not allow to describe all these specificities related to additive manufacturing. This document will therefore be regularly revised in order to incorporate the knowledge acquired in the field of additive manufacturing.

Additive manufacturing — General principles — Main characteristics and corresponding test methods

1 Scope

This document specifies the principal requirements applied to the testing of parts produced by additive manufacturing processes.

This document

— identifies quality characteristics for feedstock and parts and the corresponding test procedures,

— provides the specific procedures to build specimens using additive manufacturing process, and

— recommends the scope and content of test and supply agreements.

This document is aimed at machine manufacturers, feedstock suppliers, AM system users, part providers, and customers to facilitate the communication on main quality characteristics. It applies wherever additive manufacturing processes are used.

NOTE It is the intent to include, in future versions of this document, other characteristics such as thermal properties, electrical requirements and physical and physico-chemical properties based upon material types.

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 17295[1)], *Additive manufacturing — General principles — Part positioning, coordinates and orientation*

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

ISO/ASTM 52909, *Additive manufacturing — Finished part properties — Orientation and location dependence of mechanical properties for metal powder bed fusion*

ISO/ASTM 52915, *Specification for additive manufacturing file format (AMF) Version 1.2*

3 Terms and definitions

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

1) ISO 17295 cancels and replaces ISO/ASTM 52921-13 which is still available at: https://www.astm.org/f2921-13r19.html.

4 Main characteristics and corresponding test methods

4.1 General

This clause contains the general requirements and recommendations for the relevant tests, regardless of the material type.

For specific requirements and recommendations regarding tests and methods on specimens made of metallic materials, see Annex A.

For specific requirements and recommendations regarding tests and methods on specimens made of polymer materials, see Annex B.

For specific requirements and recommendations regarding tests and methods on specimens made of ceramic materials, see Annex C.

Each development and fabrication phase of a part has a specific purpose. The acceptance criteria for each quality characteristic are determined based on the part requirements and these can influence the choice of additive manufacturing process. This document develops the following main quality characteristics:

— feedstock:

  — size and shape: powder particle size distribution, mean particle size, morphology;

  — packing and transport properties within the AM system: apparent and tap density, flowability, pourability, filament cast and helix;

  — chemistry: chemical composition, ash/carbon content.

— parts:

  — surface requirements: appearance and colour;

  — geometric and dimensional requirements: profile, roughness, size, shape, orientation, position, dimensional tolerancing;

  — mechanical requirements: hardness, tensile strength, impact strength, compressive strength, flexural strength, fatigue strength, creep, ageing, frictional coefficient, shear resistance, and crack extension;

  — physical and chemical properties: density, chemical composition, grain size, imperfections (e.g. porosity, cracks).

NOTE The following other characteristics of parts have been identified but, due to the specificity of additive manufacturing, will be provided in a future version of this document:

— thermal properties (e.g. operating temperature range, dimensional stability in heat, softening temperatures, melting point, specific heat, thermal conductivity, and coefficient of linear thermal expansion);

— electrical requirements (e.g. disruptive strength, dielectric properties, magnetic properties, and electrical conductivity);

— physical and physico-chemical properties (e.g. internal flaws, flammability, toxicity, chemical composition, chemical resistance, water absorption, crystalline structure, suitability for food, biocompatibility, sterility, photostability, translucence, solidification point, glass transition, and corrosion).

4.2 Selection criteria

Testing categories given in Table A.1, Table B.1 and Table C.1 shall be applied to guide the relation between customer and part provider, applicable for metallic parts, polymer parts and ceramic parts respectively.

The choice of a testing category shall be subject to agreement between customer and part provider.

NOTE Test categories are defined according to the application and the type of material.

5 Part and process testing — Specifications and quality criteria

5.1 General

The quality of a part is determined by comparing its characteristics against an agreed set of requirements. The requirements shall be precisely specified within the purchase specification and include suitability for the intended application in conjunction with any specified geometric, material or performance requirements. Inspection and testing of the part and associated test specimens are performed to demonstrate compliance with the requirements.

NOTE 1 ISO/ASTM 52901 provides guidance on requirements for purchase specifications.

NOTE 2 A definition or discussion that lacks clarity can result in considerable additional costs and delays and/or inferior quality.

The form of specifications depends on the application, the nature of the features being tested, and the materials used. Specifications may also vary within one part (e.g. critical mass). Some intrinsic properties depend on the choice of material and the technology used. Relevant test procedures shall be stipulated and adhered to.

5.2 Testing the feedstocks

The condition of the feedstock can have a significant impact on the part properties. Significant variations can arise due to storage and reuse of the feedstock and variations between batches. Essential data relating to the feedstock shall be provided by the feedstock supplier.

5.3 Monitoring the process

All additive manufacturing processes are computer-assisted. This allows for the recording and statistical analyses of certain process-related data, such as process parameters and - in most cases - certain environmental conditions, which can be recorded at specified time intervals. The need to monitor the process depends on the required or anticipated reproducibility of the process and part quality for each application. Process monitoring can also be required by customer.

Where the process stability is assessed, at different intervals, consideration shall be given to selecting monitoring points where variables are consistent (e.g. constant geometry) such that any identified variations are indicative of process instability (e.g. mechanical properties, geometric features, chemical composition).

Test specimens for process monitoring should be as representative as possible compared to the part. Complementary test specimens can be used to improve the testing of dimensional accuracy, reproduction accuracy and process stability. The shape of test specimen and the nature and frequency of testing shall be specified in agreement between the customer and part provider for each application in accordance with applicable standards.

5.4 Testing the part

Relevant testing standards are given in Table A.2 for metallic parts, Table B.2 for polymer parts and Table C.2 for ceramic parts.

Tests and their acceptance criteria shall be set out in the purchase specification or agreement between customer and part provider prior to manufacturing.

Annex A
(normative)

Test methods for metallic materials

A.1 General

Testing categories given in Table A.1 to Table A.4 can be applied to guide the relation between customer and part provider, applicable for metallic parts. These testing categories define the level of criticality of the parts:

— H: tests for highly engineered or safety critical parts (e.g. safety valve);

— M: tests for functional parts that are not safety critical (e.g. flow conditioner to improve performance);

— L: tests for design or prototype parts.

For each testing category, the characteristics indicated (+) shall be considered, the characteristics indicated (o) are recommended for consideration, and the characteristics indicated (-) are not applicable.

A.2 Surface requirements

Surface requirements for metallic parts are given in Table A.1.

Table A.1 — Surface requirements for metallic parts

	Surface requirement		
	Appearance	**Surface texture**	**Colour**
H	o	+	-
M	o	+	-
L	o	o	-

A.3 Geometric and dimensional requirements

Whilst geometric dimensioning and tolerance (GD&T) and/or geometrical product specifications (GPS) requirements shall be met for all categories, tighter requirements are typically specified for parts with higher criticality levels.

A.4 Mechanical requirements

Depending on the class of the part and the technical specification, the mechanical tests shall be adapted accordingly

A.5 Physical and chemical property requirements

A.5.1 General

The physical and chemical property requirements shall be adapted according to the class of the part.

A.5.2 Specificities for additive manufacturing

A.5.2.1 General

No requirement or recommendation at the date of publication of this document.

A.5.2.2 Processing

No requirement or recommendation at the date of publication of this document.

A.5.2.3 Post-processing

In order to be representative, post-processing activities applied to the part that affect the material properties shall also be applied to the test specimens.

A.6 Performance criteria and quality characteristics

A.6.1 General

Table A.2 contains the list of main quality characteristics required from both materials and metallic parts produced by additive manufacturing, with recommended International Standards. Due to the current maturity of additive manufacturing technologies, development work is in progress to define and describe specific characteristics, but in the interim it is recommended to use the standards stated within this Annex.

Reporting guidelines should be followed in accordance with each applicable standard mentioned in Table A.2.

NOTE The test is performed with the heat treatment corresponding of the final use of the part.

A.6.2 Specificities for additive manufacturing

Due to the possibility for anisotropic behaviour in metallic parts produced by additive manufacturing processes, additional information shall be included in the reports.

NOTE 1 ISO 17295 gives guidance for location and orientation of parts and specimens within the build volume of the additive manufacturing system. ISO/ASTM 52915 provides for location and orientation of parts within a multi-part assembly (constellation) that can impact the orientation of the print on the build plate of an additive manufacturing system.

Specificity of additive manufacturing (e.g. anisotropy, test direction vs building direction) shall be indicated for all measured characteristics and shall be reported in the test report. Test results shall be reported by using the orientation and location specified in ISO 17295.

Restrictions exist for some non-homogenous materials, such as porous materials, lattice structures, etc. when using mechanical testing results.

If the metallic parts are produced using a powder bed fusion process, the specimens shall comply with the requirements of ISO/ASTM 52909.

More information on the method to characterize metallic powders are provided in ISO/ASTM 52907.

More information about NDT test methods are available in ISO/ASTM TR 52905 and ASTM E3166.