INTERNATIONAL STANDARD

ISO/ASTM 52908

First edition
2023-11

Additive manufacturing of metals — Finished part properties — Post-processing, inspection and testing of parts produced by powder bed fusion

Fabrication additive de métaux — Propriétés des pièces finies — Post-traitement, inspection et essais des pièces produites par fusion sur lit de poudre

Reference number
ISO/ASTM 52908:2023(E)

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Published in Switzerland

Contents

Page

Foreword

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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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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 Objective 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.

Introduction

As with conventional manufacturing processes (e.g. casting and milling), metallic parts produced by additive manufacturing technologies have critical-to-quality characteristics. These characteristics include density, strength, hardness, surface quality, dimensional accuracy, residual stresses, absence of cracks, voids, and structural homogeneity, which are typically tested in additively manufactured components. The quality of additively manufactured components is essential for functional components produced on an industrial scale. Thus, it is necessary to qualify additive manufacturing processes according to uniform criteria and to apply standardised in-process and post-process testing.

Additive manufacturing of metals — Finished part properties — Post-processing, inspection and testing of parts produced by powder bed fusion

1 Scope

This document specifies requirements for the qualification, quality assurance and post processing for metal parts made by powder bed fusion.

This document specifies methods and procedures for testing and qualification of various characteristics of metallic parts made by additive manufacturing powder bed fusion processes, in accordance with ISO/ASTM 52927, categories H and M.

This document is intended to be used by part providers and/or customers of parts.

This document specifies qualification procedures where appropriate to meet defined quality levels.

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 3369:2006, *Impermeable sintered metal materials and hardmetals — Determination of density*

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

ISO 18265, *Metallic materials — Conversion of hardness values*

ISO 21920-1, *Geometrical product specifications (GPS) — Surface texture: Profile — Part 1: Indication of surface texture*

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

ISO/ASTM 52907, *Additive manufacturing — Feedstock materials — Methods to characterize metal powders*

ISO/ASTM 52920, *Additive manufacturing — Qualification principles — Requirements for industrial additive manufacturing processes and production sites*

ISO/ASTM 52927, *Additive manufacturing — General principles — Main characteristics and corresponding test methods*[1)]

ISO/ASTM 52928, *Additive manufacturing — Feedstock materials — Powder life cycle management*[2)]

ISO/ASTM/TS 52930, *Additive manufacturing — Qualification principles — Installation, operation and performance (IQ/OQ/PQ) of PBF-LB equipment*

ANSI/ASME Y14.5, *Dimensioning and Tolerancing*

ASTM B311, *Standard Test Method for Density of Powder Metallurgy (PM) Materials Containing Less Than Two Percent Porosity*

1) Under preparation. Stage at the time of publication: ISO/DIS 52927:2023.

2) Under preparation. Stage at the time of publication: ISO/DIS 52928:2023.

ASTM B962, *Standard Test Methods for Density of Compacted or Sintered Powder Metallurgy (PM) Products Using Archimedes' Principle*

ASTM E8/E8M, *Standard Test Methods for Tension Testing of Metallic Materials*

DIN 50125, *Testing of metallic materials — Tensile test pieces*

3 Terms and definitions

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

ISO and IEC maintain terminological 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
grain size
average grain size in the metallurgical structure when viewed in cross-section

4 Abbreviations

The abbreviations listed in Table 2 are used throughout this document.

Table 2 — Abbreviations

AM	additive manufacturing
EDX	energy-dispersive X-ray spectroscopy
SEM	scanning electron microscope
CAD	computer aided design
NDT	non-destructive testing
QA	quality assurance
COC	certificate of conformance
ASL	approved supplier list
HIP	hot isostatic pressing
EDM	electrical discharge machining
PBF	powder bed fusion

5 Qualification

5.1 General

The manufacturer shall demonstrate the capability to produce AM parts to the requirements given in the purchase specification. The inspection and testing described in the following clauses are performed and assessed using the methods and acceptance criteria stated in the purchase specification.

NOTE Inspection and testing methods are specified at the design stage, as described in ISO/ASTM 52927, and are in accordance with the relevant standards and regulations that are required for the conformity of that part.

5.2 Part validation

Validation that the part produced complies with the requirements of the purchase specification shall be captured in a qualification record. A typical 'qualification record', shall consist of:

— technical documentation relating to part(s) produced;

— facility documentation;

— quality assurance (QA) documentation.

5.3 Technical documentation relating to part(s) produced

The technical documentation relating to part(s) produced shall contain:

— part specification in accordance with ISO/ASTM 52927, which includes inspection methods, associated plans, acceptance criteria, and representative quality indicators where applicable;

— feedstock specification, test results and declaration of conformity in accordance with ISO/ASTM 52907;

— material specification (consolidated product material properties specification);

— manufacturing plan (e.g. see ISO/ASTM 52904);

— records of destructive and non-destructive testing;

— inspection record for the part (in accordance with the purchase specification);

— other documentation required by the purchaser, regulation or product standard (e. g. material identification, labelling, product instructions).

NOTE 1 For some materials, there is a singular specification that controls both feedstock and material properties, such as metallurgical and mechanical properties.

NOTE 2 Technical specifications for metal powders are addressed in ISO /ASTM 52907.

5.4 Facility documentation

5.4.1 Additive manufacturer documentation requirements

Facility documentation requirements for industrial manufacturing sites are addressed in ISO/ASTM 52920.

For the purpose of this document, an outline of the relevant manufacturing plant and equipment shall be provided at the request of the buyer. The outline shall include the major items of equipment used for post processing, inspection, and testing (including details of geographical location).

The following facility documentation shall be provided:

— records of equipment qualification in accordance with ISO/ASTM TS 52930;

— records of powder lifecycle management in accordance with ISO/ASTM 52928.

The requirements in this subclause are met where a quality management system is in place (see 5.5).

5.4.2 Subcontractor documentation requirements

Where the manufacturer subcontracts post-processing and/or testing activities, the manufacturer shall be able to indicate the conditions under which these activities are subcontracted and shall provide a purchase specification for the operations involved.

The manufacturer shall assess and approve the subcontractors for their capability to perform the subcontracted activity to the required quality level.

5.5 Quality assurance documentation

General QA documentation requirements are met by introducing a quality management system (e.g. ISO 9001 or ISO 13485).

Additive manufacturing QA documentation requirements shall be in accordance with ISO/ASTM 52920.

6 Post processing

6.1 General

Post-processing consists of activities performed after the completion of a build cycle but prior to final inspection activities.

NOTE Intermediate inspection can be performed between post-processing activities.

Post-processing operations are typically performed to achieve the desired material properties, final geometry and surface finish, and can include the following steps:

— post-build activities (e.g. cool down, declamping, removal from the AM machine, part cleaning);

— thermal treatment;

— separation from the build platform and support structures;

— surface finishing.

At the post-processing stage there are also several system-based operations performed (i.e. not related to the AM part) to prepare for subsequent builds. These activities are covered within other standards and include:

— recovery and reprocessing of unfused powder (in accordance with ISO/ASTM 52928);

— AM equipment cleaning and maintenance (in accordance with ISO/ASTM 52920).

6.2 Post-build activities

Following successful completion of the build, the chamber is allowed to cool and unfused powder is recovered from the build chamber. Once the build chamber is opened, the build platform fasteners can be removed, and care shall be taken to avoid deflection, which could induce cracking, due to the build-up of any residual stresses within the build. (see ASTM F3530-22)

Once the build assembly is removed from the AM machine, it can be cleaned and visually inspected (e.g. for imperfections, discolouration, separation from support structures). Loose powder that remains on the build assembly after exposure to atmosphere (i.e. no longer within an inert environment) can be removed by various methods (e.g. compressed gas, brushing, vacuum, sonic or ultrasonic cleaning methods). Loose powder removed at this stage shall be considered to be waste powder and disposed of safely.

For some non-reactive materials, loose powder that is removed within a controlled environment (e.g. glovebox, automatic depowdering unit), can also be reused where allowed by the manufacturer's procedures, subject to contamination and traceability controls.

6.3 Thermal treatment

6.3.1 General

Although it is not mandatory to apply any thermal treatment to additively manufactured parts, the following points should be considered.

NOTE Thermal treatment is executed after it is ensured that all powder located in internal channels is removed.

6.3.2 Reducing residual stresses

The build-up of successive layers with rapid heating and cooling generates residual stresses in the component, which can lead to distortion. Where used, support structures help to minimise this distortion by providing stiffness within the build assembly to resist deflection due to these residual stresses. Therefore, the build assembly is typically stress relieved prior to the removal of any support structures, although this is not mandatory. The release of thermal stresses can lead to distortion, over a short or prolonged period of time. Furthermore, local stress peaks can occur in the part, which can significantly reduce fatigue strength and lead to premature cracking. Stress-relief reduces stresses in the component in a controlled manner after manufacture, thereby preventing distortion.

6.3.3 Reducing anisotropy

The as-built part can exhibit anisotropy, which may be normalised to minimise the orientation and location dependence on the mechanical properties of the formed material and achieve the final mechanical property requirements.

NOTE ISO/ASTM 52909 includes supplementary guidelines for the evaluation of finished part properties, including orientation and location dependence, for metal parts produced by powder bed fusion.

6.3.4 Prepare material for mechanical post-processing

Processes such as annealing can reduce the hardness of the as-built material to facilitate subsequent machining operations. Annealing, followed by ageing, can reduce intergranular corrosion and cracking.

6.3.5 Densification

Hot isostatic pressing (HIP) can improve material properties through the reduction of porosity and anisotropy.

NOTE 1 ASTM A 1080/A 1080M provides a standard practice for hot isostatic pressing of steels, stainless steels and related alloys.

The thermal treatment specified depends on the material and desired mechanical properties, as defined within the material specification and agreed between manufacturer and purchaser.

NOTE 2 ASTM F 3301a includes details of thermal treatments for various metals produced by powder bed fusion.

Test specimens used for destructive testing shall be representative of the part and therefore be subjected to the same thermal post-processing operations as the part they represent.

6.3.6 Annealing and aging

Annealing, followed by ageing, can also enable grain boundary carbides to enter into solution and thus prevent unacceptable grain boundary carbide precipitation, which can lead to intergranular corrosion and cracking.