SLOVENSKI STANDARD
oSIST prEN ISO/ASTM 52904:2020

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Aditivna proizvodnja - Značilnosti in tehnične lastnosti procesa - Ravnanje pri procesu fuzije plasti kovinskih prašnih delcev za doseganje kritičnih aplikacij (ISO/ASTM 52904:2019)

Additive manufacturing - Process characteristics and performance - Practice for metal powder bed fusion process to meet critical applications (ISO/ASTM 52904:2019)

Additive Fertigung - Prozessanforderungen und Qualifizierung - Verwendung des pulverbettbasierten Schmelzens von Metallen bei kritischen Anwendungen (ISO/ASTM 52904:2019)

Fabrication additive - Caractéristiques et performances du procédé - Pratique du procédé de fusion sur lit de poudre métallique en vue de répondre aux applications critiques (ISO/ASTM 52904:2019)

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Additive manufacturing — Process characteristics and performance — Practice for metal powder bed fusion process to meet critical applications

Fabrication additive — Caractéristiques et performances du procédé — Pratique du procédé de fusion sur lit de poudre métallique en vue de répondre aux applications critiques

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ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Fax: +41 22 749 09 47
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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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 documents should be noted (see www.iso.org/directives).

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This document was prepared by ASTM Committee F42, *Additive Manufacturing Technologies* (as ASTM F3303-2018), and drafted in accordance with its editorial rules. It was assigned to Technical Committee ISO/TC 261, *Additive manufacturing*, and adopted under the "fast-track procedure".

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.

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Designation: F3303 – 2018

Standard for Additive Manufacturing – Process Characteristics and Performance: Practice for Metal Powder Bed Fusion Process to Meet Critical Applications[1]

This standard is issued under the fixed designation F3303; 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 practice describes the operation and production control of metal powder bed fusion (PBF) machines and processes to meet critical applications such as commercial aerospace components and medical implants. The requirements contained herein are applicable for production components and mechanical test specimens using powder bed fusion (PBF) with both laser and electron beams.

1.2 *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.*

1.3 *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. Normative References

2.1 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.

2.2 *ASTM Standards:*[2]

E8/E8M Test Methods for Tension Testing of Metallic Materials

E11 Specification for Woven Wire Test Sieve Cloth and Test Sieves

E2910 Guide for Preferred Methods for Acceptance of Product

F2924 Specification for Additive Manufacturing Titanium-6 Aluminum-4 Vanadium with Powder Bed Fusion

F2971 Practice for Reporting Data for Test Specimens Prepared by Additive Manufacturing

F3049 Guide for Characterizing Properties of Metal Powders Used for Additive Manufacturing Processes

F3122 Guide for Evaluating Mechanical Properties of Metal Materials Made via Additive Manufacturing Processes

2.3 *ISO/ASTM Standards:*[2]

52900 Standard Terminology for Additive Manufacturing – General Principles – Terminology

52921 Terminology for Additive Manufacturing – Coordinate Systems and Test Methodologies

2.4 *ISO Standards:*[3]

4497 Metallic powders – Determination of particle size by dry sieving

D6892–1 Metallic materials – Tensile testing at ambient temperature

D6892–2 Metallic materials – Tensile testing – Part 2: Method of test at elevated temperature

8573-1 Compressed air – Part 1: Contaminants and purity classes

9001 Quality management systems – Requirements

9044 Industrial Woven Wire Cloth – Technical Requirements and Testing

13320 Particle size analysis – Laser diffraction methods

13485 Medical devices – Quality management systems – Requirements for regulatory purposes

2.5 *Other Standards:*

ANSI/ASQC C1-1996 Specification of General Requirements for a Quality Program[4]

AS9100 Quality Management Systems - Requirements for

[1] This practice is under the jurisdiction of ASTM Committee F42 on Additive Manufacturing Technologies and is the direct responsibility of Subcommittee F42.05 on Materials and Processes, and is also under the jurisdiction of ISO/TC 261.

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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.

[3] Available from International Organization for Standardization (ISO), ISO Central Secretariat, BIBC II, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, http://www.iso.org.

[4] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

Aviation, Space, and Defense Organizations[5]

3. Terms and Definitions

3.1 For the purposes of this document, the terms and definitions given in Specification F2924, ISO/ASTM 52900, ISO/ASTM 52921, Guide E2910, and the following apply.

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

– IEC Electropedia available at http://www.electropedia.org/

– ISO Online browsing platform available at https://www.iso.org/obp

3.3 *Definitions:*

3.3.1 *build programmer*—person responsible for programming a build including part orientation, part(s) nesting, and the application of critical build parameters.

3.3.2 *machine operator*—person responsible for initiating builds and turning over machines, which includes, but is not limited to, loading feedstock powder, loading build platforms, removing completed builds and routine machine cleaning and filter changes.

3.3.3 *recoater blade*—portion of the machine that comes in contact with and spreads feedstock across the build area.

3.3.3.1 *Discussion*—The recoater blade may also be called a rake, recoater, roller, or brush.

4. PBF Material Identification

4.1 Material covered by this document (that is, powder and consolidated part/PBF machine input and output), shall be identified by specification callouts including, but not limited to, the following:

4.1.1 Alloy designation according to requirements; where no alloy designation exists, the chemical composition shall be listed.

4.1.2 *Powder type*—Virgin, used, blend or mix.

4.1.3 *Surface finish*—As built, media blasted, supports removed by machining or manual deburring, in accordance with specification callouts, or any combination of the latter finish types.

4.1.4 *Dimensional tolerances*—In accordance with specification callouts or PBF machine output capability.

NOTE 1—4.1.3 and 4.1.4 apply to consolidated parts only.

5. Feedstock and Powder Batches

5.1 The material supplier shall package the powder in containers capable of preventing moisture from penetrating the containers. No other materials including desiccant bags, labels, or tags shall be placed inside the containers in contact with the powder.

5.2 All feedstock shall have a certificate of conformance from the material supplier indicating that the feedstock meets the purchase specification requirements.

5.3 Metal powder shall be purchased from an approved material supplier on the QMS (Quality Management Systems (see 6.3)), an ASL (Approved Supplier List), or a customer-directed material supplier. Powder shall be verified for conformance to the material specification. Third-party certification of powder may be used. Guide F3049, ISO 4497, and ISO 13320 provide guidance on the measurement of particle size distribution.

5.4 The component manufacturer shall have a feedstock material specification against which feedstock can be ordered and tested. Feedstock used for qualification purposes may require a limited reused powder such that the powder utilized for one qualification build to another remains as consistent as practical (for example, by using virgin feedstock as the purpose of the qualification is to check the consistency of machine operation over time).

5.4.1 A feedstock material specification shall include, but not be limited to, chemical composition, particle size distribution, and manufacturing methodology.

5.5 Powder shall be stored in environmental containment to prevent contamination and moisture absorption.

5.6 Used powder is allowed (see 7.1.1.4.1 for requirement on used powder that is processed with ceramic recoater blade).The proportion of virgin to used powder shall be recorded and reported for each production run on the manufacturing plan (Section 10). Automated powder feed systems may not allow the proportion of virgin to used powder to be accurately measured and recorded on the manufacturing plan. In such systems the feedstock shall be considered used powder. The maximum number of times that used powder can be consumed as well as the number of times any portion of a powder lot can be processed in the build chamber shall be validated in accordance with 7.3. After a build cycle, any remaining used powder may be blended with virgin powder to maintain a powder quantity large enough for the next build cycle. The critical powder attributes impacting qualifications in accordance with 7.3 shall be analyzed regularly. All used powder shall be sieved with a sieve having a mesh size appropriate for removing any agglomerations. All powder sieves used to manufacture parts shall have a certificate of conformance that they were manufactured to ISO 9044 or Specification E11.

6. Personnel Requirements

6.1 Personnel competency requirements in ISO 13485 shall apply, including appropriate education, training, skills, and experience.

6.2 Manufacturing manager, machine operator, or build programmer (as defined in Section 3) shall be trained by the machine manufacturer or qualified agency for PBF machine hardware and software, where appropriate.

6.3 On machines that are qualified in accordance with 7.3, the machine manufacturer shall provide for continuing education as new hardware and software releases are purchased and implemented. Records of such training shall be maintained in employee training folders in accordance with a local Quality Management System (for example, ISO 9001, ISO 13485,

[5] Available from SAE International (SAE), 400 Commonwealth Dr., Warrendale, PA 15096, http://www.sae.org.

ASQC C1, AS 9100) for reference with customers or outside regulatory agencies, or both.

6.4 Only persons trained in accordance with 6.1 and 6.2 shall be considered qualified personnel.

7. Qualification

7.1 Pre-Build Checks

7.1.1 This section describes pre-build checks applied to all builds independently of their purpose (for example, periodic preventive maintenance, machine/process qualification, scaling/calibration builds, etc.). The pre-build checks shall include, but not be limited to:

7.1.1.1 *Maintenance record*—Check the maintenance record (see 7.2.2) and qualification status of machine (see 7.3).

7.1.1.2 *Required feedstock quantity*—Verify that required quantity for build is available.

7.1.1.3 *Build platform (also known as build plate or start plate)*—Ensure that the build platform serial number matches the one specified in the manufacturing plan (Section 10). The build platform shall be free from any surface contamination (including dirt, oil, or grease), and any form of defects resulting in an inconsistent powder bed. Build platforms shall be visually inspected and rejected for any obvious damage or non-conformity. Platform shall be installed in PBF machine using the proper QMS instructions.

7.1.1.4 *Recoater blade*—Ensure material compatibility with feedstock and consolidated material, cleanliness, absence of any form of defects resulting in an inconsistent powder bed, and consistent recoater clearance to the build platform at all locations in conjunction with 10.1.2.2.

7.1.1.4.1 Before initiating a PBF machine build, the recoater blade shall be inspected. The machine operator shall visually inspect and verify that the recoater blade is free from any chips, scratches, debris or deformities and installed in accordance with the machine manufacturer's recommendations. Only qualified materials shall be used on a PBF machine in accordance with 7.3. The chemical composition of the recoater blade shall be recorded on the manufacturing plan. PBF machines with polymer recoater blade shall be validated to show the polymer does not contaminate the feedstock by analyzing and pairing the chemical composition of powder feedstock and that of consolidated part. When inspection is not possible due to installation location, polymer recoater blades should be replaced with a new one after the completion of each build. Used feedstock processed with a ceramic recoater blade shall not be further processed. This section does not apply to PBF machines that only use rollers to spread the powder.

7.1.1.5 *Auxiliary systems (for example, shield gas, filters)*—Ensure correct type, proper function, and cleanliness of auxiliary systems (grade 4.8 minimum for shielding gas).

7.1.1.6 *Chiller temperature and flow of heat transfer fluid*—Check chillier temperature and flow of heat transfer fluid (if applicable, in accordance with the machine manufacturer's recommendation). Record chiller temperature on the manufacturing plan prior to every build cycle.

7.1.1.7 *Build chamber environment*—For machines that have protective gas filters there shall be no flow restriction during machine operation.

7.1.1.8 *External gas*—Gas type and flow shall meet the machine manufacturer's recommendation for the feedstock.

7.1.1.9 *Feedstock and baseline machine and process parameters*—Ensure that feedstock and parameters (for example, beam offset, beam parameters, input energy) are correct for build.

7.1.1.10 *Beam power verification*—The instructions for checking the laser or electron beam power shall be determined by the component manufacturer and recorded in a QMS document. Laser or electron beam power shall be measured and documented in the manufacturing plan immediately prior to build initiation and following the completion of all builds.

7.1.1.11 *Part files, orientation and location*—All part files related to the digital geometry (for example, STL, AMF) shall match the intended revision, the part orientation and location on the build platform, as stated in the manufacturing plan.

7.1.1.12 *Machining stock*—Ensure that machining stock is added to part(s) in accordance with manufacturing plan.

7.1.1.13 *Parts nesting*—The build platform part nesting, as displayed by the PBF build processor software, shall be recorded (for example with a screen shot).

7.2 *Periodic Preventive Maintenance (Third Party Accreditation)*

7.2.1 PBF machines shall undergo preventive maintenance (PM) by trained technicians in accordance with the machine manufacturer's recommended frequency (for example, minimum of every six months or after a given number of build hours). PBF machines where preventive maintenance has lapsed shall not be used to meet the requirements herein. The maintenance procedure shall confirm the effective function and operations of each major machine and machine component that affects product quality. This shall include, but not be limited to:

7.2.1.1 *Laser or electron beam power*—Ensure that beam characteristics are within the machine manufacturer's recommended tolerance. Test that the laser or electron beam output matches software set point in accordance with the machine manufacturer's recommendation or specification requirements, whichever is more demanding. Users of power meters should consider the detector calibration uncertainty when measuring and monitoring laser power. More comprehensive beam quality measurements may be imposed on the machine vendor for machine acceptance, for example, switch on/off speed, power fluctuations after hours of operation, and beam profile deviations across the build platform. It is beyond the scope of this standard to specify machine acceptance criteria.

7.2.1.2 *Beam power at build platform*—When possible, measure laser or electron beam power at left, right, front and back of build platform (that is, build platform extremities), but at a minimum in the center of the build platform at 100% laser power or as required for electron beam. Laser or electron beam power for each energy source shall be within the machine manufacturer's recommendation or specification requirements, whichever is more demanding at all measurement locations.

NOTE 2—Beam quality and power measurements specified in 7.2.1.1 and 7.2.1.2 are for in-process control to prevent unintended changes in energy density.

7.2.1.3 *Beam positioning verification*—Ensure that software-indicated beam location and actual beam position are

within tolerances recommended by the machine manufacturer or within tolerances specified by the component manufacturer.

7.2.1.4 *Z-axis movement*—Ensure that software-controlled and actual layer movements are within the machine manufacturer's recommendation or specification requirements, whichever is more demanding.

7.2.1.5 *Recoater arm and motor*—Recoater blade alignment shall be within the machine manufacturer's recommended tolerance.

7.2.1.6 *Compressed air*—Compressed air required for the PBF machine shall be checked at each PM for any contamination in accordance with ISO 8573-1. Adjust to proper pressure and check all fittings and connections.

7.2.1.7 *Oxygen and vacuum*—Oxygen sensors shall be replaced in accordance with the machine manufacturer's recommended schedule and calibrated at a minimum of two oxygen concentration points. Vacuum shall meet the machine manufacturer's recommendation and shall have a method for calibration.

7.2.1.8 *Laser field alignment (LFA)*—The LFA on multiple-laser systems shall be calibrated according to the machine manufacturer's recommendations. Qualified machine manufacturer shall provide tolerance requirements for laser field alignment.

7.2.1.9 *Other recommended preventive maintenance*—Ensure that all other recommended preventive maintenance, as listed in the machine operation or service manual, is performed.

7.2.2 Record of maintenance activity shall be documented, dated, signed by trained technician(s) on PBF preventive maintenance document, and approved by component manufacturer quality assurance. This form shall be displayed on exterior of PBF machine showing date of service and next due date. Maintenance operations shall be monitored using a recognized procedure (for example, Guide E2910).

7.3 *Machine, Process, and Part Qualification*

7.3.1 A qualification build manufacturing plan (in accordance with Section 10) shall be created and used to build the test specimen(s) for the purpose of qualification. Once the qualification build results have been validated, the parameters used for the qualification build are recorded as PBF baseline parameters, and establish the parameters for subsequent builds (see 7.3.3).

7.3.2 *Build platform (also known as build plate or start plate)*—The component manufacturer shall have a build platform specification and all build platforms used for PBF shall conform to the specification including surface finish, flatness and parallelism requirements. Build platforms may be resurfaced. All build platforms shall be serialized, describing, at a minimum, the material. Dissimilar materials (build platform versus component) can be used provided the component meets the chemical composition engineering callouts. When a component is in direct contact with the build platform (no support structure), the cross-contaminated area on the part(s) shall be removed by appropriate processes (for example, chemical or mechanical).

7.3.3 Test specimens (consolidated material) shall be evaluated for chemical composition, microstructure, porosity and mechanical properties as specified by an appropriate standard or as agreed upon by the component manufacturer and customer. Chemical composition of the test specimens shall be verified against chemical composition requirements as indicated by the consolidated material specification. The component manufacturer shall fabricate ASTM E8, E8M, or ISO 6892 tension test blanks and additional test specimens placed, at a minimum, in five locations on the build platform as shown in Fig. 1. Additional tension test specimens built in the *Z* direction are encouraged, but not required. Guide F3122 provides guidance on evaluating mechanical properties of metal materials made using PBF. The customer may require other qualification tests. Test results shall be submitted to the customer for approval in a format conforming to Practice F2971. Once approved, all the machine parameters used to make the test specimens shall be fixed to establish machine baseline parameters. A certificate indicating the machine conforms to baseline parameters shall be posted in clear view of the machine operators, and shall remain effective on all subsequent build cycles until the PBF machine requires a new qualification.

7.3.3.1 If required by the customer specification, the gage section of the tension test specimen may be left in the as built condition, provided there are no support structures added to the gage section during the PBF process.

7.3.3.2 The component manufacturer and customer shall agree to the method for demonstrating consistency across the build platform for systems with multiple energy sources.

NOTE 3—Methods that tested five specimens from each build area covered by each energy source have been successfully used.

7.3.3.3 A reference part that is an indicator of build quality shall be produced and dimensionally measured as part of the qualification procedure. A reference part should be included in each production build cycle. In order for the test specimens and reference part(s) to be representative of future parts, all post-build activities, if any, on the specimens shall be consistent with the future parts (for example, thermal post-processing).

7.3.4 In instances where critical parameters such as beam power and scan speed are dynamically changed during the build (for example, based on part geometry or melt pool characteristics), using parameters that are different from what

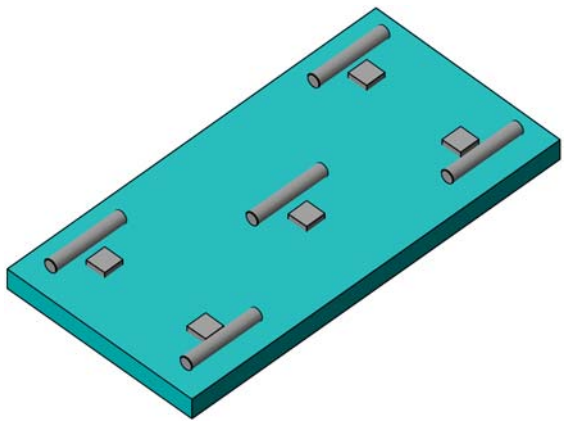

FIG. 1 Example of Tension Test Blanks and Additional Test Specimens Placed in Five Locations on a Build Platform