SLOVENSKI STANDARD

oSIST prEN ISO/ASTM 52902:2018

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Aditivna proizvodnja - Preskusni artefakti - Standardizirano vodilo za ocenjevanje geometrijske zmogljivosti aditivnih proizvodnih sistemov (ISO/ASTM DIS 52902:2018)

Additive manufacturing - Test artefacts - Standard guideline for geometric capability assessment of additive manufacturing systems (ISO/ASTM DIS 52902:2018)

Additive Fertigung - Testkörper - Allgemeine Leitlinie für die Bewertung der geometrischen Leistung additiver Fertigungssysteme (AM-Systeme) (ISO/ASTM DIS 52902:2018)

Fabrication additive - Pièces types d'essai - Ligne directrice standard pour l'évaluation de la capacité géométrique des systèmes de fabrication additive (ISO/ASTM DIS 52902:2018)

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Additive manufacturing — Test artefacts — Standard guideline for geometric capability assessment of additive manufacturing systems

Fabrication additive — Artefacts d'essais — Ligne directrice standard pour l'évaluation de la capacité géométrique des systèmes de fabrication additive

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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 documents 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).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on 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 the following URL: www.iso.org/iso/foreword.html.

ISO/ASTM 52902 was prepared by Technical Committee ISO/TC 261, *Additive manufacturing*, Joint Group JG 67, *Additive Manufacturing — General Principles —Functionally Graded Additive Manufacturing* and by Technical Committee CEN/TC 438, *Additive manufacturing* in collaboration.

Additive manufacturing — Test artefacts — Standard guideline for geometric capability assessment of additive manufacturing systems

1 Scope

This standard covers the general description of benchmarking test piece geometries along with quantitative and qualitative measurements to be taken on the benchmarking test piece(s) to assess the performance of additive manufacturing (AM) systems. This performance assessment may serve the two following purposes: AM system capability evaluation, and an AM system calibration. The benchmarking test piece(s) is primarily used to quantitatively assess the geometric performance of an AM system. The standard describes a suite of test geometries, each designed to investigate one or more specific performance metrics, and several example configurations of these geometries into test piece(s). The standard prescribes quantities and qualities of the test geometries to be measured, but does not dictate specific measurement methods. Various user applications may require various grades of performance. This standard discusses examples of feature configurations, as well as measurement uncertainty requirements, to demonstrate low and high grade examination and performance. This standard does not discuss a specific procedure or machine settings for manufacturing a test piece although these should be recorded as per ASTM F2971 and other relevant process specific specifications.

2 Normative references

ISO/ASTM 52900:2015, *Additive manufacturing — General principles — Terminology*

ISO/ASTM 52915:2016, *Specification for additive manufacturing file format (AMF) Version 1.2*

ISO 17296-2:2015, *Additive manufacturing — General principles — Part 2: Overview of process categories and feedstock*

ISO 17296-3:2014, *Additive manufacturing — General principles — Part 3: Main characteristics and corresponding test methods*

ISO 25178:2012, *Geometrical Product Specification — Surface texture: Areal International Organization for Standardisation collection of international standards relating to the analysis of 3D areal surface texture*

ISO 4287:1997, *Geometrical Product Specifications (GPS) — Surface texture: Profile method — Terms, definitions and surface texture parameters*

ISO 4288:1996, *Geometrical Product Specifications (GPS) — Surface texture: Profile method — Rules and procedures for the assessment of surface texture*

ISO/ASTM 52921:2013, *Standard terminology for additive manufacturing — Coordinate systems and test methodologies*

ISO 98-1:2009, *Uncertainty of Measurement — Part 1: Introduction to the expression of uncertainty in measurement*

ISO 17025:2005, *General requirements for the competence of testing calibration laboratories*

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

B89.7.3.2, Guidelines for the Evaluation of Dimensional Measurement Uncertainty

B46.1, Surface Texture (Surface Roughness, Waviness, and Lay)

JCGM 100, *Evaluation of Measurement data — Guide to the Expression of Uncertainty in Measurement*

Z540. 3: 2006, *Calibration Standard Published*

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 terminological databases for use in standardization at the following addresses:

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

— ISO Online browsing platform: available at http://www.iso.org/obp

4 Significance and Use

4.1 Measurements and observations described in this test method are used to assess the performance of an AM system [AM system defined here to mean the combination of machine, material and process categories (ISO 17296-2)].

The primary characterization of the AM system obtained by this standard is via geometric accuracy, surface finish, and minimum feature sizes of the benchmarking test piece(s).

4.2 **Comparing results from one machine:** The test piece(s) can be built and measured when the new machine is installed as a performance baseline. The test piece(s) may be used to periodically evaluate the performance or diagnose a fault in one AM system, for example, after system maintenance or as defined by the requirements of a quality system.

The test piece(s) described in this test method may be used as a demonstration of capabilities for a contract between a buyer and seller of AM parts or AM systems.

Data from the measurements described in this test method can be used to gauge the impact of new process parameters or material on performance.

Certain test geometries may be included with every build on a particular AM system to help establish performance traceability. Depending on the needs of the end user, not all test artefacts need to be built, and individual test artefacts can be built separately if required.

5 General guidelines for producing artefacts

5.1 This clause outlines guiding principles that are applicable for producing all of the test artefact geometries in this standard. Please note that reporting requirements are previewed in connection with the production steps in this clause, but more details about recording and reporting can be found with the individual artefact descriptions given in Clause 7.

5.2 **Need to use feedstock conforming to a material specification:** In order to assure repeatable results, the use of a quality feedstock material is needed. A feedstock material specification should be selected or determined by the end user and the feedstock used for test artefact trials should match said specification. For example, the specification may include the particulate properties (particle size, size distribution, morphology) for powder feed stock, bulk properties (such as flow) and chemical properties (such as chemical composition and level of contamination). Although the details of the material specification may not be disclosed (unless otherwise agreed between supplier and purchaser), it should be documented by the producer and reported with a unique alphanumeric destination as specified by F2971 (element “B” in Annex A1). For powder-based processes, the material specification should specifically address limitations of powder re-use and percent of virgin/re-used powder.

5.3 Need to undertake artefact building according to a documented process specification: The processing of the material in the AM system should be undertaken according to a documented process specification/manufacturing plan, as specified by F2971 (element "C" in Annex A1). This may be a proprietary internal standard or external standard (subject to buyer/seller negotiations), but the producer should document user-definable settings and conditions surrounding the building of parts. For example, it would document the layer thickness; build strategies (e.g., scan path, tool path, and/or scan parameters), temperatures, etc. used during the build. This process should be consistent for all test artefacts produced within one build. Note that these requirements might be different for each use, so the parameters in the process specification should be agreed between the vendor and end user.

5.4 File formats and preparation: The file format used and steps of the digital file preparation including slice parameters should be included in the process specification. The physical output of additive manufacturing can never exceed the digital model input into the process. Any discrepancies between these will affect the outcome of tests on the artefacts and for this reason, best practice for the control of the file formats and preparation is discussed here.

5.5 Download files: The 3D digital models for standard test artefact geometries can be downloaded in *.step format at http://standards.iso.org/iso/52902/ed-1/en. Alternative data formats, such as AMF, will also be made available to download, as they are released.

5.6 Discussion of file conversion: When a CAD model is converted to AMF, STL (or any intermediate file format); sufficient fidelity must be maintained to ensure that the test artefact produced from it fairly reflects the capabilities of the AM system under assessment. The file conversion tolerance selected should ensure that the maximum deviation of the data from the nominal CAD model is less than one quarter and, based on good measurement practice, ideally less than one tenth of the expected accuracy of the AM system being assessed. Currently most additive manufacturing equipment cannot produce features with a resolution better than 10 µm, therefore CAD models are saved to STL/AMF ensuring at least a 2,5 µm accuracy or better. This is only general guidance and should be confirmed for the specific output system. It is recommended that users check the maximum deviation and moreover, record the conversion parameters used, as well as any maximum deviation (chord height and angular tolerance).

Files should not be scaled up or down either during conversion or afterward. Machine correction factors (e.g., offsets, axis scaling, etc.) may be used and should be documented as part of the process specification.

5.7 AMF preferred (with conversion instructions/ resolutions): The AMF file format as defined by ISO/ASTM 52915 is the preferred model format for test artefact geometry representation due to its ability to store high fidelity geometry with embedded units in an intermediate file format.

5.8 Need for Test Specification and Test Process: This document forms the basis for the general *Test Plan/Specification* described in F2971 (element "D" in Annex A1), but specifics about its implementation need recording to accurately document the *Test Process* (element "E" in Annex A1), used for producing the parts as discussed in Clause 6.

5.9 Quantity of test artefacts: For a complete test of machine performance, two things dictate the quantity of the test artefacts produced. First, the Test Specification/Test Process must ensure a quantity of samples, typically no less than five, so that statically significant measurements can be made. Second, sufficient coverage (See 5.5.) of the build platform needs to be made to account for variations in performance between build locations. Fewer test artefacts with less complete coverage may be used for spot checks or limited demonstrations. The number of artefacts should be agreed upon between the buyer and seller.

5.10 Position and orientation of test artefacts: As per F2971 (element "F" in Annex A1) it is mandatory to report results in combination with the test artefacts' build position and orientations according to the convention set forth in ISO/ASTM 52921.

5.11 Considerations for orientation: Since these test artefacts are intended to reveal the strengths and weaknesses of additive building techniques there will be failed build geometries. It is worth considering which features are likely to fail and place them in a position that minimises the risk that this will lead to an outright failure of the features/parts/artefacts in the rest of the build. For example, in a powder bed process, it may be advisable to position parts that more likely to fail at a higher level in the overall build to reduce the risk that failed parts or sections of parts impinge on other components in the build or the AM machine mechanism.

5.12 Labelling: It may be useful to add labels to parts in order to identify respective artefact orientations and positions in the build. Labelling is summarised in 7.4.

5.13 Coverage: It is important for test artefacts be made with sufficient coverage of the build volume to get representative data for where real parts are made. Coverage evaluates variability throughout the build volume. This is best practice for all AM processes, and is especially critical for processes that have a "sweet spot" (for example, some galvometer-steered laser systems give more repeatable results in the center of the platform). It is suggested that artefact distribution span at least 80% of the machine's build platform area. If build location effects are known or deemed irrelevant for the particular trial being performed, then a single build location may be selected and used, as agreed between vendor and user.

Long artefacts, which reach across the extents of the build, are necessary to detect corrections that are not linear or are periodic in nature.

5.14 Arrays: Geometry should not be scaled (since this affects the measurement outputs), but may be patterned in an array to give larger coverage areas.

5.15 Part consolidation: When arrays of parts are needed for better coverage, it may be most practical to build a single combined part instead of trying to build arrays of adjacent individual parts. This can be achieved by consolidating adjacent AMF or STL files prior to slicing and other file preparation steps.

As AM is a layered process (in z-direction) and often based on pixels (in x/y-direction), the exact position of the part in the build might affect the test significantly. This is especially true of artefacts testing machine resolution. A minor translation of the part might influence rounding off issues influencing whether a specific layer or pixel will build or not. This could be caused during preparation of the slice file and during orienting the slice file in to the working area in the machine. It is recommended to report results in combination with the test artefacts' build orientations according to the convention set forth in ISO/ASTM 52921.

With certain AM processes (especially with metals), heat build-up from processing large cross sectional areas near to the test artefacts may affect their geometrical accuracy. Therefore, it is advised that the manufacturer shall ensure compliance with specified distances.

5.16 Supports & Post processing: Where possible supports should be avoided or supports employed which do not impede or affect in any way the intended measurement. Supporting strategy, including, but not limited to material, geometry, removal technique, etc., must be fully documented in the process specification.

Data reported from this standard is to be in the as-built condition prior to any surface or downstream processing. In the case of unavoidable post-processing undertaken prior to measurement (e.g., removal of necessary support material), details of the process should be reported as part of the process specification. The reporting should include a description of any abrasive media and how it was applied to the surface of the artefacts. In addition, data after additional post-processing treatments (such as sand blasting of metal parts for example) may be obtained but only if clearly noted and presented together with as-built measurements.

6 General guidelines for measuring artefacts

6.1 This clause outlines guiding principles that are applicable for measuring all of the test artefact geometries in this standard. The specific measurements are specified in Clause 7 describing the individual artefact geometries. This standard does not prescribe any specific measurement methods, rather the measurements described below can be accomplished by a variety of techniques and devices (e.g., coordinate measuring machine, optical scanner, dial indicators with calibrated motion devices, surface profilometers, etc.). The ISO 17296-3 could be used to improve communication between these stakeholders concerning test methods. Please note that reporting requirements are previewed in connection with the measurement steps in this clause, but more details about recording and reporting can be found in Annex B and C.

6.2 Measure parts as built: The test artefact should be allowed to cool to room temperature and then measured directly after it is removed from the system used to build it, before any post-processing is performed. The end user may require that parts be held at a set temperature and humidity prior to measurement. If the parts are built by a powder bed based process, the parts should be completely de-powdered (support powder removed) before measurement. If the parts are built on a build platform, perform the measurements without removing the part from the platform. (Removal from a build platform may affect the shapes of the artefacts, thereby influencing the results. If measurement is not possible on the platform, this must be explicitly stated in the report.) If post-processing is desired, report all details of each post-processing step and measure the part before and after each post-processing steps (reporting all measurement results).

6.3 Measurement strategy: It is well known that measurement strategy affects the overall measurement uncertainty; this is true for dimensional measurements and surface measurements alike. Measurement strategy, here, involves the device chosen to perform the measurement along with the number of points selected to represent the feature or surface and the distribution of points along the feature or surface. For roughness measurements, the measurement strategy includes any applied filters (e.g., the cut-off length). Measurement strategy is a complicated subject and is often very specific to the part or feature being measured. As such, there is no general "best practice" for performing these measurements. However, some tips are provided in Annexes B and C. The measurement uncertainty is ultimately the important concept, and, with consideration given to the available measurement devices, using a measurement strategy that minimizes the measurement uncertainty within any given constraints should be the primary focus of the user.

Note that nominally "flat" surfaces may be very uneven or rough. Multiple points may need to be measured to obtain a mean result.

6.4 Measurement uncertainty: The standard uncertainty of each measurement should be reported along with the measurement. Guidance on determining measurement uncertainty can be found in the following references:

— ASME B89.7.3.2 for uncertainty in dimensional measurements;

— ASME B46.1 for surface texture measurements;

— JCGM 100:2008 Guide to the expression of uncertainty in measurement (GUM) for measurement uncertainty in general;

— ISO/IEC GUIDE 98-1:2009(E) Evaluation of measurement data — An introduction to the Guide to the expression of uncertainty in measurement and related documents.

Users should document any calibration and/or quality maintenance system for the measurement processes and equipment used. Measurement device and resolution must be disclosed in the report.

7 Artefact Geometries

7.1 General

There are seven types of artefacts described in the clauses that follow. Each artefact is intended to test a different aspect of a system's performance or capability.

7.2 Accuracy

7.2.1 Linear Artefact

7.2.1.1 Purpose: This artefact tests the linear positioning accuracy along a specific machine direction. Depending on artefact orientation and machine configuration, errors in the artefact may provide a basis for positioning compensation or diagnosing specific error motions in the system's positioning system.

7.2.1.2 Geometry: Figure 1 depicts the geometry of the linear artefact. The artefact is comprised of prismatic protrusions atop a rectangular solid base. A bounding box for the entire feature is 55 mm × 5 mm × 8 mm. The end protrusions are 2,5 mm × 5 mm × 5 mm. The central protrusions are 5 mm cubes. Spacing of the protrusions increases along the length of the artefact from 5 mm to 7.5 mm, 10 mm, and 12,5 mm.

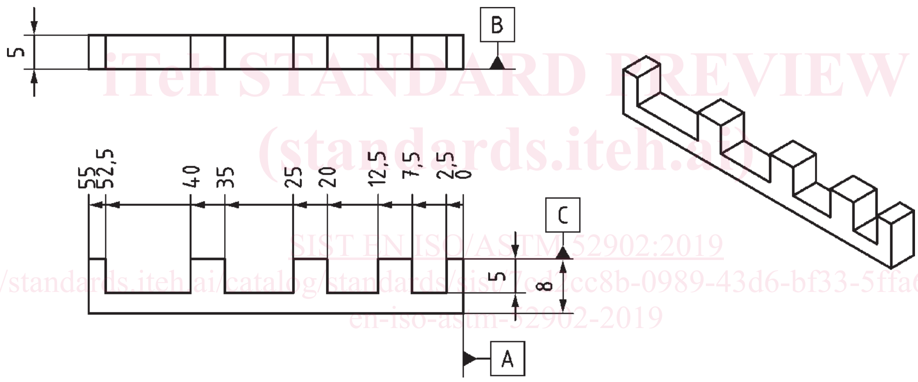

Figure 1 — Engineering drawing of linear test artefacts

If a longer test of linear accuracy is desired, multiple linear artefacts can be appended to one another. The 2,5 mm length of the end protrusions means that when two or more linear artefacts are appended, the central protrusions will all be 5 mm cubes. Figure 2 shows an example. If this option is chosen, please note 5.14.

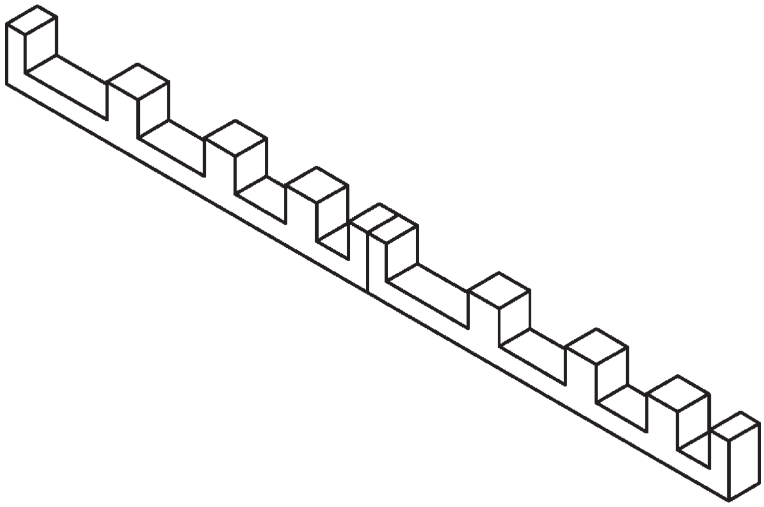

Figure 2 — Two linear accuracy test artefacts appended to each other

If a shorter test of linear accuracy is required, the geometry of an alternative test artefact should be agreed upon by the user and supplier, and will follow similar design principals to the part shown in Figure 1. The alternative artefact should have non-equally spaced features and should test both protrusions and gaps (i.e., distances with material in between datum features and distances with space in between datum features).

7.2.1.3 Measurement: The primary measurement for the linear artefact is the positions of the cube faces relative to the primary datum at the end of the artefact (see Figure 1). Alternatively, the lengths of each protrusion can be measured and the spacing between each protrusion can be measured. Optional measurements available are the straightness of the base along the length of the artefact, parallelism of each side of the base along the length of the artefact, and the heights of each protrusion.

7.2.2 Considerations

Default orientations for a thorough overview of linear accuracy should include at least one test artefact aligned parallel to each axis (x, y, and z) in the machine coordinate system. When this is done, orthogonal orientation notation should be used to document the orientation as per ISO/ASTM 52921. An alternative might be to align one linear artefact with the motion of one of the machine's positioning axis (for example the x-axis slide in a gantry system). This alternative orientation may better link errors in the part with error motions in the positioning system.

Orientations that may cause collision or damage from a wiper or recoating blade should be avoided.

It is often desirable to test linear accuracy through the extent of the machine's positioning capabilities. Users should consider positioning linear artefacts through the middle of the build area as well as near the ends of travel.

In the case of a vertically oriented linear artefact, the use of support structures should be avoided if possible. If support structures are necessary (for example, beneath the protrusions) the support strategy (including geometry, material, and removal technique) must be fully documented. Care should be taken to select a support strategy that minimizes the adverse impact on the measuring process/accuracy.

7.2.3 Circular Artefact

7.2.3.1 Purpose: These artefacts are intended to test the dynamic accuracy of the method that delivers the energy source to the material of an additive manufacturing system (apparatus).

The basic configuration of these artefacts is created to be able to separate the influence of the material and external sources of error that may be present in the entire apparatus.

