



SLOVENSKI STANDARD
oSIST prEN ISO/ASTM 52945:2022
01-september-2022

[Not translated]

Additive manufacturing for automotive - Qualification principles - Generic machine evaluation and specification of key performance indicators for PBF-LB/M processes (ISO/ASTM DIS 52945:2022)

Additive Fertigung für die Automobilindustrie – Grundsätze der Qualifizierung – Generische Maschinenbewertung und Spezifikation von Leistungskennzahlen für PBF-LB/M-Prozesse (ISO/ASTM DIS 52945:2022)

Fabrication additive pour l'automobile - Principes de qualification - Évaluation de la machine générique et spécifications des indicateurs clefs de performance pour les procédés PBF-LB/M (ISO/ASTM DIS 52945:2022)

Ta slovenski standard je istoveten z: prEN ISO/ ASTM 52945

ICS:

25.030 3D-tiskanje Additive manufacturing

oSIST prEN ISO/ASTM 52945:2022 en,fr,de

DRAFT INTERNATIONAL STANDARD

ISO/ASTM DIS 52945

ISO/TC 261

Secretariat: DIN

Voting begins on:
2022-07-13Voting terminates on:
2022-10-05

Additive manufacturing for automotive — Qualification principles — Generic machine evaluation and specification of key performance indicators for PBF-LB/M processes

Fabrication additive pour l'automobile — Principes de qualification — Évaluation de la machine générique et spécifications des indicateurs clefs de performance pour les procédés PBF-LB/M

ICS: 25.030

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Reference number
ISO/ASTM DIS 52945:2022(E)

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Published in Switzerland

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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).

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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 aim to create a common set of ISO/ASTM standards on Additive Manufacturing.

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

This document provides a methodology to evaluate PBF-LB/M AM-machines in the context of automotive on an objective basis. The need to provide a document standardizing this topic exists because in high-volume industrial production, the reproducibility of the produced component is crucial to meet production goals. Therefore, reproducibility and capability of the machines used for manufacturing need to be evaluated upfront. A methodology and performance characteristics are introduced to enable the evaluation on an objective and quantitative basis. The documentation resulting from the AM-machine evaluation is used to obtain a reliable orientation selection and evaluation of PBF-LB/M AM-machines.

Moreover, the document provides guidelines for machine production KPIs which can be used in procurement, production planning and production to improve the understanding between the machine manufacturer and user.

The requirements regarding quality and planning of build jobs are specific for the automotive industry. The introduced generic approach can be expanded to other industries.

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Additive manufacturing for automotive — Qualification principles — Generic machine evaluation and specification of key performance indicators for PBF-LB/M processes

1 Scope

This document defines the methodology for generic AM-machine evaluation in automotive environment using objective test criteria and provides the framework for an objective AM-machine evaluation and comparison. This document finds application in benchmarks, in the preparation of purchase decisions, but also in AM-machine evaluation within the machine procurement, acceptance, and qualification processes.

Furthermore, this document specifies machine KPIs in the context of machine procurement, production planning and production of PBF-LB/M components. It aims to reach a detailed understanding between machine supplier and machine user with respect to the acceptance criteria during the procurement process and evaluation of machine performance during running production.

This document is applicable to the additive manufacturing technology PBF-LB/M. The terminology in this document is defined in ISO/ASTM 52900.

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

ISO/ASTM 52902, *Additive manufacturing — Test artifacts — Geometric capability assessment of additive manufacturing systems*

ISO/ASTM 52928, *Additive manufacturing — Feedstock materials — Powder life cycle management*

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

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

ISO 4499-4, *Hardmetals — Metallographic determination of microstructure — Part 4: Characterisation of porosity, carbon defects and eta-phase content*

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

ISO 25178 (all parts), *Geometrical product specifications (GPS) — Surface texture: Areal*

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

VDI 3423, *Technical availability of machines and production lines — Terms, definitions, determination of time periods and calculation*

VDI 3405, *Additive manufacturing processes, rapid manufacturing — Basics, definitions, processes*

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3 Terms and definitions

For the purposes of this document, the terms and definitions of 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 performance characteristics
defined characteristics which are measured in a defined framework (in this document based on generic build jobs and produced specimens) and can be used to evaluate machines on an objective basis

3.2 machine KPIs
performance indicators that measure the performance of a production machine in a defined framework (e.g. timeframe, defined production lots, etc.)

EXAMPLE overall equipment effectiveness

3.3 quality level
defined ranges of values for a specified set of quality parameters such as relative density, surface roughness, mechanical properties, etc.

3.4 specimen package
set of different specimens according to [Table 5](#)

4 Methodology for generic machine evaluation

4.1 Specification of Use-Cases

4.1.1 General

This clause introduces the methodology of generic machine evaluation. The generic machine evaluation shall be used to carry out an assessment to evaluate the performance of a PBF-LB/M machine on a defined objective basis.

The methodology of generic machine evaluation introduced here is not intended to define and verify compliance of target metrics, but should instead be used to generate information and efficiency metrics to enable machine assessment and comparison. Further details of the machine acceptance process are shown in ISO/ASTM TS 52930.

The generic machine evaluation shall be used to generate a sufficient, neutral, and documented evaluation basis for two different use-cases, which are described [4.1.2](#) and [4.1.3](#).

4.1.2 Use-Case 1 – Benchmarking of machines (evaluation reference according to 4.2.5):

The framework and methodology introduced in [4.3.1](#) shall be used in the context of benchmarking of machines. Therefore, a minimum of 1 run of the described build jobs according to [4.2.2](#) shall be produced and tested in the described way. To strengthen the statistical significance of the benchmark, production and evaluation of additional build jobs shall be necessary. This is an option at the discretion of the machine manufacturer or the user.

4.1.3 Use-Case 2 – Generic evaluation in factory/site acceptance test (according to ISO/ASTM 52930-1):

The framework and methodology introduced in [4.3.1](#) shall furthermore be used in the machinery procurement process, more specific in the factory and site acceptance test. Before using the methodology the specific target values for the performance, indicators shall be agreed on between user and machine manufacturer. During factory and site acceptance test, at least one build job run is mandatory.

This methodology can also be used to evaluate build job-to-build job performance. For a better evaluation of the machine, further evaluations of build jobs with specific relevant part designs can be taken into consideration. The frame conditions for such specific build jobs can be derived from the framework of the expected (future) build jobs, or be pre-arranged by agreement between machine manufacturer and user.

4.2 Specification of specimen and build job design

4.2.1 Specification of generic specimen and testing standards

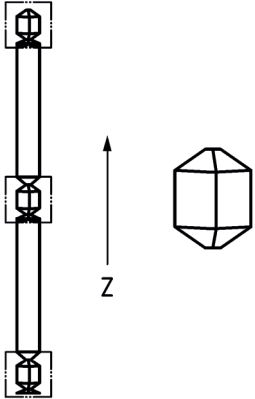
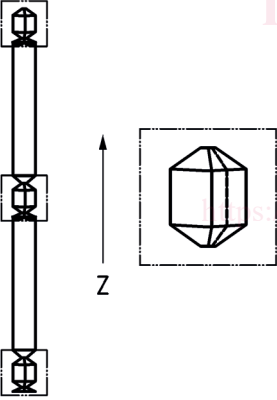
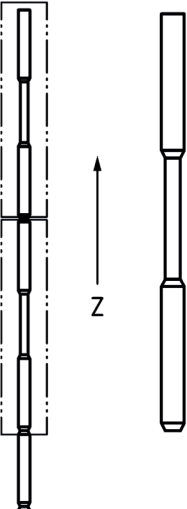
In the following, the test specimens used in the generic construction jobs and for the evaluation of these construction jobs as well as the associated tests are defined. This clause gives an overview of the relevant use cases for the generic machine evaluation and introduces the framework for the data generation (specimens used, test methods, build job design and quality requirements).

Since specimens are not sufficiently described in ISO/ASTM 52902, new specimen geometries to be used throughout the generic build job are introduced in [Table 1](#).

Part, as well as build job powder removal methods cannot be changed, in order to maintain consistent mechanical and surface quality of the specimen. The surface measurement shall be performed prior to the porosity measurement.

The introduced methodology is applied to quasi-static mechanical properties, relative density, and surface. Further properties (e.g. dynamic and cyclic properties) are excluded on purpose and can be included in individually designed build jobs following this methodology or individual agreements between user and machine manufacturer.

Table 1 — Specification of specimen for measurement of surface roughness, relative density and tensile strength

Test specimen	Test standard, purpose & description	Test procedure and criteria
	<p>Surface measurement:</p> <ul style="list-style-type: none"> — Test standard: ISO 25178 — Test specimen: 10 mm × 10 mm × 10 mm diamond surface/density specimen — Test purpose: <p>Measurement of surface roughness on:</p> <ul style="list-style-type: none"> — 45° — 90° and — 135° surfaces <ul style="list-style-type: none"> — Test specimen surface: <p>powder removed with pressured gas (no surface modification)</p>	<ul style="list-style-type: none"> — Measurement (according to ISO/ASTM 52902) of S_z, S_a, S_{sk} and S_{ku}, on each of the 4 surfaces for 45°, 90°, 135° angle against the build plate — Determination of mean value and quantiles for each cube — Area of measurement shall be the complete area that is available in each direction — Typically used measurement filters according to ISO/ASTM 52902
	<p>Porosity measurement:</p> <ul style="list-style-type: none"> — Test standard: <ul style="list-style-type: none"> — Preparation: ISO 4499-4 — Porosity measurement: ISO 4499-4 <ul style="list-style-type: none"> — Test specimen: <p>10 mm × 10 mm × 10 mm diamond surface/density specimen</p> <ul style="list-style-type: none"> — Test purpose: <p>measurement relative density in cross section</p> <ul style="list-style-type: none"> — A testing with the Archimedes method according to ISO 3369 can be added 	<ul style="list-style-type: none"> — Cross section cut through the diamond specimen — Preparation of the cross section cut according to the test standard — Measurement of the relative density according to the test standard in 25 x magnification
	<p>Tensile test (as-built surface):</p> <ul style="list-style-type: none"> — Test standard: ISO 6892-1 — Test specimen: <p>Near net shape tensile specimen (according to ASTM E8M, the requirement regarding surface roughness maybe waived)</p> <ul style="list-style-type: none"> — Tensile testing near net shape with as-built surface (no post processing) — Enabling tensile strength trend analysis over height 	<ul style="list-style-type: none"> — Testing according to test standard and measurement of R_m, $R_{p0,2}$ and A