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Additive manufacturing — System performance and reliability — Acceptance tests for laser metal powder-bed fusion machines for metallic materials for aerospace application

Fabrication additive — Performance et fiabilité du système — Essais de réception pour machines de fusion laser sur lit de poudre pour les matériaux métalliques pour l'application aérospatiale

Member bodies are requested to consult relevant national interests in ISO/TC 44/SC 14 before casting their ballot to the e-Balloting application.

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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 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 ISO/TC 261, *Additive manufacturing*, in cooperation with ASTM F 42, *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.

Additive manufacturing — System performance and reliability — Acceptance tests for laser metal powder-bed fusion machines for metallic materials for aerospace application

1 Scope

This document specifies requirements and test methods for the qualification and re-qualification of laser beam machines for metal powder bed fusion additive manufacturing for aerospace applications.

It can also be used to verify machine features during periodic inspections or following maintenance and repair activities.

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 11146 (all parts), *Lasers and laser-related equipment — Test methods for laser beam widths, divergence angles and beam propagation ratios*

ISO 11554, *Optics and photonics — Lasers and laser-related equipment — Test methods for laser beam power, energy and temporal characteristics*

ISO/ASTM 52900, *Additive manufacturing — General principles — Part 1: Fundamentals and vocabulary*

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

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO/ASTM 52900, ISO/ASTM 52921 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 http://www.electropedia.org/

3.1
scanning speed
relative linear speed of the laser beam movement in the plane of the build platform (working plane)

3.2
warm-up time
time from switching on the machine until the build cycle can be started, as specified by the machine manufacturer

3.3
feeding platform
platform that moves incrementally to supply powder to the *powder spreading device* (3.4)

3.4
powder spreading device
powder supply mechanism, which distributes and evenly spreads the powder on the build surface

3.5
rated laser power
the maximum power capability as specified by the laser manufacturer

3.6
minimum beam waist position
focal spot a location at which the beam has the most concentrated energy and the smallest cross sectional area

4 Equipment

Equipment shall be installed, operated and maintained according to the documented instructions.

5 Environmental and operational conditions

The environmental and operational conditions during qualification testing shall meet the requirement ranges if specified by the machine manufacturer and shall conform to the conditions which are specified by a machine user during production, as examples the following:

a) temperature;

b) humidity;

c) services/utilities (e.g. supply of electrical power, compressed air, shielding gas, water);

d) shocks/vibrations;

e) chamber pressure

f) process gas purity.

Health and safety measures relating to laser radiation and to fire and explosion protection shall be observed.

6 Qualification testing

6.1 General

The qualification testing of laser beam machines for metal powder bed fusion additive manufacturing shall comprise as a minimum the requirements specified in 6.2 to 6.7.

The measurement shall be performed with a calibrated measuring instrument according to the measuring instrument instructions.

6.2 Laser beam tests

6.2.1 Testing the laser power for continuous wave lasers

The laser power shall be measured. The measurement should be performed according to ISO 11554, as applicable.

The nominal machine power settings shall be compared with the actual values. The measurement shall be performed with a calibrated measuring instrument at the point of use (i.e. inside the build chamber). The instrument shall be capable of accurate measurement of the actual laser power range.

The laser power measurement shall conform to the requirements of production by covering the typical power range. If this range is unknown, it is recommended to measure at a minimum of three points including 30 % and 90 % of the maximum nominal laser power.

If specified by the machine manufacturer, a warm-up time shall be applied.

6.2.2 Testing the laser power stability for continuous wave lasers

The laser power stability should be measured according to ISO 11554, if applicable. If ISO 11554 is not applicable the following procedure should be applied. If a warm-up time is specified, the stability measurements shall start immediately after the warm-up time is completed.

Unless otherwise agreed by the contracting parties, demonstrate laser power stability by making the following power measurements after all optical elements, without powder:

a) maximum rated laser power after specified warm-up time of the machine;

b) maximum rated-laser power taken not later than 2 min after laser is held at the maximum-rated-laser power for 15 min minimum;

Variation between the two measurements shall not exceed ±5 %.

NOTE See 3.5 for the definition of rated laser power.

The laser power stability should be measured according to ISO 11554, if applicable.

6.2.3 Testing of pulsed wave lasers

The characteristics shall be measured according to ISO 11554. The requirements shall be agreed by the contracting parties.

6.2.4 Evaluation of the laser beam characteristics

The laser beam characteristics (spot size, profile and symmetry) shall be determined with suitable test equipment at the working plane with the laser beam in a vertical direction to the working plane.

Unless otherwise agreed by the contracting parties, the evaluation of the laser beam characteristics shall be performed according to the appropriate part of ISO 11146 (all parts).

The result shall be compared to the requirements for spot size, profile and symmetry.

6.2.5 Evaluation of the minimum laser beam waist position in different working plane locations

After the warm-up time is completed, the minimum beam waist position (focal point) shall be determined in the centre and in four points at the extremities of the surface available for building the parts.

A value for the beam waist position in z-axis shall be given with reference to the build surface.

The minimum beam waist position can be determined by producing parallel lines with the laser on a test sheet at different build platform heights (Z-axis). The thinnest line represents the focus position.

6.2.6 Evaluation of the thermal stability of the minimum beam waist position

The evaluation of the stability of the minimum beam waist position shall be determined at 10 %, 50 % and 90 % of the maximum nominal laser power after the warm-up time is completed.

The evaluation shall be carried out with laser beam in a vertical direction at the working plane with suitable test equipment.

Unless otherwise agreed by the contracting parties, the minimum time for application of each power setting shall be 15 min.

The results of this evaluation shall be compared to the result of the evaluation in 6.2.5 and/or the evaluation of the spot size in 6.2.4, dependent on the measurement methods used.

6.2.7 Testing the laser beam position

The configuration of the laser beam position (field correction) in relation to the working plate shall be determined. This can be done by means of suitable geometric patterns produced by the laser and their measurement.

The vector of the *X*-*Y*-deviations of the laser beam position from the specified positions shall not exceed 0,06 mm, unless otherwise agreed by the contracting parties.

6.2.8 Trajectory accuracy

For the determination of the trajectory accuracy, at a given scanning speed, a geometric pattern shall be applied to a test sheet. Annex B gives an example of a geometric pattern for the trajectory accuracy test. The scanning speed at which the trajectory accuracy is determined shall be documented.

The pattern for the determination of the trajectory accuracy should encompass the total working range and the scanning speed range and is measured with optical instruments. The following shall be assessed:

— conformance of the entry point to the exit point at closed or complementary contours;

— trajectory accuracy when changing direction (inertia of the optical system);

— overlapping area between different exposure forms (e.g. contour and volume exposure).

6.2.9 Scanning speed

Scanning speed measurements shall be performed in x- and y-directions as well as in (45 ± 15)° direction.

The scanning speed for the measurement can be specified by the user.

EXAMPLE The scanning speed can be determined by laser engraving (melt track) on a test sheet in the plane of the working platform. For this purpose, a defined trajectory length is applied in a specified period of time. The trajectory length is subsequently measured and divided by the actual laser switch-on time. The metering of the actual laser switch-on time is carried out for example at the laser control station.

The maximum permissible deviation of the measured scanning speeds from the specified value is ±5 %, unless otherwise agreed by the contracting parties.

6.2.10 Requirements for equipment with multiple laser beam sources

Where a multi laser machine is to be used to manufacture parts, each of which is entirely within one laser's working zone, the specifications as detailed in 6.2.1 to 6.2.9 shall be applied separately to each working zone.

Where a multi laser machine is to be used to manufacture parts, any of which span more than one laser's working zone, additional cross-calibrations shall be required, as agreed by the contracting parties.

When multiple lasers target the same location at any point in the build area, the distance between any two laser beam positions shall not exceed 0,06 mm, unless otherwise agreed by the contracting parties.

The measurement results shall be documented.

6.3 Mechanical function test

6.3.1 General

The mechanical functions relevant for the process shall be checked for their precision and their reproducibility.

6.3.2 Build platform positioning

The precision and reproducibility of the movement of the build platform shall be determined over a defined range of movements, e.g. by means of a dial indicator or a glass scale.

For this purpose, the build platform shall be moved by progressive stages, which should correspond to the targeted powder coating thickness values or their multiple.

Measurements shall be taken at a minimum of five build platform heights (0 %, 25 %, 50 %, 75 %, 100 % of total build platform travel range), a minimum of 5 successive movements shall be conducted at each platform height, with unloaded build platform in the highest positions and under a weight load in the lowest positions. The weight load shall be specified in relation to the material to be processed (relative density) and the holding capacity, at a minimum of 30 % of the holding capacity.

Tolerances shall be agreed upon by the contracting parties.

6.3.3 Feeding platform positioning

This subclause is only applicable for machines which are equipped with feeding platform(s).

The precision and reproducibility of the movement of the feeding platform shall be determined over a specified range of movements, e.g. by means of a dial indicator or a glass scale.

For this purpose, the feeding platform shall be moved by distances that correspond to the amount of powder needed for depositing one or multiple layers of the intended powder layer thickness.

Measurements shall be taken at a minimum of five feeding platforms heights (0 %, 25 %, 50 %, 75 %, 100 % of total feeder platform travel range), a minimum of 5 successive movements shall be conducted at each platform height, with unloaded feeding platforms in the highest positions and under a weight load in the lowest positions. The weight load shall be specified in relation to the material to be processed (relative density) and the holding capacity. Tolerances shall be agreed upon by the contracting parties.

6.3.4 Other powder feed processing mechanics

Machines where the powder is delivered to the feed region by a method that is not based on a feeding platform requires that a method for measuring and verification of the repeatability the delivered amount of powder to be specified. The tolerances for the delivered amount of powder shall be determined by agreement between the contracting parties.

6.3.5 Movement of the powder spreading device

The function of the powder spreading device shall be inspected for uniform and repeatable operation. The inspection should be performed under operational conditions, i.e. with powder.

6.4 Heating system

The functionalities of the heating systems shall be demonstrated or verified as specified by machine user.

6.5 Atmosphere inside the working space

By means of suitable sensor technology and control systems, it shall be ensured that the atmosphere conforms to the requirements throughout the process and these requirements shall be specified.