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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 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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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 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, 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.

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Additive manufacturing for aerospace — Process characteristics and performance —

Part 2: Directed energy deposition using wire and arc

1 Scope

This document specifies requirements for the additive manufacturing of metallic parts with directed energy deposition (DED) in the aerospace industry.

Within the application scope of this document, wire is used as feedstock, and arc processes (gas-shielded metal arc processes (MIG/MAG/GMAW), tungsten inert gas processes (TIG/GTAW), plasma arc processes (PAW)) are used as the main energy source.

This document is to be used in conjunction with the engineering documents, if required by the engineering authority.

This document does not address health and safety issues.

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.

~~<std>ISO 14175, *Welding consumables — Gases and gas mixtures for fusion welding and allied processes*</std>~~

~~<std>ISO/ASTM 52900, *Additive manufacturing — General principles — Fundamentals and vocabulary*</std>~~

~~<std>ISO 14175, *Welding consumables — Gases and gas mixtures for fusion welding and allied processes*~~

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

ISO/ASTM 52926-5, *Additive manufacturing of metals — Qualification principles — Part 5: Qualification of operators for DED-Arc*

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~~ terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at <https://www.iso.org/obp> ~~https://www.iso.org/obp~~

— IEC Electropedia: available at <https://www.electropedia.org> ~~https://www.electropedia.org/~~

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3.1 preliminary additive procedure specification pAPS

document containing the required variables of the additive manufacturing process which has to be qualified

Note 1-to-entry:-The pAPS contains process specific parameters and will form a section of the manufacturing plan.

3.2 additive procedure specification APS

document that has been qualified and provides the required variables of the additive manufacturing process to ensure repeatability during production

Note 1-to entry:-The APS contains process specific parameters and will form a section of the manufacturing plan.

Note-2-to entry:-Further information on the qualification of processes can be found in the ISO 15614 series.

3.3 key process variable KPV

aspects of the manufacturing process that may impact the capability to meet the specified requirements that include physical, chemical, metallurgical, mechanical and dimensional properties

[SOURCE: SAE AMS 7005:2019-01-31, 8.2.1]

3.4 engineering authority

organization that has the responsibility for the structural integrity or maintenance of airworthiness of the hardware and compliance with all relevant documents

[SOURCE: ISO 24394:2019, 3.9] 2023, 3.8, modified — "design" was removed from the term and Notes to entry have been deleted.]

3.5 build platform

base which provides a surface upon which the building of the part/s, is started and supported throughout the build process

[SOURCE: ISO/ASTM 52900:2021, 3.3.5]

3.6 substrate

base metal utilized to initiate the deposition of material that can remain a portion of the preform

[SOURCE: SAE AMS 7005:2019-01-31, 8.2.1, modified — "may" has been replaced with "can". Note 1 to entry added]

Note 1-to-entry:-A substrate can be integral to the final part whereas a build platform will be removed from the final part.

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3.7 point of use

location where the process is performed e.g. gas nozzle or torch, trailing nozzle, gas chamber (if used)

4 Requirements for the feedstock

The properties of the feedstock to be used shall be specified. In order to guarantee a constant delivery quality ISO 544, ISO 15792 (all parts) and ISO 14344 can be used. Typical properties include:

- feedstock diameter;
- chemical composition;
- surface condition;
- storage conditions;
- traceability (e.g. heat lot, batch).

5 Qualification of the machine operator

The qualification of the machine operator shall be carried out in accordance to ISO/ASTM 52926-5 and the examination shall be taken every 2 years to ensure certification to the process. Alternative qualification of machine operator may be carried out, if approved by the engineering authority. Example of such are included in SAE AMS 7005:2019, 4.8 and Appendix C and ISO 24394 but with adaptations to the specific DED process and type of DED machine user interface.

NOTE DED processes within the scope of this document share many of the key characteristics with established welding processes such as MIG/MAG (GMAW), TIG (GTAW) and plasma (PAW) as well as mixed variants. The user interface is standardized or manufacturer-specific.

Practical and theoretical examinations are required. For the practical examination, the machine operator sets up the machine for the process and prepares it for the product to be manufactured. This is done on the basis of an APS and a prepared product-specific programme as well as internal specifications.

Machine set-up can include the following:

- wire change;
- change of protective gas supply;
- replacement of wearing parts;
- cleaning of the machine;
- loading the production programme;
- inspection of the overall condition of the machine;
- maintenance.

The content of the theoretical examination shall be adapted to the DED process and the DED machine type of user interface. Testing and evaluation are the responsibility of the welding or additive

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manufacturing coordinator, examiner or examining body and shall be documented. For the theoretical examination, the guidelines for the theoretical part of the examination from ISO 24394 can be applied, if applicable. A company defined training program per SAE AMS 7005:2019, Clause C.2 may be used if approved by the engineering authority.

In the practical part of the test, the machine operator shall prove the ability to operate the DED machine according to an existing APS. Defined test pieces or production parts can be used for practical testing.

An example for a certificate for a machine operator test can be found in Annex A, Annex A.

6 Qualification of the DED machine

6.1 Machine qualification

Each individual DED machine shall be qualified by a qualification test programme within its working range, (see ISO 17662 or SAE AMS 7032 for information) as specified by the machine user and approved by the engineering authority.

The machine qualification test programme shall include the main activities of calibration/verification, deposition of test specimens and established maintenance plan.

Within the scope of this document, a DED machine can consist of the following components. Depending on the type of machine, the following can be verified, if applicable:

- power source (see IEC 60974-14);
- moving axes (see ISO 14744-4, ISO 14744-5 and ISO 15616-2 for general guidance, although the application is formally limited to beam welding, or for industrial robots see ISO 9283);
- wire feed rate according to the wire diameter and the wire feedstock;
- wire straightening;
- wire alignment to melt pool feed point;
- machine environment;
- enclosure of the machine or the work area, if needed;
- machine controller;
- control systems (e.g. temperature, weld pool size, process height);
- process gases;
- hot wire system;
- heat treatment system for substrate/build platform (if applicable);
- appropriate build of test samples to evaluate the machine functionality;
- machine and auxiliary equipment software version(s);

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