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Additive manufacturing of metals — Qualification principles —

Part 1: General qualification of operators

Fabrication additive de métaux — Principes de qualification —
Partie 1: Qualification générale des opérateurs

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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 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, 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).

A list of all parts of the ISO/ASTM 52926 group standard can be found on the ISO website.

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

For many companies, additive manufacturing represents an alternative to more conventional manufacturing processes such as casting, forging and milling. The trend towards complex components, decentralised production and customer specific products allows an economically feasible use for more and more areas. This also applies to many series applications, which comprise completely different demands on the efficiency of the processes. In particular, components used in different fields (e.g., automotive industry, mechanical engineering, railway sector, aerospace, process and industrial plants, medical technology, etc.) are subject to high demands in terms of quality and safety. This creates a need for norms and standards that provide a transparent baseline for the production of components for a great variety of application areas.

The manufacturing of products used for applications subjected to specific requirements, relies on that the products' compliance to these requirements can be assured. Additive manufacturing is no exception to this. To this end, the production chain and environment should be designed in such a way that the process quality and the resulting product quality are always consistent and reproducible. To assure this consistency and reproducibility, it is of utmost importance to ensure that the involved workforce is adequately qualified for all stages in the production.

Since this document is designed not to be cross-technology, the different processes are indicated in the relevant four parts of the standard.

This document offers a common approach for the qualification of professionals in AM. If the requirements of ISO/ASTM 52926 series are fulfilled, the scope of an audit can be greatly reduced.

Additive manufacturing of metals — Qualification principles —

Part 1: General qualification of operators

1 Scope

This document specifies the activities and responsibilities of the AM operators in the field of the additive manufacturing (AM) technologies dealing with metallic parts production.

This document is intended to provide guidance for qualification of AM machine operators in general industrial applications. Where industry-specific requirements exist for the qualification of AM operators, such as ISO/ASTM 52942 for aerospace applications, those industry-specific standards are used instead of this document.

2 Normative references

The following documents are referred to in the text in such a way that some or all 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*

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 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
AM operator, noun
AM machine operator
AM system operator
person who operates machines and auxiliary equipment in the additive manufacturing system

Note 1 to entry: AM system operators normally follow specified procedures and instructions for the AM process and associated requirements, for example, preparation of the equipment and EHS.

3.2
examiner, noun
person who has been appointed to verify conformance to the applicable standard

Note 1 to entry: In certain cases, an external independent examiner can be required [see ISO/IEC 17024].

[SOURCE: ISO 14732:—, 3.12, modified Note 1 to entry to include a reference to ISO/IEC 17024].

4 Operator qualification

4.1 General

The qualification test for AM system/machine operators should follow a suitable documented procedure and include the assessment principles defined in each specific part of ISO/ASTM 52926 series.

4.2 Essential variables and the range of qualification

4.2.1 General

The qualification of AM operators for additive manufacturing is based on essential variables. For each essential variable, a range for which the qualification is valid and applicable, is specified.

If the AM operator is expected to work outside the range of qualification, a new qualification test is required.

The essential variables concern:

a) The various AM processes for metals (see 4.2.2);

b) The various feedstock types and material groups (see 4.2.3);

c) The various types of AM machines (see 4.2.4).

4.2.2 The various AM processes for metal

There are several additive manufacturing processes for building parts in metallic materials. A general overview and illustrations of different AM process categories and materials is available in ISO 17296-2. Definitions for the different process categories are published in ISO/ASTM 52900, where a guideline for identification of the individual processes is available in Annex A, general description of fundamental process principles is available in ISO/ASTM 52900:2021, Annex B.

In this document specific DED and PBF processes for metal are addressed and the qualification depends on the process, so the AM operator has different qualifications for several processes. A new process requires a new qualification test.

The process-specific requirements are specified within the other parts of ISO/ASTM 52926, as listed below:

— ISO/ASTM 52926-2: Qualification of operators for PBF-LB;

— ISO/ASTM 52926-3: Qualification of operators for PBF-EB;

— ISO/ASTM 52926-4: Qualification of operators for DED-LB;

— ISO/ASTM 52926-5: Qualification of operators for DED-Arc.

4.2.3 The various feedstock types and material groups

The assessment in the framework of the qualification scope should be adapted according to the material group in use for production, as reported in ISO/ASTM 52942.

Material group A: Unalloyed steel, low-alloyed steels, high-alloyed ferritic steels.

Material group B: Austenitic, martensitic and precipitation hardening steels.

Material group C: Titanium and titanium alloys, niobium, zirconium, and other reactive metals.

Material group D: Aluminium and magnesium alloys.

Material group E: Materials that do not conform to other material groups (e.g. molybdenum, tungsten, copper alloys, titanium aluminide).

Material group F: Nickel alloys, cobalt alloys.

A qualification made in a single material group may also be extended according to the Table 1 provided the AM operator has shown knowledge of these materials during assessment.

Table 1 — Range of qualification for parent material

Material group used in qualification test	May qualify for material group					
	A	B	C	D	E	F
A	X	X				X
B	X	X				X
C			X			
D				X		
E					X	
F	X	X				X

Requirements differ between material groups due to various reasons, such as:

— compatibility of the material with selected shielding gas;

— hazards to personnel (e.g. inhalation or skin exposure to powders);

— hazards to equipment and facility (e.g. explosion, fire).

NOTE Where multiple material groups are used in a facility, typically a common procedure is utilised, that satisfies the most stringent requirements of all material groups used

4.2.4 The various types of AM machines

The difference in qualification requirements for different AM machines depend on differences between:

— AM machine manufacturer;

— Machine model - where different models from one manufacturer use identical operating procedures, all these models are qualified;

— Human machine interface (HMI) software version.

Requalification should be required when updates to the machine interface change operational procedures.

4.3 Assessment principles

An examiner should be designated, in writing, as responsible for the AM operator qualification test, requalification and/or disqualification.

The qualification body should specify a minimum pass mark that is no less than 60 % for each theoretical and practical test. Specific industry sectors or applications can require a higher minimum pass mark.

The theoretical and practical tests should include the content given in the different parts of the ISO/ASTM 52926 series when applicable.

For proving the practical skills, the AM operator should demonstrate the necessary process steps and skills for a specific AM process and machine. The candidate should also demonstrate the required skills in setting up the AM process in accordance with the relevant manufacturing plan.

The additional specific skills listed in the different parts ISO/ASTM 52926 series should be assessed on the practical qualification test when the specific tasks or skills are part of the AM operator role in the company.

The candidate should pass the theoretical test before advancing to the practical test.

The theoretical test is valid for AM process, feedstock (based on Table 1) and machine technology from different manufacturers. The successful completion of the theoretical test qualifies the candidate for practical assessment of multiple machines.

The candidate can take the combined test (theoretical and practical) a maximum of three times. Where the candidate fails a third time the relevant training should be repeated before attempting the test again.

5 Qualification test certificate

Wherever possible, the examination or assessment should be conducted by a person with a level of competence equal or higher than the person under assessment.

If the AM operator failed to pass the combined test (theoretical and practical), no qualification test certificate should be issued.

The certificate should contain as a minimum the following:

a) name;

b) employee number/unique identifier;

c) AM process for metal;

d) machine model (machine manufacturer, the specific machine type) of the machine(s) used for the practical assessment;

e) human machine interface (HMI) software version;

f) material group(s) addressed in the combined test;

g) if applicable, the trained and tested additional specific skills;

h) date of issue of the certificate;

i) expiration date for period of validity;

j) name and signature of the examiner.

The certificate should be issued under the responsibility of the examiner or examining body. A suggested certificate format is provided in Annex A.

6 Validity of testing

6.1 General

The qualification test certificate is valid only for the machine model, material(s), process(es) and skills which had been assessed and should be considered applicable to all applications.

The period of validity should be specified by the part manufacturer, based on the requirements of the application area(s) served, where these are specified.

When the period of validity is not specified by the part manufacturer or by the specific industry sector or application, a maximum validity of 5 years should apply.

The company or qualification body can choose to recognize a certificate from another entity or require to re-test the candidate, as necessary.

Where the function of the human machine interface (HMI) is changed in a way that requires additional training, due to a system software update, then a new qualification test and certificate is required.

6.2 Conditions of validity

The qualification test certificate is valid until there is a change to the qualified essential variables (see 4.2).

The validity of the test certificate expires in case of:

a) There is evidence that the AM operator doesn't fulfil the requirements of the qualification (e.g., unsatisfactory results consistently occur on representative parts, which are related to AM operator activities affecting the setup or performance of the system);

b) The AM operator has not been working for more than 6 months on the machine model of the qualification. A retention record is required.

6.3 Re-qualification test

Re-qualification test is required if one or more of the following conditions changes:

— The various AM processes for metals;

— The various feedstock types and material groups;

— The various types of AM machines;

— Certificate validity expired (see 6.2).

The re-qualification test can be given by any of the following methods or combinations of them:

a) a written objective test (each question of the test has 4 possible answers and only one is correct);

b) oral questioning following a set of written questions;

c) computer testing;

d) demonstration/observation testing to a written set of criteria.

The test of job knowledge is limited to the matters related to the AM process used in the test.

Annex A
(informative)

Qualification test certificate of machine operators for metallic parts production

Identification details

Qualification test certificate number: _____

Certification of operator qualification of machines for additive manufacturing of metallic parts (in accordance with ISO/ASTM 52926 series) for the process: _____

Surname, first name: _____

Employee number/unique identifier: _____

Employer and location: _____

Date of certification (dd-mm-yyyy) _____

Details of the test

Machine manufacturer and models: _____

Material group(s): _____

Human machine interface software version: _____

Description of the assessed advanced skills or any limitations, if applicable: _____

Identification of the examining body

Place of issue: _____

Date of issue (dd-mm-yyyy): _____

Certificate expiry date (dd-mm-yyyy): _____

Examining body or company _____

Examiner name: _____

Examiner signature _____

Requalification	Valid until