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Introduction

This draft standard is based on national and international discussions. Your comments on this draft are invited and will assist in the preparation of the consequent standard.

For international standards, comments will be reviewed by the relevant UK national committee before sending the consensus UK vote and comments to the international committee, which will then decide appropriate action. If the international standard is approved, it is usual for the text to be published as a British Standard.

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Template for comments and secretariat observations

Date: xx/xx/20xx	Document: ISO/DIS xxxx
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1	2	(3)	4	5	(6)	7
MB	Clause No./ Subclause No./Annex (e.g. 3.1)	Paragraph/ Figure/Table/Note	Type of comment	Comment (justification for change) by the MB	Proposed change by the MB	Secretariat observations on each comment submitted
	3.1	Definition 1	ed	Definition is ambiguous and needs clarifying.	Amend to read '...so that the mains connector to which no connection...'	
	6.4	Paragraph 2	te	The use of the UV photometer as an alternative cannot be supported as serious problems have been encountered in its use in the UK.	Delete reference to UV photometer.	

DRAFT INTERNATIONAL STANDARD

ISO/ASTM DIS 52948

ISO/TC 261

Secretariat: DIN

Voting begins on:
2023-10-02

Voting terminates on:
2023-12-25

Additive manufacturing for metals — Non-destructive testing and evaluation — Imperfections classification in PBF parts

Fabrication additive de métaux — Essais et évaluations non destructifs — Classification des imperfections dans les pièces PBF

ICS: 25.030; 19.100

This document is circulated as received from the committee secretariat.

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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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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 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).

Introduction

Metal laser powder bed fusion (PBF) additive manufacturing (AM) using a laser beam (PBF-LB) or an electron beam (PBF-EB) is in full development. It consists of depositing layers of powder on a tray and fusing each layer with a laser or electron beam. It is thus possible to produce parts of great geometric complexity.

The control of this process is the subject of numerous studies to attain the best possible quality. It is essential to supplement the approaches addressed by these studies with a standard describing observable imperfections to serve as a basis for non-destructive testing (NDT).

Knowledge of the imperfections generated by the manufacturing process and their standardised classification are preliminary and essential steps in defining and applying acceptance.

Additive manufacturing for metals — Non-destructive testing and evaluation — Imperfections classification in PBF parts

1 Scope

This document specifies the classification of imperfections likely to be generated during an additive manufacturing process by PBF-LB (laser beam powder bed fusion) or PBF-EB (electron beam powder bed fusion) for metallic parts.

This document also indicates the most probable causes of the formation of imperfections and includes illustrations.

This can be extended to other additive manufacturing process categories as long as no other related standard exists.

Acceptance criteria for imperfections are not included in this document.

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 version cited applies. For undated references, the latest version of the referenced document (including any amendments) applies.

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

ISO 3252, *Powder metallurgy — Vocabulary*

3 Terms and definitions

For the purposes of this document, the terms and definitions of ISO 3252, ISO/ASTM 52900 and the following apply.

ISO and IEC maintain terminological databases for use in standardisation at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <https://www.electropedia.org/>

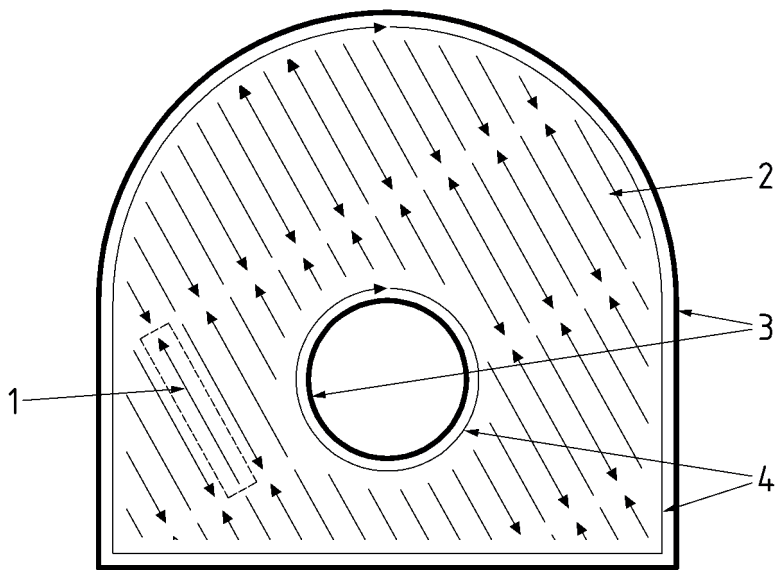
3.1

contour

one or a set of scan trajectories following the edges of the layer

Note 1 to entry: Among scanning strategies, it is very common to use one or more contours, which consist of paths that follow the edges of the layer.

Note 2 to entry: See [Figure 1](#).



- Key**
- 1 weld bead
 - 2 core scanning strategy
 - 3 geometric edge
 - 4 contour

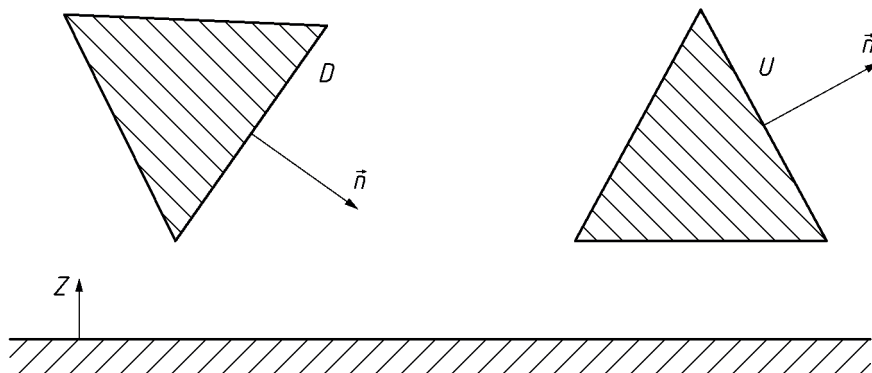
Figure 1 — Example of a manufacturing strategy using a contour

3.2
downskin area

D
(sub-)area where the normal vector projection on the z-axis is negative

Note 1 to entry: See [Figure 2](#).

[SOURCE: ISO/ASTM 52911-1, 3.2 modified — reference to Figure 2 instead of Figure 1]



- Key**
- $\vec{n}$ normal vector
 - D* downskin area (left)
 - U* upskin area (right)

Figure 2 — Upskin and downskin areas *U* and *D* (extracted from Figure 1 of ISO/ASTM 52911-1)

3.3

imperfection

any discontinuity or deviation observed from a specification (geometrical, material integrity)

3.4

lack of fusion

LOF

type of process-induced porosity, in which the powder or wire feedstock is not fully melted or fused onto the previously deposited substrate

Note 1 to entry: In PBF, this type of flaw can be an empty cavity, or contain unmelted or partially fused powder, referred to as unconsolidated powder.

Note 2 to entry: LOF typically occurs in the bulk, making its detection difficult.

Note 3 to entry: Like voids, LOF can occur on the build layer plane (layer/horizontal LOF) or across multiple build layers (cross layer/vertical LOF).

[SOURCE: ISO/TR ASTM 52905, 3.2]

3.5

powder spreading device

layering device

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

[SOURCE: ISO/ASTM 52941, 3.4 modified — addition of accepted term layering device]

3.6

scanning strategy

concept that describes the laser or electron beam path at each layer

Note 1 to entry: The scanning strategy is automatically generated by the machine or by upstream software. There is a wide variety of scanning strategies.

Note 2 to entry: See [Figure 3](#) where each arrow represents a weld bead.

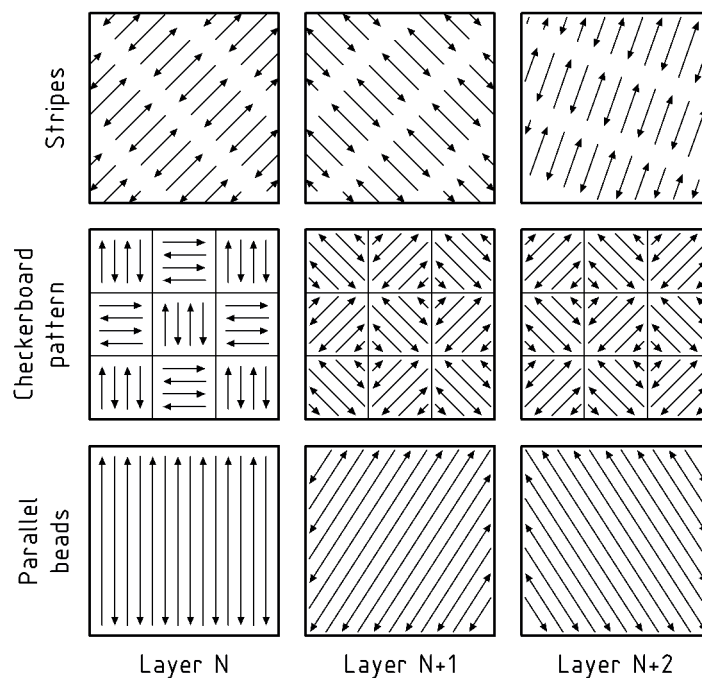


Figure 3 — Different types of scanning strategy

3.7
upskin area
U

(sub-)area where the normal vector *n* projection on the *z*-axis is positive

Note 1 to entry: See [Figure 2](#).

[SOURCE: ISO/ASTM 52911-1, 3.4 modified — reference to Figure 2 instead of Figure 1]

3.8
bead
continuous line of fused metal

4 Classification of imperfections

4.1 General

The principle of the classification (or numbering) system is based on six groups of imperfections according to [Table 1](#).

Table 1 — Classification of imperfection by type

Class	Imperfection type
1	Crack
2	Porosity
3	Solid inclusion
4	Lack of fusion ^a
5	Shape imperfection and dimensional imperfection ^b
6	Other imperfection type
^a Also defined as cross-layer or layer on ISO/ASTM TR 52905 and vertical LoF or Horizontal LoF in ASTM E3166.	
^b Equivalent to layer shift in ISO/ASTM TR 52905 and ASTM E3166.	

The occurrence of imperfections can be related to issues in the process or the machine (see [Annex B](#)), the powder (see [Annex C](#)), or issues arising during stages subsequent to the manufacturing process (see [Annex D](#)).

4.2 Designation

In this document, the imperfection class (or numbering) shall be preceded by the prefix PBF which corresponds to PBF processes using a laser or electron beam.

When a designation is required for an imperfection, it shall have the following structure:
ISO/ASTM 52948-PBF-[nnn].

With

- ISO/ASTM 52948 for reference to this document
- PBF indicating powder bed fusion (with laser or electron beam)
- nnn classification index according to the type of imperfection (see [4.3](#))

EXAMPLE The designation ISO/ASTM 52948-PBF-112 according to this document refers to a crack within a part produced using powder bed fusion.

To simplify reading, in the following imperfections are designated PBF- [nnn].

4.3 Detailed classification of imperfections occurring in additive manufacturing

4.3.1 General

For each type of imperfection, the [Tables 2](#) to [7](#) indicate its designation, position and orientation, an illustration if applicable, and the main causes and associated comments. Additional illustrations can be found in [Annex A](#).

4.3.2 Cracks

A crack shall be classified according to [Table 2](#).

NOTE ISO/ASTM 52911-1 on conception on post-treatment provides guidance on how to reduce cracks.

4.3.3 Porosity

Porosity shall be classified according to [Table 3](#).

4.3.4 Inclusions

Inclusions shall be classified according to [Table 4](#).

4.3.5 Lack of fusion

Lack of fusion shall be classified according to [Table 5](#).

4.3.6 Shape imperfections and dimensional imperfections

Shape imperfections and dimensional imperfections shall be classified according to [Table 6](#).

4.3.7 Other imperfections

Other imperfections shall be classified according to [Table 7](#).

Table 2 — Classification of cracks

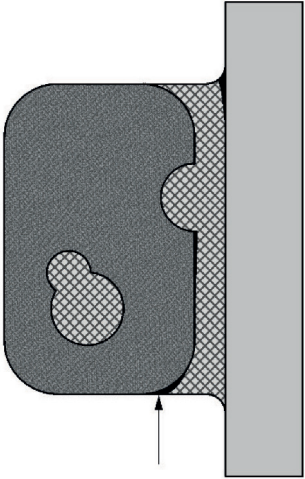
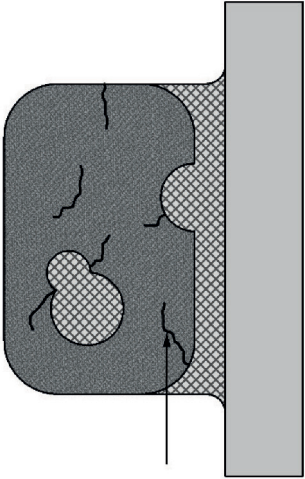
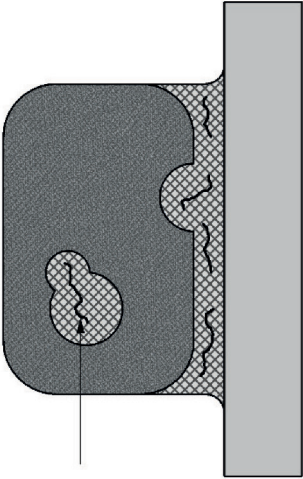
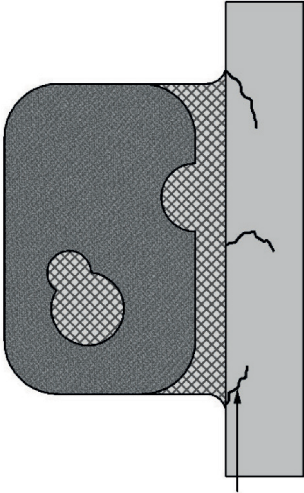
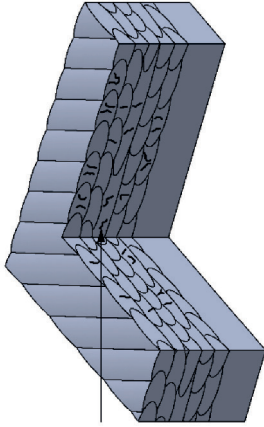
PBF no.	Designation	Typical location/orientation	Illustration	Main causes and comments
110	Crack	Stress concentration zone	NA	These are often cracks of mechanical origin resulting from the presence of significant residual stresses. These residual stresses and the risk of cracks are mitigated in the case of preheating build plate or chamber (in particular in PBF-EB). They appear after adding the top layers.
111	Crack at the interface between parts/support or parts/plate or Support/plate	Interface	 See also Figure A.1	Connections between zones, from a geometrical point of view (no connection radius for example), from a metallurgical point of view (lack of fusion, or from a mechanical point of view insufficient dimensioning) are frequently to blame. The process parameters can also be involved. Materials are unequally sensitive to the phenomenon. These imperfections can appear during subsequent heat treatment or cutting.
112	Part crack	Part		They are mainly due to the presence of high residual stresses and the part's geometry (a solid part with stress concentration zones will be more sensitive). The chosen process parameters also have an impact, as does the chosen grade.

Table 2 (continued)

PBF no.	Designation	Typical location/orientation	Illustration	Main causes and comments
113	Support crack	Support		They are mainly due to the presence of high residual stresses. An undersizing of the supports is possible. Supports geometry, sizing, and the process parameters used can also be the cause of the imperfection.
114	Crack in the plate	Plate		Cracks in the plate, generally initiated along a part, are due to residual stresses generated during manufacture which impact the plate. A weak or non-existent connection radius between the part and plate is detrimental, as are solid parts. The process parameters also have an important role.
120	Microcrack	None	NA	
121	Microcrack in core	Core	 See also Figure A.2	They are mainly related to solidification or microstructural phase changes. Metallurgical imperfection, often difficult to detect using NDT due to its size. Some materials, such as certain nickel alloys, are more sensitive. NOTE This type of crack is usually only visible under a microscope (x 50 minimum).