Technical
Report

ISO/ASTM TR 52958

Additive manufacturing of metals — Powder bed fusion (PBF) — In-situ coaxial photodiode monitoring for lack of fusion flaw detection in PBF-LB

Fabrication additive de métaux — Fusion sur lit de poudre — Surveillance par photodiode coaxiale in situ pour la détection de défauts de fusion en PBF-LB

Sample Document
get full document from standards.iteh.ai

First edition
2026-05

Reference number
ISO/ASTM TR 52958:2026(en)

© ISO/ASTM International 2026

Sample Document

get full document from standards.iteh.ai

COPYRIGHT PROTECTED DOCUMENT

© ISO/ASTM International 2026

All rights reserved. Unless otherwise specified, or required in the context of its implementation, no part of this publication may be reproduced or utilized otherwise in any form or by any means, electronic or mechanical, including photocopying, or posting on the internet or an intranet, without prior written permission. Permission can be requested from either ISO at the address below or ISO's member body in the country of the requester. In the United States, such requests should be sent to ASTM International.

ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11

Email: copyright@iso.org
Website: www.iso.org

ASTM International
100 Barr Harbor Drive, PO Box C700
West Conshohocken, PA 19428-2959, USA
Phone: +610 832 9634
Fax: +610 832 9635
Email: khooper@astm.org
Website: www.astm.org

Published in Switzerland

ISO/ASTM TR 52958:2026 • https://standards.iteh.ai/catalog/standards/iso/0a00a24b-2267-45e0-9e11-45b9add0c89f/iso-astm-tr-52958-2026

Contents

Page

Foreword .... **iv**

1 Scope **1**

2 Normative references **1**

3 Terms and definitions **1**

4 Significance and use **2**

5 Design of coupons **3**
- 5.1 General 3
- 5.2 Intentionally seeded flaws 4
- 5.3 Randomized/stochastic flaws 6

6 Sensor description **6**

7 Flaw detection algorithms **7**
- 7.1 General 7
- 7.2 Statistical algorithms 8
  - 7.2.1 General 8
  - 7.2.2 Absolute limits (AL) 9
  - 7.2.3 Short term fluctuations (STF) 11
  - 7.2.4 Workflow 11
- 7.3 Machine-learning approach: clustering algorithm 13
  - 7.3.1 Self-organizing map (SOM) 14
  - 7.3.2 *K*-means 15

8 Implementation of customized algorithms to components with randomized flaws and the associated voxelization thereof **16**

9 Case study: procedural implementation and validation results **19**

Bibliography **25**

Sample Document
get full document from standards.iteh.ai

© ISO/ASTM International 2026 – All rights reserved

ISO/ASTM TR 52958:2026 • https://standards.iteh.ai/catalog/standards/iso/0a00a24b-2267-45e0-9e11-45b9add0c89f/iso-astm-tr-52958-2026

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).

ISO draws attention to the possibility that the implementation of this document may involve the use of (a) patent(s). ISO takes no position concerning the evidence, validity or applicability of any claimed patent rights in respect thereof. As of the date of publication of this document, ISO had not received notice of (a) patent(s) which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at www.iso.org/patents. ISO shall not be held responsible for identifying any or all such patent rights.

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.

Sample Document

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).

Get full document from standards.iteh.ai

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.

© ISO/ASTM International 2026 – All rights reserved

Additive manufacturing of metals — Powder bed fusion (PBF) — In-situ coaxial photodiode monitoring for lack of fusion flaw detection in PBF-LB

1 Scope

This document provides a workflow comprising experimental procedures and flaw detection algorithms aimed at locating flaws in parts produced during the powder bed fusion-laser-based (PBF-LB) process of metals. It emphasizes the use of coaxial photodiode-based in-situ monitoring and statistical and clustering machine learning algorithms, particularly for detecting lack of fusion-induced flaws. The workflow delineates setting thresholds for statistical detection and determining the number of clusters for machine learning algorithms, utilizing intentional seeded flaws in parts. Validation procedures are provided through computed tomography scanner data. Hardware limitations and considerations for multi-laser processes are addressed, with attention to potential 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.

Sample Document

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

3 Terms and definitions

get full document from standards.iteh.ai

For the purposes of this document, the terms and definitions given in ISO/ASTM 52900 and the following apply:

ISO and IEC maintain terminology 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
clustering algorithm
unsupervised machine learning methods with unlabelled input data is grouped by similarity

3.2
coaxial photodiode arrangement
type of sensor arrangement on the powder bed fusion-laser-based machine aligned with the laser beam path

3.3
computed tomography
CT
non-destructive examination technique capturing radiographic projections of an object at various rotational angles followed by mathematically reconstruction to produce a three-dimensional volume data set or one or more two-dimensional cross-sectional images

© ISO/ASTM International 2026 – All rights reserved

ISO/ASTM TR 52958:2026 • https://standards.iteh.ai/catalog/standards/iso/0a00a24b-2267-45e0-9e11-45b9add0c89f/iso-astm-tr-52958-2026

3.4

data alignment

process of transforming different sets of geometrically or temporally related data into a single, global coordinate system

3.5

data registration

procedure of data alignment and assignation of a persistent identification to the aligned data set

3.6

ex-situ analysis

measurement procedure performed after the completion of the build cycle

3.7

flaw indicator

indicator corresponding to the location of flaws predicted by the flaw detection algorithm

3.8

lack of fusion

type of process-induced porosity with not fully melted or fused powder particles onto the previously deposited substrate.

[SOURCE: ASTM E3166-20, 3.4.7]

3.9

reference datum feature

notch, groove, or similar feature added to the geometry in a seeded flaw coupon to ease data alignment and registration of porosity locations for CT-scan ex-situ analysis

Sample Document

3.10

intentionally seeded flaw

act of intentionally creating flaws through computer-aided design or manipulation of designated processing parameters, resulting in the placement of the anticipated flaw or the act of intentionally creating a flaw through the insertion of an artificial object

get full document from standards.iteh.ai

4 Significance and use

A workflow for indirect flaw detection and analysis documentation during PBF-LB is provided by using the signals received from a coaxial photodiode that can detect flaws, including lack of fusion, in fabricated components.

These flaws may have detrimental effects on the mechanical performance of fabricated parts. The workflow of this document provides a procedure to identify the range of upper and lower thresholds required for the statistical detection algorithms to identify stochastic lack of fusion defects induced during the process. It provides a procedure to identify the number of clusters required for machine learning detection algorithms. In the validation procedure, the datasets collected from a CT scanner that are registered and voxelized can be used. It is noted that the size of detectable flaw, as determined by the procedure outlined in this document, is contingent upon the resolution and frequency of the hardware employed, specifically a co-axial photodiode and its associated data acquisition card. For instance, when utilizing a commonly available photodiode with a frequency of 60 kHz, the procedure and algorithms specified by this document are unable to detect flaws smaller than 100 µm.

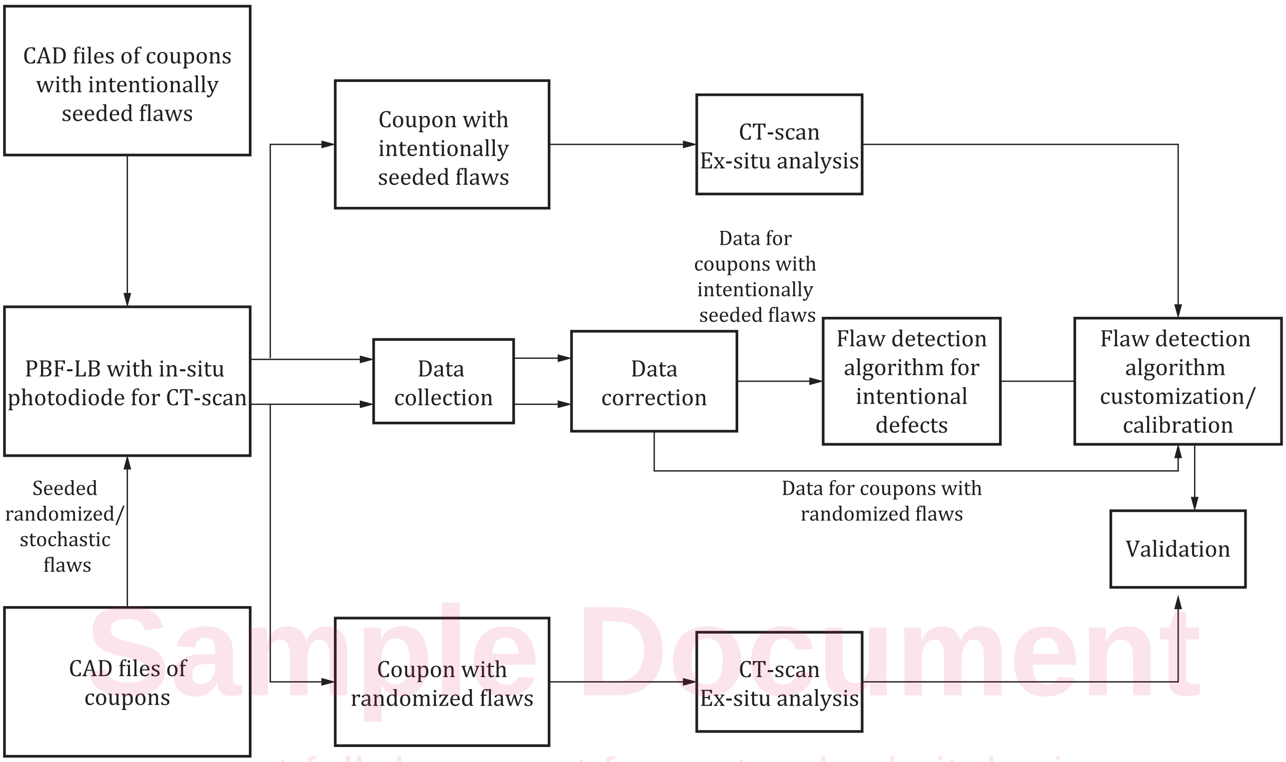
In general, an in situ photodiode installed coaxially provides information from the process signature and flaws. However, the recorded in situ data needs to be corrected to remove chromatic and monochromatic distortion. The corrected data analyse by two main algorithms to identify flaws:

a) statistically, and

b) by machine learning.

© ISO/ASTM International 2026 – All rights reserved

These algorithms can be systematically optimized and customized to detect lack of fusion flaws. To this end, intentionally seeded flaws are first added to the computer-aided design (CAD) of coupons to tune the parameters of the algorithms. Then, the customized algorithm is tested by detecting randomized/stochastic flaws created by powder bed fusion-laser based with intentionally decreased energy density. The comparison of detection results could be analysed by algorithms with the CT data applied through a volumetric approach to identify the randomized/stochastic flaws. A flowchart illustrating the progression in this document is shown in Figure 1.



Sample Document
get full document from standards.iteh.ai

Figure 1 — Schematic for calibration flow needed for detecting the lack of fusion flaw

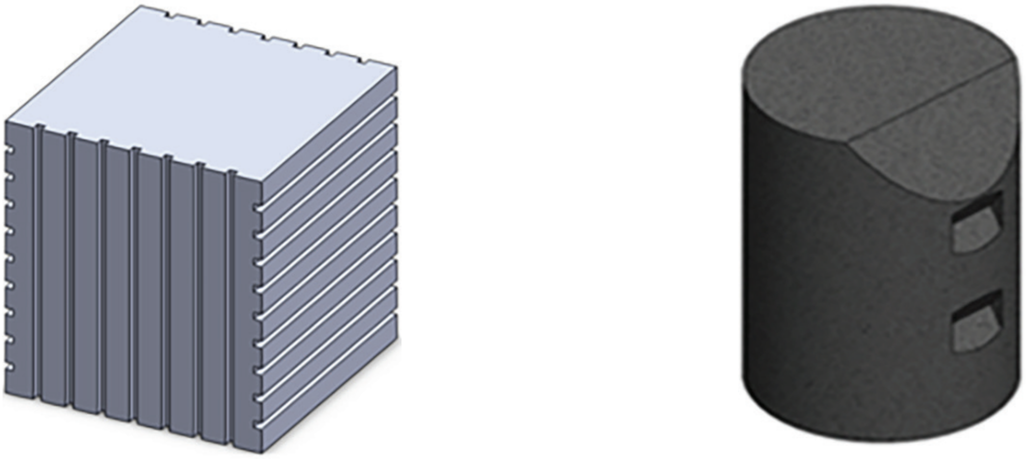
5 Design of coupons

5.1 General

To customize and calibrate the detection algorithms systematically, two sets of coupons are suggested. Reference datum features can also be added to the geometry to ease data alignment and data registration of porosity locations in the ex situ analysis that is CT-scan in this practice. Figure 2 represents some suggestions for registry notches/grooves.

© ISO/ASTM International 2026 – All rights reserved

ISO/ASTM TR 52958:2026 • https://standards.iteh.ai/catalog/standards/iso/0a00a24b-2267-45e0-9e11-45b9add0c89f/iso-astm-tr-52958-2026



a) Added vertical and horizontal registry grooves **b) Added inclined notches**

Figure 2 — Addition of registry grooves and inclined notches to the geometry of the coupon

5.2 Intentionally seeded flaws

The effect of the lack of fusion flaw can be mimicked by embedding intentional seeds/voids in the coupons. According to ISO/ASTM TR 52Same as above906[1], for creating these seeds, various sizes, distributions, and geometries of seeds can be added to the computer-aided design. Two forms of spherical and cylindrical intentional seeded flaws can be considered where the size of spherical flaws is identified by their diameter and the size of cylindrical flaws is identified by their cross-sectional diameter and height. Note that the minimum size of the intentional flaw is dictated by the PBF-LB restrictions. It is, however, recommended that the feature size of flaws is set in the computer-aided design model to three different classes:

Sample Document
Get full document from standards.iteh.ai

The minimum size possible to be made by the PBF-LB (for example 100 µm for the diameter of spheres and 100 µm for height and diameter of cylinders) depending on the resolution and laser spot size:

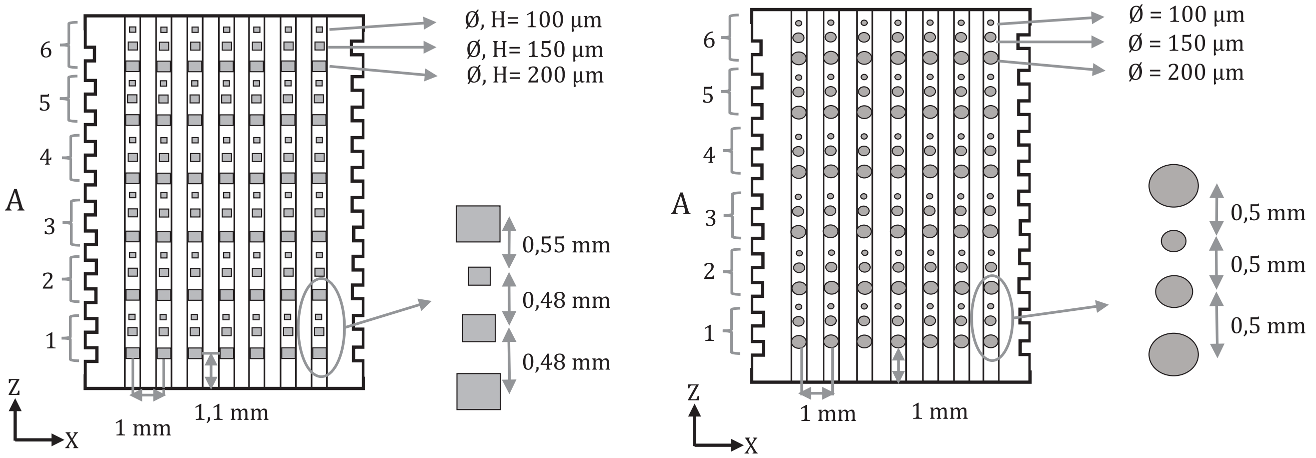
a) the minimum value plus 50 µm (for example 150 µm for the above-mentioned parameters);

b) the minimum value plus 100 µm (for example 200 µm for the above-mentioned parameters).

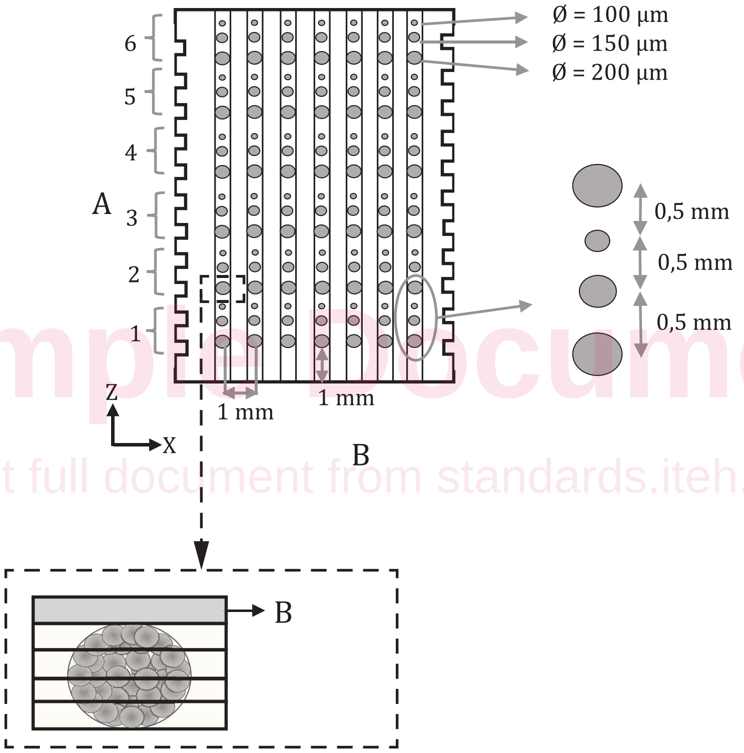
Note that within the layers in which the intentional flaws are made, an optimum down-skin parameter is used to endure the mechanical integrity of the intentional flaw. The capping layer, however, can have no down-skin setting.

Two examples of intentionally seeded flaws are shown in Figure 3. Figure 3 a) and b) represent two dimensional cross sections of samples showing the distribution of the intentionally seeded flaws (cylindrical and spherical), respectively. In Figure 3 a), six nominally identical sets of three sizes of cylindrical flaws (Ø, *H* = 200 µm, Ø, *H* = 150 µm, and Ø, *H* = 100 µm are shown; in Figure 3 b), six nominally identical sets of three sizes of spherical flaws (Ø = 200 µm, Ø = 150 µm, and Ø = 100 µm) where Ø is the diameter and *H* is the height, in microns, are demonstrated; in Figure 3 c), the capping layer of spherical flaws are represented.

© ISO/ASTM International 2026 – All rights reserved



a) Cylindrical type **b) Spherical type**



Sample Document
get full document from standards.iteh.ai

c) Schematic of spherical flaws showing the capping layer

Key

A	sets (clustered intentional voids)
B	capping layer

NOTE 1 All dimensions are in SI coordinate system.

NOTE 2 Figures 3 a) and 3 b) are published under an open access CC by 4.0 license.

Figure 3 — Two dimensional cross sections of samples showing the distribution of different types of intentionally seeded flaws

© ISO/ASTM International 2026 – All rights reserved