Designation: F3615 – 23

Standard Practice for Additive Manufacturing — Powder Bed Fusion — Condition-Defined Maintenance for Optical Systems[1]

This standard is issued under the fixed designation F3615; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice provides:

1.1.1 Recommendations for the design and integration of an area scan camera system (referred to as "camera system") into a laser powder bed fusion (PBF-LB/M) machine to assess the health condition of the scanner protective window (SPW),

1.1.2 Recommendations for data acquisition with the aforementioned system,

1.1.3 Description of a methodology for processing the aforementioned data, and

1.1.4 Recommendation on ex-situ measurements of laser beam parameters and part properties suitable for labeling of the processed condition data.

1.2 Many of the operational descriptions included in this practice are intended as general overviews. They may not present the detailed information required.

1.3 *Units*—The values stated in SI units are to be regarded as the standard. No other units of measurement are included in this standard.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 The following standards are referred to in the text in such a way that some or all of their content constitutes requirements of this practice. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced standard (including any amendments) applies.

2.2 *ISO Standards:*[2]

ISO 13372 Condition monitoring and diagnostics of machines — Vocabulary

ISO 17850 Photography — Digital cameras — Geometric distortion (GD) measurements

2.3 *ISO/ASTM Standards:*[3]

ISO/ASTM 52900 Terminology for Additive Manufacturing — General Principles — Terminology

ISO/ASTM 52930 Additive Manufacturing — Qualification principles — Installation, operation and performance (IQ/OQ/PQ) of PBF-LB equipment

2.4 *Federal Standard:*

U.S. Air Force MIL-STD-150A Photographic Lenses[4]

3. Terminology

3.1 *Definitions:*

3.1.1 Terminology for additive manufacturing (AM) can be found in ISO/ASTM 52900. Terms related to condition monitoring and machine maintenance can be found in ISO 13372.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *laser-affected area, n*—maximum area of an optical element that can be affected by the laser beam because of dynamic deflection of the laser beam (that is, by a moving mirror before said optical element).

3.2.1.1 *Discussion*—In a laser powder bed fusion (PBF-LB/M) machine, the laser-affected area corresponds to the maximum build area of the machine projected into the scanner protective window (SPW) plane.

3.2.2 *scanner protective window, SPW, n*—highly transmissive laser window installed in PBF-LB/M machines at the interface between the process chamber and the optical system

[1] This practice is under the jurisdiction of ASTM Committee F42 on Additive Manufacturing Technologies and is the direct responsibility of Subcommittee F42.01 on Test Methods.

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[2] Available from International Organization for Standardization (ISO), ISO Central Secretariat, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, https://www.iso.org.

[3] For referenced ASTM and ISO/ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[4] Available from https://www.dsp.dla.mil/Specs-Standards

to encapsulate sensitive optical elements (for example, focusing lenses, scanner mirrors) in a dust-tight manner and protect them from contamination.

4. Significance and Use

4.1 The overall objective of this practice is to provide recommendations for the systematic acquisition of image data that indicate the health condition of the wear-sensitive SPW in PBF-LB/M machines. These data may allow a user to determine calibration and maintenance cycles based on the actual health condition of the SPW.

4.2 The recommendations are intended for original equipment manufacturers (OEMs) of PBF-LB/M machines to provide guidance for the implementation of sensor systems to acquire spatially resolved data about the health condition of the SPW.

4.3 The recommendations are intended for users of PBF-LB/M machines to provide guidance for the assessment of the actual health condition of the SPW to:

4.3.1 Flag when a calibration or maintenance of the optical system is needed and alert the user or OEM to perform the calibration or maintenance and

4.3.2 Generate statistical estimates for the useful life, or critical health state, of the SPW based on data recorded over the long term. The statistics may be used to derive maintenance cycles that allow a better utilization of the useful life of the SPW than current predetermined maintenance cycles.

5. Camera System

5.1 This practice covers a camera system for monitoring the health condition of the SPW (contaminants or defects on SPW surface) consisting of:

5.1.1 Area scan camera,

5.1.2 Objective lens, and

5.1.3 Lighting.

5.2 The user of this standard should select the components of the camera system such that the laser-affected area of the SPW is imaged with a resolution of at least 30 µm/px (Fig. X1.1).

5.3 In some PBF-LB/M machines, the size of the SPW is designed to fit the laser-affected area, requiring monitoring of the entire SPW surface. For machines where the previous does not apply, the following can be considered to select the components:

5.3.1 The short sensor edge of the camera is required to image the largest dimension of the laser-affected area, $D_{LA,SPW}$, in sufficient resolution. The largest dimension of the laser-affected area may be estimated as follows:

$$D_{LA,SPW} = D\left(1 - \frac{e'}{e}\right) + d_{L,SPW} \quad [mm] \tag{1}$$

where:

D = maximum dimension of the build area,
$d_{L,SPW}$ = laser spot diameter in SPW plane,
e = working distance of the machine, and
e' = distance between SPW and the working plane (Fig. 1).

5.3.1.1 For the purpose of this practice, Eq 1 should be used as an approximation for both machines with dynamic focusing unit and machines with F-Theta lens. However, the user of this standard should be aware that Eq 1 contains simplifications that are acceptable for the purpose of this standard but lead to errors when applied to other matters.

5.3.2 For a Gaussian beam, the laser spot diameter, $d_{L,SPW}$, in the SPW plane is approximated as follows:

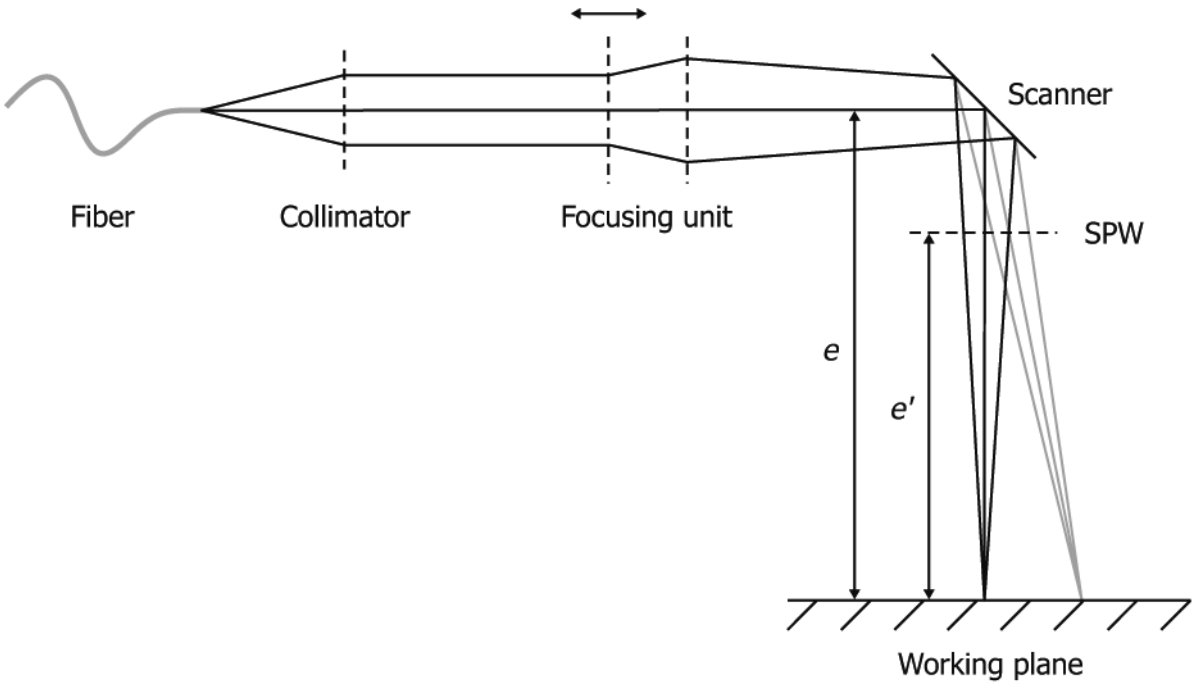

FIG. 1 Typical Layout of a PBF-LB/M Optical System and Relevant Distances