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Standard Guide for Additive Manufacturing of Metals — Data — File Structure for In-Process Monitoring of Powder Bed Fusion (PBF)[1]

This standard is issued under the fixed designation F3605; 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 guide provides standardized procedures and requirements for converting acquired in-process monitoring data into one file representing the printing process of powder bed fusion (PBF) for quality evaluation.

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

1.3 This guide covers:
1.3.1 Data registration,
1.3.2 Extraction of in-process data, and
1.3.3 File conversion and visualization.

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 *ISO/ASTM Standards:*[2]

ISO/ASTM 52900:2015 Standard Terminology for Additive Manufacturing — General Principles — Terminology

ISO/ASTM 52915:2020 Specification for Additive Manufacturing File Format (AMF) Version 1.2

ISO/ASTM 52921:2013 Standard Terminology for Additive Manufacturing — Coordinate Systems and Test Methodologies

3. Terminology

3.1 *Definitions*—For the purpose of this guide, refer to the terms and definitions in ISO/ASTM 52900:2015 and ISO/ASTM 52915:2020.

4. Summary of Guide

4.1 The raw data could be obtained from various in-process monitoring systems. This guide does not involve specific details of these systems, such as sensors and controllers. It is assumed that the user has completed the system setup and calibration and can successfully collect the in process monitoring data.

4.2 The user shall provide the details of the data-processing method and choose the information embedded into the final converted file to satisfy their special requirements. They shall be fully aware of the effect of data processing to avoid extracting misleading information and erroneous interpretation.

NOTE 1—Any data processing is recommended to be applied only to a working copy of the data with the raw data preserved.

4.3 The focus of this guide is on extracting and demonstrating the information from the printing process and leaves the part quality to the user to draw their own conclusion.

5. Significance and Use

5.1 The converted file will be organized in a specific structure to reflect the relationship between the in-process monitoring data with the quality of the printing process.

5.2 This standard file structure will help ensure the data compatibility across various printing systems, analyses, and illustration software. It aims to be self-explaining and easy to use to accommodate data sharing in a large base of users.

5.3 The converted file can be used for the evaluation of printing quality and the detections of defects and anomalies.

6. Data Registration

6.1 This necessary procedure aims to transform different sets of geometrically or temporally related in-process data into a single and global coordinate system before converting them into one file.

[1] This guide is under the jurisdiction of ASTM Committee F42 on Additive Manufacturing Technologies and is the direct responsibility of Subcommittee F42.08 on Data.

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[2] For referenced 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.

6.2 The in-process data include all the information acquired from the layer-wise raw data captured by monitoring sensors in the powder bed fusion (PBF) process.

NOTE 2—The layer-wise raw data refers to all the raw data that are acquired during the printing process of each layer (or each build cycle).

NOTE 3—Different sensors generate various layer-wise data types (for example, temperature sequence at a certain point or line, optical or infrared image, topography data by three dimensional (3D) camera). The raw data for each layer are a time series of data (for example, images, videos). In the PBF process, all data can be processed and transformed into a static (non-temporal) representation for each layer.

6.3 The registration method depends on the data acquisition method.

6.3.1 The in-process data captured by various sensors with different characteristics usually have different resolutions, sampling frequencies, and so forth. Data registration could be based on the characteristic parameters of lower-resolution or higher-resolution sensors. Data interpolation or omission may be applied to match all the data from different-performance sensors during registration.

6.3.2 For the synchronously acquired data, the spatial coordinate is aligned during data registration. In Fig. 1, data registration of the synchronously acquired layer-wise images from different sensors is presented.

NOTE 4—Synchronously acquired data refer to data that are acquired by various sensors, in which all data points from one sensor can be matched or referenced to any data point of the other sensor.

6.3.3 For the asynchronously acquired data, both the spatial and temporal coordinates are aligned during data registration.

NOTE 5—Asynchronously acquired data refer to data that are acquired by various sensors and have different starting times or sample frequencies.

6.3.4 Data interpolation or omission during the spatial and temporal alignment may affect data accuracy and introduce errors.

7. Extraction of In-Process Data

7.1 The sensors in the PBF process capture a larger amount of layer-wise raw data. The user may not be interested in all of them. Extraction of in-process data is intended to extract data from the registered layer-wise data based on the user's special requirements, for example, data of a certain type or data from region of interest (ROI).

7.2 *Extraction Processes:*

7.2.1 Pre-process the registered data for each layer.

7.2.2 Choose the representative layer-wise data at a designated time of each build cycle according to the user's requirements (for example, after laser scanning or after powder coating) and transform the layer-wise registered data into a static (non-temporal) representation for each layer and so the layer number coincides with the z axis.

NOTE 6—In the PBF process, the data of each layer (or build cycle) usually have the same z coordinate calculated by multiplying layer number and height. If the representative layer-wise data is not chosen at a designated time for each layer (or build cycle), a time series of data (for example, images, videos) yield multiple data points at the same x, y, and z coordinates and the converted 3D file will fail to be read and visualized by the visualization tools.

7.2.3 Determine the sampling points and their space coordinates for the extracted data of each layer.

7.2.3.1 All the sampling points in the extracted data are defined by x, y, and z coordinates; the time axis follows the z axis in the PBF process.

7.2.3.2 Considering the different characteristics of various sensors, file size, data accuracy, data processing time, and so forth, a compromise should be made when determining the sample size.

7.2.4 Extract the in-process information of all sampling points for each layer.

7.2.4.1 The basic in-process information that will be embedded into the final file is directly extracted from the layer-wise data, such as temperature values from thermocouple or infrared (IR) images, or gray values from optical images.

NOTE 7—In the ith layer (having the same z coordinates expressed as z_i), the point extracted data have fixed x and y coordinates [for example, $S_i = f(x_0,y_0,z_i)$]; the 1D extracted data have varing x or y coordinates [for example, $S_i = f(x,y_0,z_i)$]; the 2D extracted data have varying x and y

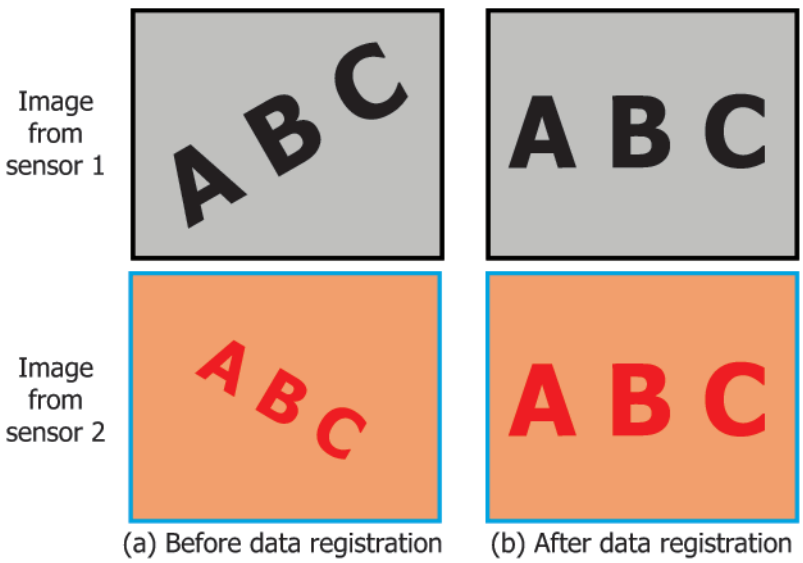

FIG. 1 Layer-Wise Images from Different Sensors (a) Before and (b) After Data Registration