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.

INTERNATIONAL

Designation: F3530 – 22

Standard Guide for Additive Manufacturing — Design — Post-Processing for Metal PBF-LB[1]

This standard is issued under the fixed designation F3530; 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 document provides guidance to designers who are considering the use of metal Laser Powder Bed Fusion (PBF-LB) method for their products. This guide outlines the following post-processing operations that can be considered after completion of a build on a metal additive manufacturing system:

1.1.1 Powder removal,

1.1.2 Thermal post-processing,

1.1.3 Build platform removal,

1.1.4 Support removal,

1.1.5 Machining, and

1.1.6 Surface finishing.

1.2 The topics of non-destructive testing (NDT) and inspection are beyond the scope of this document as it requires a comprehensive guide in its own right. Also, outside the scope are other metal PBF processes such as powder bed fusion – electron beam (PBF-EB) and hybrid additive manufacturing (methods combining additive manufacturing and subtractive manufacturing technologies in a single machine).

1.3 With respect to existing ISO/ASTM standards, this guide is positioned between ISO/ASTM 52910 and process-specific design guidelines such as ISO/ASTM 52911-1.

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 existing standards are relevant to additive manufacturing (AM) design.

2.2 *ISO/ASTM Standards:*[2]

52900 Additive manufacturing — General Principles — Fundamental and vocabulary

52910 Additive manufacturing — Design — Requirements, guidelines and recommendations

52911-1 Additive manufacturing — Design — Part 1: Laser-based powder bed fusion of metals

3. Terminology

3.1 Terminology relating to additive manufacturing in ISO/ASTM 52900 shall apply.

3.2 *Acronyms:*

3.2.1 *3D*—3-dimensional

3.2.2 *AM*—additive manufacturing

3.2.3 *CAD*—computer aided design

3.2.4 *CMM*—coordinate measurement machine

3.2.5 *CNC*—computerized numerical control

3.2.6 *ECM*—electro-chemical machining

3.2.7 *EDM*—electrical discharge machining

3.2.8 *FEA*—finite element analysis

3.2.9 *HAZ*—heat affected zone

3.2.10 *HIP*—hot isostatic pressing

3.2.11 *LM*—laser melting

3.2.12 *PBF-LB*—powder bed fusion – laser beam

3.2.13 *NDT*—non-destructive testing

3.2.14 *RFPE*—reference free part encapsulation

3.2.15 *XCT*—X-ray computed tomography

[1] This guide is under the jurisdiction of ASTM Committee F42 on Additive Manufacturing Technologies and is the direct responsibility of Subcommittee F42.04 on Design.

Current edition approved April 1, 2022. Published July 2022. DOI: 10.1520/F3530-22.

[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.

Copyright © ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959. United States

4. AM Process Workflow

4.1 Similar to other production methods, the first step in the AM workflow begins with an idea of the part to build. An AM part must start in a software that describes its geometry.

4.1.1 Commonly, the AM process workflow is often perceived to be as simple as modelling the CAD geometry and transferring it to the machine to obtain the final part. In practice, there are a number of other key steps involved in the process as illustrated in Fig. 1. Although the workflow is illustrated linearly, this is often iterative, for example, lessons learned from a preliminary build or post-process feedback into a new iteration of the design for manufacture or build preparation. See ISO/ASTM 52910 for more detail.

4.1.2 AM has its own manufacturing constraints. Therefore, the next stages consider reducing risk in the design for the specific AM process.

4.1.3 Once the part is built, it is post-processed. This generally involves de-powdering, thermal post-processing, build platform and support removal, machining critical interfaces (if required) and surface finishing etc.

4.1.4 Finally, the part could be inspected using various contact and non-contact methods such as structured light/laser scanning, XCT and CMM etc. These steps are outside the scope of this document.

5. The Importance of Design for AM Post-Processing

5.1 To design optimum parts to be built using AM, consideration must be given to the manufacturing process. Every step downstream in the process should be considered during the design stage (even if it is being outsourced to a bureau service) to ensure a suitable outcome is achieved. Fig. 2 depicts some of the downstream requirements to be taken into consideration in the design phase. Taking care of these requirements will not only improve the final product but also reduce the associated health and safety risks due to powders, part design, and operators exposure to machines when post-processing.

5.2 If the build and post-processing requirements are not considered at the design stage, there is a higher likelihood that redesigns and rebuilds of the part may be necessary. The consequences of a redesign or rebuild may include:

5.2.1 Increased costs due to failed builds or repeated builds due to quality issues.

5.2.2 Reduced functionality, for example, as-built surface roughness or parts not to tolerance.

5.2.3 Wasted resources if builds fail and parts have to be scrapped.

5.2.4 Waste of material and resources from support structures and sacrificial build features.

5.2.5 Time delays caused by unsuccessful builds or excessive post-processing.

5.3 Most AM parts will need some form of post-processing after the actual 'build' process has taken place. Depending on the AM process used, the geometry of a part, and the desired properties, different post-processing may be needed. Typical operations carried out after a metal PBF-LB build are described in the next sections with their challenges and design considerations. Description of how each process is carried out with common methods can be found in the appendix.

6. Powder Removal

6.1 *Background:*

6.1.1 PBF processes fill the whole volume of the build chamber with powder during a build, irrespective of the part's geometry. Therefore, once the AM build is complete, the part must be removed from the powder and will require depowdering. The removed powder can be sieved and recycled for the next build.

6.1.2 Powder removal may also be critical to eliminate contamination of other systems or patient requirements for implanted parts.

6.2 *Challenges in Powder Removal:*

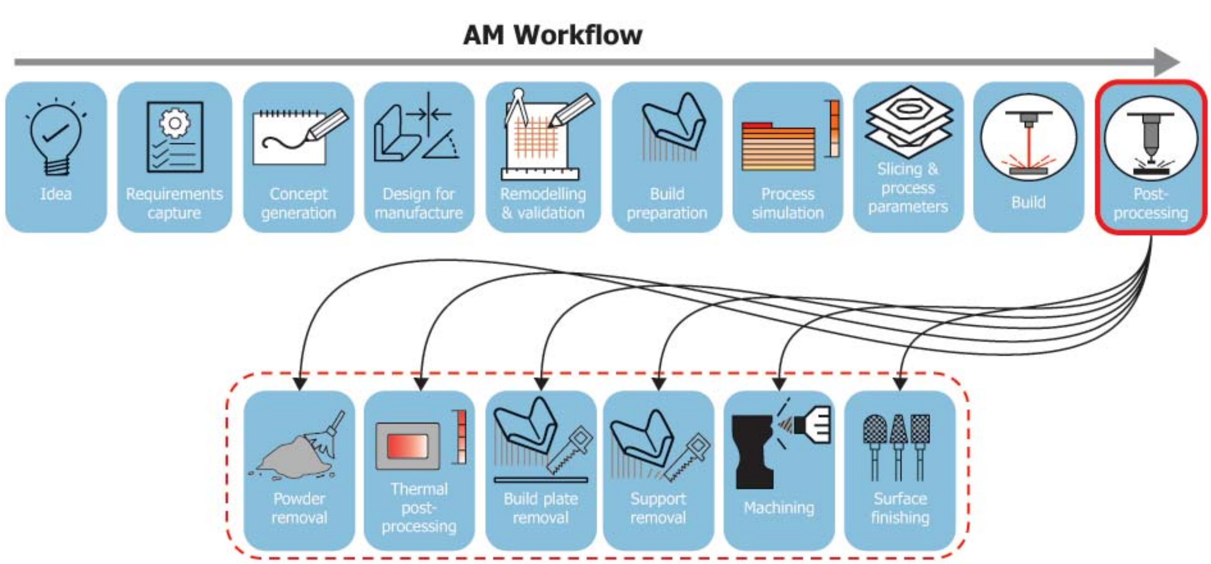

FIG. 1 Typical AM Workflow and Post-Processing Steps (Copyright MTC, all rights reserved)