Additive manufacturing — Design — Requirements, guidelines and recommendations[1]

This standard is issued under the fixed designation ISO/ASTM 52910; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision.

1. Scope

1.1 This document gives requirements, guidelines and recommendations for using additive manufacturing (AM) in product design.

1.2 It is applicable during the design of all types of products, devices, systems, components or parts that are fabricated by any type of AM system. This document helps determine which design considerations can be utilized in a design project or to take advantage of the capabilities of an AM process.

1.3 General guidance and identification of issues are supported, but specific design solutions and process-specific or material-specific data are not supported.

1.4 The intended audience comprises three types of users:

1.4.1 designers who are designing products to be fabricated in an AM system and their managers;

1.4.2 students who are learning mechanical design and computer-aided design; and

1.4.3 developers of AM design guidelines and design guidance systems.

1.5 *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 and health practices and determine the applicability of regulatory limitations prior to use.*

2. Normative references

2.1 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 reference document (including any amendments) applies.

2.2 *ISO/ASTM Standard:*[2]

ISO/ASTM 52921 Standard terminology for additive manufacturing – Coordinate systems and test methodologies

3. Terms and Definitions

3.1 *Definitions:* For the purposes of this document, the terms and definitions given in ISO/ASTM 52921 and the following apply.[3]

Additive manufacturing processes categories

3.1.1 *binder jetting*—additive manufacturing process in which a liquid bonding agent is selectively deposited to join powder materials. **[SOURCE: ISO/ASTM 52900:—[4]]**

3.1.2 *directed energy deposition*—additive manufacturing process in which focused thermal energy is used to fuse materials by melting as they are being deposited. **[SOURCE: ISO/ASTM 52900: —Note to entry has been deleted]**

3.1.3 *material extrusion*—additive manufacturing process in which material is selectively dispensed through a nozzle or orifice. **[SOURCE: ISO/ASTM 52900]**

3.1.4 *material jetting*—additive manufacturing process in which droplets of build material are selectively deposited. **[SOURCE: ISO/ASTM 52900: —Note to entry has been deleted]**

3.1.5 *powder bed fusion*—additive manufacturing process in which thermal energy selectively fuses regions of a powder bed. **[SOURCE: ISO/ASTM 52900]**

3.1.6 *sheet lamination*—additive manufacturing process in which sheets of material are bonded to form an object. **[SOURCE: ISO/ASTM 52900: —"a part" has been replaced with "an object"]**

3.1.7 *vat photopolymerization*—additive manufacturing process in which liquid photopolymer in a vat is selectively cured by light-activated polymerization. **[SOURCE: ISO/ASTM 52900]**

3.2 *Other definitions:*

3.2.1 *design consideration*—topic that can influence decisions made by a part designer.

3.2.1.1 *Discussion*—The designer determines to what extent the topic can affect the part being designed and takes appropriate action.

---

[1] This international standard is under the jurisdiction of ASTM Committee F42 on Additive Manufacturing Technologies and is the direct responsibility of Subcommittee F42.04 on Design and is also under the jurisdiction of ISO/TC 261.

Current edition approved July 23, 2018. Published July 2018. DOI: 10.1520/ISO_ASTM59210-18.

[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.

[3] ISO and IEC maintain terminological databases for use in standardization at the following addresses: ISO Online browsing platform: available at http://www.iso.org/obp, and IEC Electropedia: available at http://www.electropedia.org/.

[4] Under preparation. Stage at the time of publication: ISO/DIS 52900:2018.

3.2.2 *process chain*—sequence of manufacturing processes that is necessary for the part to achieve all of its desired properties.

4. Purpose

4.1 This document provides requirements, guidelines and recommendations for designing parts and products to be produced by AM processes. Conditions of the part or product that favor AM are highlighted. Similarly, conditions that favor conventional manufacturing processes are also highlighted. The main elements include the following:

4.1.1 the opportunities and design freedoms that AM offers designers (Clause 5).

4.1.2 the issues that designers should consider when designing parts for AM, which comprises the main content of these guidelines (Clause 6), and

4.1.3 warnings to designers, or "red flag" issues, that indicate situations that often lead to problems in many AM systems (Clause 7).

4.2 The overall strategy of design for AM is illustrated in Fig. 1. It is a representative process for designing mechanical parts for structural applications, where cost is the primary decision criterion. The designer could replace cost with quality, delivery time, or other decision criterion, if applicable. In addition to technical considerations related to functional, mechanical or process characteristics, the designer should also consider risks associated with the selection of AM processes.

4.3 The process for identifying general potential for fabrication by AM is illustrated in Fig. 2. This is an expansion of the "identification of general AM potential" box on the left side of Fig. 1. As illustrated, the main decision criteria focus on material availability, whether or not the part fits within a machine's build volume, and the identification of at least one part characteristic (customization, lightweighting, complex geometry) for which AM is particularly well suited. These criteria are representative of many mechanical engineering applications for technical parts, but are not meant to be complete.

4.4 An expansion for the "AM process selection" box in Fig. 1 is presented in Fig. 3, illustrating that the choice of material is critical in identifying a suitable process or processes. If a suitable material and process combination can be identified, then consideration of other design requirements can proceed, including surface considerations and geometry, static physical and dynamic physical properties, among others. These figures are meant to be illustrative of typical practice for many types of mechanical parts, but should not be interpreted as prescribing necessary practice.

5. Design opportunities and limitations

5.1 *General*

Additive manufacturing differs from other manufacturing processes for several reasons and these differences lead to unique design opportunities and freedoms that are highlighted here. As a general rule, if a part can be fabricated economically using a conventional manufacturing process, that part should probably not be produced using AM. Instead, parts that are good candidates for AM tend to have complex geometries, custom geometries, low production volumes, special combinations of properties or characteristics, or some combination of these characteristics. As processes and materials improve, the emphasis on these characteristics will likely change. In Clause 5, some design opportunities are highlighted and some typical limitations are identified.

5.2 *Design opportunities:*

5.2.1 *Background*—AM fabricates parts by adding material in a layer-by-layer manner. Due to the nature of AM processes, AM has many more degrees of freedom than other manufacturing processes. For example, a part can be composed of millions of droplets if fabricated in a material jetting process. Discrete control over millions of operations at micro to nano scales is both an opportunity and a challenge. Unprecedented levels of interdependence are evident among considerations and manufacturing process variables, which distinguishes AM from conventional manufacturing processes. Capabilities to take advantage of design opportunities can be limited by the complexities of process planning.

5.2.2 *Overview*—The layer-based, additive nature means that virtually any part shapes can be fabricated without hard tooling, such as molds, dies or fixtures. Geometries that are customized to individuals (customers or patients) can be economically fabricated. Very sophisticated geometric constructions are possible using cellular structures (honeycombs, lattices, foams) or more general structures. Often, multiple parts that were conventionally manufactured can be replaced with a single part, or smaller number of parts, that is geometrically more complex than the parts being replaced. This can lead to the development of parts that are lighter and perform better than the assemblies they replace. Furthermore, such part count reduction (called part consolidation) has numerous benefits for downstream activities. Assembly time, repair time, shop floor complexity, replacement part inventory and tooling can be reduced, leading to cost savings throughout the life of the product. An additional consideration is that geometrically complex medical models can be fabricated easily from medical image data.

5.2.3 In many AM processes, material compositions or properties can be varied throughout a part. This capability leads to functionally graded parts, in which desired mechanical property distributions can be fabricated by varying either material composition or material microstructure. If effective mechanical properties are desired to vary throughout a part, the designer can achieve this by taking advantage of the geometric complexity capability of AM processes. If varying material composition or microstructure is desired, then such variations can often be achieved, but with limits dependent on the specific process and machine. Across the range of AM processes, some processes enable point-by-point material variation control, some provide discrete control within a layer, and almost all processes enable discrete control between layers (vat photopolymerization is the exception). In the material jetting and binder jetting processes, material composition can be varied in virtually a continuous manner, droplet-to-droplet or even by mixing droplets. Similarly, the directed energy deposition process can produce variable material compositions by varying