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Additive manufacturing — General principles — Fundamentals and vocabulary

Fabrication additive — Principes généraux — Fondamentaux et vocabulaire

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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).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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.

This document was prepared by 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).

This second edition of ISO/ASTM 52900 replaces the first edition (ISO/ASTM 52900:2015), which has been technically revised. The main changes compared to the previous edition are as follows:

- new and modified terms and definitions;
- abbreviations added for seven process categories;
- new annex for the specification of AM processes based on process categories and determining characteristics ([Annex A](#)).

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.

Introduction

Additive manufacturing (AM) is the general term for those technologies that successively join material to create physical objects as specified by 3D model data. These technologies are presently used for various applications in engineering industry as well as other areas of society, such as medicine, education, architecture, cartography, toys and entertainment.

During the development of additive manufacturing technology, there have been numerous different terms and definitions in use, often with reference to specific application areas and trademarks. This is often ambiguous and confusing, which hampers communication and wider application of this technology.

It is the intention of this document to provide a basic understanding of the fundamental principles for additive manufacturing processes, and based on this, to give clear definitions for terms and nomenclature associated with additive manufacturing technology. The objective of this standardization of terminology for additive manufacturing is to facilitate communication between people involved in this field of technology on a worldwide basis.

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Additive manufacturing — General principles — Fundamentals and vocabulary

1 Scope

This document establishes and defines terms used in additive manufacturing (AM) technology, which applies the additive shaping principle and thereby builds physical three-dimensional (3D) geometries by successive addition of material.

The terms have been classified into specific fields of application.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

ISO and IEC maintain terminological 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 General terms

3.1.1

3D printer, noun

machine used for *3D printing* (3.3.1)

3.1.2

additive manufacturing, noun

AM

process of joining materials to make *parts* (3.9.1) from 3D model data, usually *layer* (3.3.7) upon layer, as opposed to subtractive manufacturing and formative manufacturing methodologies

Note 1 to entry: Historical terms include: additive fabrication, additive processes, additive techniques, additive layer manufacturing, layer manufacturing, solid freeform fabrication and freeform fabrication.

Note 2 to entry: The meaning of “additive-”, “subtractive-” and “formative-” manufacturing methodologies is further discussed in [Annex B](#).

3.1.3

additive system, noun

additive manufacturing system

additive manufacturing equipment

machine and auxiliary equipment used for *additive manufacturing* (3.1.2)

3.1.4

AM machine, noun

section of the *additive manufacturing system* (3.1.3) including hardware, machine control software, required set-up software and peripheral accessories necessary to complete a *build cycle* (3.3.8) for producing *parts* (3.9.1)

3.1.5

AM machine user, noun

operator of or entity using an *AM machine* (3.1.4)

3.1.6

AM system user, noun

additive system user

operator of or entity using an entire *additive manufacturing system* (3.1.3) or any component of an *additive system* (3.1.3)

3.1.7

front, noun

<of a machine; unless otherwise designated by the machine builder> side of the machine that the operator faces to access the user interface, or primary viewing window, or both

3.1.8

material supplier, noun

provider of material/*feedstock* (3.6.6) to be processed in an *additive manufacturing system* (3.1.3)

3.1.9

multi-step process, noun

type of *additive manufacturing* (3.1.2) process in which *parts* (3.9.1) are fabricated in two or more operations where the first typically provides the basic geometric shape and the following consolidates the part to the fundamental properties of the intended material

Note 1 to entry: Fundamental properties of the intended product material are typically metallic properties for intended metallic products, ceramic properties for intended ceramic products, polymer properties for intended polymer (plastic) products and composite material properties for products intended to be made of a composite material.

Note 2 to entry: Removal of the support structure and cleaning can many times be necessary; however, in this context, this operation is not considered as a separate process step.

Note 3 to entry: The principle of *single-step* (3.1.10) and multi-step processes is further discussed in [Annex B](#).

3.1.10

single-step process, noun

type of *additive manufacturing* (3.1.2) process in which *parts* (3.9.1) are fabricated in a single operation where the basic geometric shape and basic material properties of the intended product are achieved simultaneously

Note 1 to entry: Removal of the support structure and cleaning can many times be necessary; however, in this context, this operation is not considered as a separate process step.

Note 2 to entry: The principle of single-step and *multi-step processes* (3.1.9) is further discussed in [Annex B](#).

3.2 Process categories

3.2.1

binder jetting, noun

BJT

additive manufacturing (3.1.2) process in which a liquid bonding agent is selectively deposited to join powder materials

Note 1 to entry: Identification of different binder jetting processes shall be consistent with the method described in [Annex A](#).

3.2.2**directed energy deposition**, noun**DED**

additive manufacturing (3.1.2) process in which focused thermal energy is used to fuse materials by melting as they are being deposited

Note 1 to entry: “Focused thermal energy” means that an energy source (for example laser, electron beam or plasma arc) is focused to melt the materials being deposited.

Note 2 to entry: Identification of different directed energy deposition processes shall be consistent with the method described in [Annex A](#).

3.2.3**material extrusion**, noun**MEX**

additive manufacturing (3.1.2) process in which material is selectively dispensed through a nozzle or orifice

Note 1 to entry: Identification of different material extrusion processes shall be consistent with the method described in [Annex A](#).

3.2.4**material jetting**, noun**MJT**

additive manufacturing (3.1.2) process in which droplets of feedstock material are selectively deposited

Note 1 to entry: Example feedstock materials for material jetting include photopolymer resin and wax.

Note 2 to entry: Identification of different material jetting processes shall be consistent with the method described in [Annex A](#).

3.2.5**powder bed fusion**, noun**PBF**

additive manufacturing (3.1.2) process in which thermal energy selectively fuses regions of a *powder bed* (3.8.5)

Note 1 to entry: Identification of different powder bed fusion processes shall be consistent with the method described in [Annex A](#).

3.2.6**sheet lamination**, noun**SHL**

additive manufacturing (3.1.2) process in which sheets of material are bonded to form a *part* (3.9.1)

Note 1 to entry: Identification of different sheet lamination processes shall be consistent with the method described in [Annex A](#).

3.2.7**vat photopolymerization**, noun**VPP**

additive manufacturing (3.1.2) process in which liquid photopolymer in a vat is selectively cured by light-activated polymerization

Note 1 to entry: Identification of different vat photopolymerization processes shall be consistent with the method described in [Annex A](#).

3.3 Processing: general

3.3.1

3D printing, noun

fabrication of objects through the deposition of a material using a print head, nozzle or another printer technology

Note 1 to entry: This term is often used in a non-technical context synonymously with *additive manufacturing* (3.1.2) and, in these cases, typically associated with machines used for non-industrial purposes including personal use.

3.3.2

build chamber, noun

enclosed location within the *additive manufacturing system* (3.1.3) where the *parts* (3.9.1) are fabricated

3.3.3

build space, noun

location where it is possible for *parts* (3.9.1) to be fabricated, typically within the *build chamber* (3.3.2) or on a *build platform* (3.3.5)

3.3.4

build volume, noun

total usable volume available in the machine for building *parts* (3.9.1)

3.3.5

build platform, noun

<of a machine> base which provides a surface upon which the building of the *parts* (3.9.1) is started and supported throughout the build process

Note 1 to entry: In some systems, the *parts* (3.9.1) are built attached to the build platform, either directly or through a *support* (3.3.9) structure. In other systems, such as certain types of *powder bed* (3.8.5) systems, a direct mechanical fixture between the part and the build platform is not necessarily required.

3.3.6

build surface, noun

area where material is added, normally on the last deposited *layer* (3.3.7), which becomes the foundation upon which the next layer is formed

Note 1 to entry: For the first layer, the build surface is often the *build platform* (3.3.5).

Note 2 to entry: In the case of *directed energy deposition* (3.2.2) processes, the build surface can be an existing part onto which material is added.

Note 3 to entry: If the orientation of the material deposition or consolidation means (or both) is (are) variable, it may be defined relative to the build surface.

3.3.7

layer, noun

<matter> material laid out, or spread, to create a surface

3.3.8

build cycle, noun

single process cycle in which one or more components are built by successive joining of material within the *build space* (3.3.3) of the *additive manufacturing system* (3.1.3)

3.3.9

support, noun

structure separate from the *part* (3.9.1) geometry that is created to provide a base and anchor for the part during the building process

Note 1 to entry: Supports are typically removed from the part prior to use.

Note 2 to entry: For certain processes such as *material extrusion* (3.2.3) and *material jetting* (3.2.4), the support material can be different from the part material and deposited from a separate nozzle or print head.

Note 3 to entry: For certain processes such as metal *powder bed fusion* (3.2.5) processes, auxiliary supports can be added to serve as an additional heat sink for the part during the building process.

3.3.10

process parameters, noun

operating parameters and system settings used during a *build cycle* (3.3.8)

3.3.11

system set-up, noun

configuration of the *additive manufacturing system* (3.1.3) for a build cycle

3.3.12

manufacturing lot, noun

set of manufactured *parts* (3.9.1) having commonality between *feedstock* (3.6.6), *production run* (3.3.14), *additive manufacturing system* (3.1.3) and *post-processing* (3.6.10) steps (if required) as recorded on a single manufacturing work order

Note 1 to entry: The additive manufacturing system can include one or several *AM machines* (3.1.4) and/or post-processing machine units as agreed by *AM* (3.1.2) provider and customer

3.3.13

manufacturing plan, noun

document setting out the specific manufacturing practices, technical resources and sequences of activities relevant to the production of a particular product including any specified acceptance criteria at each stage

Note 1 to entry: For *additive manufacturing* (3.1.2), the manufacturing plan typically includes, but is not limited to, *process parameters* (3.3.10), preparation and *post processing* (3.6.10) operations as well as relevant verification methods.

Note 2 to entry: Manufacturing plans are typically required under a quality management system such as ISO 9001 and ASQ C1.

3.3.14

production run, noun

set of all *parts* (3.9.1) produced in one *build cycle* (3.3.8) or sequential series of build cycles using the same *feedstock* (3.6.6) batch and process conditions

3.3.15

process chain, noun

sequence of operations necessary for the *part* (3.9.1) to achieve desired functionality and properties

3.4 Processing: data

3.4.1

Additive Manufacturing File Format, noun

AMF

file format for communicating *additive manufacturing* (3.1.2) model data including a description of the 3D surface geometry with native support for colour, materials, lattices, textures, constellations and metadata

Note 1 to entry: Additive Manufacturing File Format (AMF) can represent one of multiple objects arranged in a constellation. Similar to *STL* (3.4.6), the surface geometry is represented by a triangular mesh, but in AMF the triangles can also be curved. AMF can also specify the material and colour of each volume and the colour of each triangle in the mesh. ISO/ASTM 52915^[2] gives the standard specification of AMF.

3.4.2

AMF consumer, noun

software reading (parsing) the *AMF* (3.4.1) file for fabrication, visualization or analysis

Note 1 to entry: AMF files are typically imported by *additive manufacturing equipment* (3.1.3), as well as viewing, analysis and verification software.

3.4.3

AMF editor, noun

software reading and rewriting the *AMF* (3.4.1) file for conversion

Note 1 to entry: AMF editor applications are used to convert an AMF from one form to another, for example to convert all curved triangles to flat triangles or convert porous material specification into an explicit mesh surface.

3.4.4

AMF producer, noun

software writing (generating) the *AMF* (3.4.1) file from original geometric data

Note 1 to entry: AMF files are typically exported by CAD software, scanning software or directly from computational geometry algorithms.

3.4.5

STEP, noun

standard for the exchange of product model data

Note 1 to entry: This is an International Standard that provides a representation of product information along with the necessary mechanisms and definitions to enable product data to be exchanged. ISO 10303^[4] applies to the representation of product information, including components and assemblies, the exchange of product data, including storing, transferring, accessing and archiving.

Note 2 to entry: ISO 10303-238, commonly referred to as STEP-NC, specifies the slicing operation and other mechanical commands in the AM process.

3.4.6

STL, noun

file format for model data describing the surface geometry of an object as a tessellation of triangles used to communicate 3D geometries to machines in order to build physical *parts* (3.9.1)

Note 1 to entry: The STL file format was originally developed as part of the CAD package for the early STereoLithography Apparatus, thus referring to that process. It is sometimes also described as “Standard Triangulation Language” or “Standard Tessellation Language”, though it has never been recognized as an official standard by any standards developing organization.

3.4.7

PDES, noun

Product Data Exchange Specification

data exchange specification using *STEP* (3.4.5)

Note 1 to entry: Originally, a product data exchange specification developed in the 1980s by the IGES/PDES Organization, a program of US Product Data Association (USPRO). It was adopted as the basis for and subsequently superseded by ISO 10303^[4] STEP.

3.4.8

attribute, noun

<data> characteristic representing one or more aspects, descriptors or elements of the data

Note 1 to entry: In object-oriented systems, attributes are characteristics of objects. In Extensible Markup Language (XML)^[10], attributes are characteristics of *elements* (3.3.10).

Note 2 to entry: In the *AMF* (3.4.1)-file, attributes can, for example, be used to carry notices enabling backwards traceability to CAD components, or markers that allow track and trace mechanisms for the file.

3.4.9**comment**, noun

<data> remark in source code which does not affect the behaviour of the program

Note 1 to entry: Comments are used for enhancing human readability of the file and for debugging purposes.

Note 2 to entry: In the *AMF* (3.4.1)-file, comments can, for example, be used to carry material specification or notices enabling backwards traceability to CAD components.

3.4.10**element**, noun

information unit within an XML^[10] document consisting of a start tag, an end tag, the content between the tags and any *attributes* (3.4.8).

Note 1 to entry: In the XML framework of *AMF* (3.4.1), an element can contain data, attributes structures such as constellations, as well as including other elements.

3.4.11**facet**, noun

three- or four-sided polygon that represents an element of a 3D polygonal mesh surface or model

Note 1 to entry: Triangular facets are used in the file formats most significant to *AM* (3.1.2): *AMF* (3.4.1) and *STL* (3.4.6); however, *AMF* files permit a triangular facet to be curved.

3.4.12**surface model**, noun

mathematical or digital representation of an object as a set of planar or curved surfaces, or both, that can, but does not necessarily have to represent a closed volume

3.4.13**3D scanning**, noun

3D digitizing

method of acquiring the shape and size of an object as a 3-dimensional representation by recording x, y, z coordinates on the object's surface and through software converting the collection of points into digital data

Note 1 to entry: Typical methods use some amount of automation, coupled with a touch probe, optical sensor or other device.

Note 2 to entry: In additive manufacturing process chains, 3D scanning can typically be used for generation of surface models, in situ monitoring, non-destructive testing, as well as verification of the part geometry.

3.5 Processing: positioning, coordinates and orientation**3.5.1****bounding box**, noun

<of a part> orthogonally oriented minimum perimeter cuboid that can span the maximum extents of the points on the surface of a 3D *part* (3.9.1)

Note 1 to entry: Where the manufactured part includes the test geometry plus additional external features (for example labels, tabs or raised lettering), the bounding box may be specified according to the test part geometry excluding the additional external features if noted. Different varieties of bounding boxes are illustrated in ISO/ASTM 52921^[8].

3.5.2**arbitrarily oriented bounding box**, noun

<of a part> *bounding box* (3.5.1) calculated without any constraints on the resulting orientation of the box

3.5.3

machine bounding box, noun

<of a part> *bounding box* (3.5.1) for which the surfaces are parallel to the *machine coordinate system* (3.5.11)

3.5.4

master bounding box, noun

bounding box (3.5.1) which encloses all of the *parts* (3.9.1) in a single build

3.5.5

geometric centre, noun

centroid

<of a bounding box> location at the arithmetic middle of the *bounding box* (3.5.1)

Note 1 to entry: The geometric centre of the bounding box can lie outside the *part* (3.9.1) that is enclosed by the bounding box.

3.5.6

orthogonal orientation notation, noun

description of the orientation of the *bounding box* (3.5.1) according to overall length in decreasing magnitude, parallel to the axes of the *machine coordinate system* (3.5.11)

Note 1 to entry: Notation typically consists of a combination of X, Y and Z, each referring to the corresponding axis as defined by the machine coordinate system.

Note 2 to entry: Orthogonal orientation notation requires that the bounding box be aligned with the machine coordinate system. Machine coordinate system and different bounding boxes, including examples of orthogonal orientation notation, are illustrated in ISO/ASTM 52921^[8].

3.5.7

initial build orientation, noun

<of a part> orientation of the part as it is first placed in the *build volume* (3.3.4)

Note 1 to entry: Initial build orientation is illustrated in ISO/ASTM 52921^[8].

3.5.8

part reorientation, noun

rotation around the *geometric centre* (3.5.5) of the part's *bounding box* (3.5.1) from the specified *initial build orientation* (3.5.7) of that *part* (3.9.1)

Note 1 to entry: Part reorientation is illustrated in ISO/ASTM 52921^[8].

3.5.9

build envelope, noun

largest external dimensions of the *x-axis* (3.5.16), *y-axis* (3.5.17) and *z-axis* (3.5.18) within the *build space* (3.3.3) where *parts* (3.9.1) can be fabricated

Note 1 to entry: The dimensions of the build space are larger than the build envelope.

3.5.10

nesting, participle

situation when *parts* (3.9.1) are made in one *build cycle* (3.3.8) and are located such that their *bounding boxes* (3.5.1), *arbitrarily oriented* (3.5.2) or otherwise, overlap

3.5.11**machine coordinate system**, noun

three-dimensional coordinate system as defined by a fixed point on the *build platform* (3.3.5), with the three principal axes labelled *x-axis* (3.5.16), *y-axis* (3.5.17) and *z-axis* (3.5.18) with rotary axis about each of these axes labelled A, B and C, respectively, where the angles between x-, y- and z-, can be Cartesian or defined by the machine manufacturer

Note 1 to entry: Machine coordinate system is fixed relative to the machine, as opposed to coordinate systems associated with the *build surface* (3.3.6), which can be translated or rotated. Machine coordinate system is illustrated in ISO/ASTM 52921^[8].

3.5.12**origin**, noun

zero point

(0, 0, 0)

<when using x-, y- and z-coordinates> designated universal reference point at which the three primary axes in a coordinate system intersect

Note 1 to entry: Coordinate system can be Cartesian or as defined by the machine manufacturer. The concept of origin is illustrated in ISO/ASTM 52921^[8].

3.5.13**build origin**, noun

origin (3.5.12) most commonly located at the centre of the *build platform* (3.3.5) and fixed on the build facing surface

Note 1 to entry: The location of the build origin can be defined otherwise by the build set-up.

3.5.14**machine origin**, noun

machine home

machine zero point

origin (3.5.12) as defined by the machine manufacturer

3.5.15**part location**, noun

location of the *part* (3.9.1) within the *build volume* (3.3.4)

Note 1 to entry: The part location is normally specified by the x-, y- and z-coordinates for the position of the *geometric centre* (3.5.5) of the part's *bounding box* (3.5.1) with respect to the *build origin* (3.5.13). Part location is illustrated in ISO/ASTM 52921^[8].

3.5.16**x-axis**, noun

<of a machine; unless otherwise designated by the machine builder> axis in the *machine coordinate system* (3.5.11) that runs parallel to the *front* (3.1.7) of the machine and perpendicular to the *y-axis* (3.5.17) and *z-axis* (3.5.18)

Note 1 to entry: Unless otherwise designated by the machine builder, the positive x-direction runs from left to right as viewed from the front of the machine while facing toward the *build volume* (3.3.4) *origin* (3.5.12).

Note 2 to entry: It is common that the x-axis is horizontal and parallel to one of the edges of the *build platform* (3.3.5).

3.5.17**y-axis**, noun

<of a machine; unless otherwise designated by the machine builder> axis in the *machine coordinate system* (3.5.11) that runs perpendicular to the *x-axis* (3.5.16) and *z-axis* (3.5.18)

Note 1 to entry: Unless otherwise designated by the machine builder, the positive direction is defined in ISO 841^[1] to make a right-hand set of coordinates. In the most common case of an upwards z-positive direction, the positive y-direction then runs from the *front* (3.1.7) to the back of the machine as viewed from the front of the machine.

Note 2 to entry: In the case of building in the downwards z-positive direction, the positive y-direction then runs from the back of the machine to the front as viewed from the front of the machine.

Note 3 to entry: It is common that the y-axis is horizontal and parallel to one of the edges of the *build platform* (3.3.5).

3.5.18

z-axis, noun

<of a machine; unless otherwise designated by the machine builder> axis in the *machine coordinate system* (3.5.11) that runs perpendicular to the *x-axis* (3.5.16) and *y-axis* (3.5.17)

Note 1 to entry: Unless otherwise designated by the machine builder, the positive direction is defined in ISO 841^[1] to make a right-hand set of coordinates. For processes employing planar layer-wise addition of material, the positive z-direction then runs normal to the *layers* (3.3.7).

Note 2 to entry: For processes employing planar layer-wise addition of material, the positive z-direction is the direction from the first layer to the subsequent layers.

Note 3 to entry: Where addition of material is possible from multiple directions (such as with certain *directed energy deposition* (3.2.2) systems), the z-axis can be identified according to the principles in ISO 841:2001, 4.3.3^[1], which addresses "swivelling or gimbaling."

3.6 Processing: material

3.6.1

batch, noun

<of feedstock> defined quantity of *feedstock* (3.6.6) with uniform properties and composition

Note 1 to entry: One batch of any feedstock can be used in one or more production runs using different process parameters.

Note 2 to entry: For some types of feedstock, for example powders and resins, one batch can consist of *virgin* (3.6.4) material, used material or a blend of virgin and used materials.

3.6.2

lot, noun

<of feedstock> quantity of *feedstock* (3.6.6) produced under traceable controlled conditions from a single manufacturing process cycle

Note 1 to entry: The size of a feedstock lot is determined by the *feedstock supplier* (3.6.8). It is common that the supplier distributes a portion of a lot to different *AM system users* (3.1.6).

Note 2 to entry: Source documentation of the feedstock lot is required for several *AM* (3.1.2) product applications. Source documentation is referred to as a "statement of conformity" and an "inspection document", or sometimes also referred to as a "certificate of conformance", "factory certificate" or "certificate of analysis".

3.6.3

virgin, adjective

<feedstock> condition of *feedstock* (3.6.6) from a single manufacturing *lot* (3.6.2) before being applied to the *additive manufacturing* (3.1.2) process

Note 1 to entry: Virgin condition typically means that the feedstock is in the condition as intended by the supplier.

Note 2 to entry: The requirements for virgin feedstock can vary depending on process, material and application of the final product. A further distinction can be necessary for some materials in specific applications.

Note 3 to entry: Feedstock without significant change from its original condition may still be regarded as virgin.

Note 4 to entry: Feedstock can degrade over time, independent of being applied to the additive manufacturing process. Feedstock that has undergone any significant change under any condition cannot be regarded as virgin.

Note 5 to entry: The significance and the permissible variation from the original state are typically determined based on the requirements for the application of the final product.

3.6.4**spreadability**, noun

<of feedstock> ability of a *feedstock* (3.6.6) material to be spread out in *layers* (3.3.7) that fulfil the requirements for the *AM* (3.1.2) process

Note 1 to entry: The specification of the conditions for the spreading of a layer in an *AM machine* (3.1.4), including, but not limited to, the machine setup and the process parameters, are typically determined by the process requirements with respect to the intended application of the final part.

Note 2 to entry: The spreading behaviour of a specific feedstock material depends on the physical properties of that material under the given process conditions.

3.6.5**feedstock**, noun

DEPRECATED: source material

DEPRECATED: starting material

DEPRECATED: base material

DEPRECATED: original material

bulk raw material supplied to the *additive manufacturing* (3.1.2) building process

Note 1 to entry: For additive manufacturing building processes, the bulk raw material is typically supplied in various forms such as liquid, powder, suspensions, filaments, sheets, etc.

3.6.6**feedstock manufacturer**, noun

entity that produces the *feedstock* (3.6.6)

Note 1 to entry: In additive manufacturing, the feedstock manufacturer can often be a different entity than the *feedstock supplier* (3.6.8).

3.6.7**feedstock supplier**, noun

feedstock vendor

provider of *feedstock* (3.6.6)

Note 1 to entry: In additive manufacturing, the feedstock supplier can often be a different entity than the *feedstock manufacturer* (3.6.7).

3.6.8**fusion**, noun

act of uniting two or more units of material into a single unit of material

3.6.9**cure**, verb

change the physical properties of a material by means of a chemical reaction

Note 1 to entry: One of the most important curing operations in additive manufacturing is the changing of a polymer resin from liquid to solid by light-activated cross-linking of molecule chains.

3.6.10**post-processing**, noun

process step, or series of process steps, taken after the completion of an *additive manufacturing* (3.1.2) *build cycle* (3.3.8) in order to achieve the desired properties in the final product

3.7 Processing: material extrusion**3.7.1****build sheet**, noun

<material extrusion> removable sheet, to which the *part* (3.9.1) is attached during the *build cycle* (3.3.8)

Note 1 to entry: The purpose for the build sheet is to provide a disposable barrier between the part and *build platform* (3.3.5) in certain machines.

Note 2 to entry: The build sheet is usually fastened to the build platform by vacuum or by other means.

3.7.2

extruder head, noun

extrusion head

assembly comprising *feedstock* (3.6.6) delivery mechanism and extrusion nozzle(s)

Note 1 to entry: A common design of the head contains a motorized pinch wheel delivery mechanism to push filament through the extrusion head. The head often contains a heating element.

3.7.3

extrusion nozzle, noun

component with an orifice through which *feedstock* (3.6.6) is extruded

3.7.4

filament, noun

feedstock (3.6.6) characterized by extreme length relative to its uniform cross section

Note 1 to entry: Polymer filaments are typically manufactured by extrusion and metal filaments by drawing.

Note 2 to entry: Filaments made of metal are commonly referred to as wire.

3.7.5

pellets, noun

small mass of preformed *feedstock* (3.6.6) material, having relatively uniform dimensions in any given batch

Note 1 to entry: Pellets of smaller size can be referred to as micro-pellets.

3.8 Processing: powder bed fusion

3.8.1

batch feed processing, noun

<of feedstock> method of preparation and delivery operations performed on a specific batch of *feedstock* (3.6.6) as needed for the *build cycle* (3.3.8)

Note 1 to entry: Powder batch feed operations can typically include blending or mixing powders to the desired composition, or drying, alternatively humidifying the powder to reach properties desirable for the AM (3.1.2) process.

Note 2 to entry: Batch feed processing is distinguished from *continuous feed processing* (3.8.2) by being limited to a finite amount of feedstock sufficient to complete one or more full build cycles.

3.8.2

continuous feed processing, noun

<of feedstock> method of preparation and delivery operations performed to supply *feedstock* (3.6.6) in an uninterrupted process as needed for the *build cycle* (3.3.8)

Note 1 to entry: Powder feedstock operations can typically include blending or mixing powders to the composition desired for the build cycle.

Note 2 to entry: Continuous feed processing is distinguished from *batch feed processing* (3.8.1) by not being limited to a finite amount of feedstock.

3.8.3

feed region, noun

<in powder bed fusion> location in the machine where *feedstock* (3.6.6) is stored and from which a portion of the feedstock is repeatedly conveyed to the *powder bed* (3.8.5) during the *build cycle* (3.3.8)

3.8.4**overflow region**, noun

<in powder bed fusion> location in the machine where excess powder is collected and stored after a layer has been deposited during a *build cycle* (3.3.8)

Note 1 to entry: For certain machine types, the overflow region can consist of one or more dedicated chambers or a powder recycling system.

3.8.5**powder bed**, noun

part bed

location in an *additive manufacturing system* (3.1.3) where *feedstock* (3.6.6) is deposited and selectively fused by means of a heat source or bonded by means of an adhesive to build up *parts* (3.9.1)

3.8.6**powder blend**, noun

quantity of powder made by thoroughly intermingling powders originating from one or several powder *lots* (3.6.2) of the same nominal composition

Note 1 to entry: A common type of powder blend consists of a combination of *virgin* (3.6.4) powder and *used powder* (3.8.9). The specific requirements for a powder blend are typically determined by the application or by agreement between the supplier and end-user.

Note 2 to entry: A distinction is made between blended powders and mixed powders, in which case blended powders are combinations of powders with nominally identical composition, whereas mixed powders are combinations of powders with different compositions.

3.8.7**powder mix**, noun**powder mixture**

quantity of powder made by thoroughly intermingling powders of different nominal composition

Note 1 to entry: A distinction is made between blended powders and mixed powders, in which case blended powders are combinations of powders with nominally identical composition, whereas mixed powders are combinations of powders with different compositions.

3.8.8**part cake**, noun

<in a powder bed fusion process that uses a heated build chamber> lightly bound powder surrounding the fabricated *parts* (3.9.1) at the end of a *build cycle* (3.3.8)

3.8.9**used powder**, noun

powder that has been supplied as *feedstock* (3.6.6) to an *AM machine* (3.1.4) during at least one previous *build cycle* (3.3.8)

3.8.10**laser sintering**, noun

LS

powder bed fusion (3.2.5) process used to produce objects from powdered materials using one or more lasers to selectively fuse or melt the particles at the surface, *layer* (3.3.7) upon layer, in an enclosed chamber

Note 1 to entry: Most LS machines partially or fully melt the materials they process. The word “sintering” is a historical term and a misnomer, as the process typically involves full or partial melting, as opposed to traditional powdered metal sintering using a mould and heat and/or pressure.

3.9 Parts: general

3.9.1

part, noun

joined material forming a functional element that can constitute all or a section of an intended product

Note 1 to entry: The functional requirements for a part are typically determined by the intended application.

3.9.2

lattice, noun

lattice structure

geometric arrangement composed of connective links between vertices (points) creating a functional structure

3.10 Parts: applications

3.10.1

prototype, noun

physical representation of all or a component of a product that, although limited in some way, can be used for analysis, design and evaluation

Note 1 to entry: Requirements for *parts* (3.9.1) used as prototypes depend on the individual needs for analysis and evaluation and are therefore typically determined in agreement between supplier and end-user.

3.10.2

prototype tooling, noun

set of moulds, dies and other devices used for prototyping purposes

Note 1 to entry: This type of tooling can sometimes be used to test the tool design and/or to produce end-use *parts* (3.9.1) while production tooling is being manufactured. On these occasions, the tooling is typically referred to as bridge tooling.

Note 2 to entry: Prototype tooling is sometimes referred to as bridge tooling or soft tooling.

3.10.3

rapid prototyping, noun

<in additive manufacturing> application of *additive manufacturing* (3.1.2) intended for reducing the time needed for producing *prototypes* (3.10.1)

Note 1 to entry: Historically, rapid prototyping (RP) was the first commercially significant application for additive manufacturing and has therefore been commonly used as a general term for this type of technology.

3.10.4

rapid tooling, noun

<in additive manufacturing> application of *additive manufacturing* (3.1.2) intended for the production of tools or tooling components with reduced lead times as compared to conventional tooling manufacturing

Note 1 to entry: Rapid tooling can be produced directly by the additive manufacturing process or indirectly by producing patterns that are in turn used in a secondary process to produce the actual tools.

Note 2 to entry: Besides additive manufacturing, the term “rapid tooling” can also apply to the production of tools with reduced lead times by subtractive manufacturing methods, such as CNC milling, etc.

3.11 Parts: properties

3.11.1

accuracy, noun

closeness of agreement between a measured result and an accepted reference value

Note 1 to entry: In the context of *additive manufacturing* (3.1.2), the accepted reference is typically the digital model.

Note 2 to entry: The accuracy of an additive manufacturing process can be different in *x*, *y* and *z*-directions. This means that a part accuracy in these cases is dependent on the part orientation relative to the machine coordinate system.

3.11.2

precision, noun

<build process> closeness of agreement between the results obtained on multiple parts under prescribed conditions

Note 1 to entry: The precision of an *additive manufacturing* (3.1.2) process can be dependent on the location within the *build space* (3.3.3) and can also be different in *x*, *y* and *z*-directions.

Note 2 to entry: Precision depends on inherent variations in the build process and does not relate to the accepted reference value.

3.11.3

resolution, noun

dimensions of the smallest part feature that can controllably be built

Note 1 to entry: In the context of *additive manufacturing* (3.1.2), the dimensions are typically recorded in *x*-, *y*- and *z*-directions.

Note 2 to entry: In a layer-wise building process, the resolution in *z*-direction is typically identical to the layer thickness.

Note 3 to entry: The resolution of the *part* (3.9.1) can vary in different directions due to the orientation of the part during the *build cycle* (3.3.8).

3.11.4

as-built, adjective

state of *parts* (3.9.1) made by an additive process before any *post-processing* (3.6.10), besides, if necessary, the removal from a *build platform* (3.3.5) as well as the removal of *support* (3.3.9) and/or unprocessed *feedstock* (3.6.6)

Note 1 to entry: As-built condition can refer to parts with or without supports, on or off the build platform.

3.11.5

as-designed, adjective

state representing the *part* (3.9.1) to be built by an additive process in digital form, typically as 3D model data

Note 1 to entry: The digital model can be expressed as a proprietary CAD-file, *AMF-file* (3.4.1), *STL-file* (3.4.6), *STEP-file* (3.4.5) or any other similar form of 3D model data.

3.11.6

fully dense, adjective

state in which the material of the fabricated part is without significant content of voids

Note 1 to entry: In practice, material completely free of voids is difficult to produce by any manufacturing process and some micro-porosity is generally present.

Note 2 to entry: The significance and the permissible content of voids are typically determined based on the requirements for the application of the final product.

3.11.7

near net shape, adjective

condition where the components require little *post-processing* (3.6.10) to meet dimensional tolerance

3.11.8

porosity, noun

<property> presence of small voids in a *part* (3.9.1) making it less than *fully dense* (3.11.6)

Note 1 to entry: Porosity can be quantified as a ratio, expressed as a percentage of the volume of voids to the total volume of the part.

3.11.9

repeatability, noun

degree of alignment of two or more measurements of the same property using the same equipment and in the same environment

Note 1 to entry: In *additive manufacturing* (3.1.2), repeatability typically refers to the degree of alignment of measurable properties between identical *parts* (3.9.1), produced using the same *process parameters* (3.3.10) and *system set-up* (3.3.11) but in different *build cycles* (3.3.8).

3.12 Parts: evaluation

3.12.1

inspection plan, noun

set of instructions specifying the process of verification including appropriate resources and sequence of inspections to be referenced by the *manufacturing plan* (3.3.13)

3.12.2

first article, noun

first production part

part (3.9.1) submitted for testing and evaluation for conformance with specified requirements stipulated by a purchase order or otherwise before or in the initial stages of production

3.12.3

reference part, noun

part (3.9.1) with characteristics similar to the desired final part(s) which may have different geometry, scale or features that can be easily measured or characterized

Note 1 to entry: Reference parts are typically sacrificial parts with simple geometries that are used to verify build properties and reduce measurement effort.

3.12.4

final inspection, noun

pre-shipment inspection

process of verification of manufactured *parts* (3.9.1) prior to shipment in order to confirm the fulfilment of the requirements stipulated by a purchase order or otherwise

3.12.5

qualification, noun

process of demonstrating whether an entity is capable of fulfilling specified requirements

Note 1 to entry: In *additive manufacturing* (3.1.2), qualification typically involves *parts* (3.9.1), materials, equipment, operators and processes.

[SOURCE: ISO/IEC/IEEE 12207:2017, 3.1.40^[5], modified — Note 1 to entry was added.]

Annex A (normative)

Identification of AM processes based on process categories and determining characteristics

A.1 General

Additive manufacturing process categories are used to provide a general, structural distinction between different AM processes, based on the process architecture and typical process characteristics. However, sometimes there is need for further specification of different processes within each process category; for example, distinction between powder bed fusion of polymers and powder bed fusion of metals, or powder bed fusion of metals using a laser beam and powder bed fusion of metals using an electron beam. This annex is intended to serve as an aid for those who wish to identify a process in more detail than just through the process categories, using generic terms and abbreviations.

A.2 Structure, use of markers and acronyms

Specification of different processes within a process category should follow a general-to-specific principle, beginning with specification of the process category, followed by distinguishing features for the AM process and the materials processed.

In this specification, the process features should be preceded by a dash, "-", and materials be preceded by a slash, "/".

EXAMPLE Process category–process feature/material(s). The specification can be brought into further detail by adding distinguishing features and more specified material distinction.

Abbreviations for process categories shall be applied as specified under [3.2](#).

Abbreviations for process features should be as follows:

- For binder jetting:
 - If the parts are joined directly with the bonding of the intended part material in a single process step, this type of process is identified by: -SSt (single-step process).
 - If the parts need further process steps for consolidation and formation of the bonds of the intended part material, -MSt (multi-step process).
- For directed energy deposition: -LB for laser beam, -EB for electron beam and -Arc when the directed energy source is an electric arc.
- For material extrusion: -CRB if the material is bonded by a chemical reaction, -TRB if the material is bonded by a thermal reaction.
- For material jetting: -UV if the jetted material needs curing by ultraviolet light exposure, -CRB if the jetted material is bonded by a chemical reaction, -TRB if the jetted material is bonded by a thermal reaction.
- For powder bed fusion: -LB for laser beam, -EB for electron beam and -IrL when the thermal energy source is infrared light.
- For sheet lamination: -AJ for adhesive joining and -UC for ultrasonic consolidation.

- For vat photopolymerization: -UVL for curing by ultra violet laser beam exposure, -UVM for curing by exposure to ultra violet light selectively shining through a mask, -LED for curing by exposure to lights from light emitting diodes.

Abbreviations for basic types of materials should be as follows:

- M for metallic materials;
- P for polymer materials;
- C for ceramic materials;
- Cp for composite materials of different basic type, for example polymer matrix with metal or ceramic filler.

The composition of composite materials should be listed starting with the most significant component material, followed by the second most significant component material separated by a comma (,), etc.

EXAMPLE Photopolymer with alumina filler: /PP,Al2O3, or tungsten carbide in cobalt matrix: /WC,Co.

The meaning of the abbreviations used for specification of a process in a document should be specified in a list of terms and abbreviations within the same document, unless the abbreviations have been included and defined in a published standard, in which case the document should refer to this standard.

A.3 Examples

- Powder bed fusion of Ti6Al4V using an electron beam: PBF-EB/M/Ti6Al4V.

The process category is powder bed fusion (PBF), an electron beam is used for consolidation (-EB), it is a metallic material (/M), more specifically Ti6Al4V (/Ti6Al4V). However, since electron beams only can be used to consolidate conductive material and the alloy Ti6Al4V hardly can be mistaken for anything but a metallic material, the "/M" can in this case be omitted and the specification is thus: PBF-EB/Ti6Al4V.

- Powder bed fusion of cobalt chrome using a laser based system: PBF-LB/M/CoCr.

The process category is powder bed fusion (PBF), using a laser beam (-LB), in a metallic material (/M), and Cobalt Chrome alloy (/CoCr). Similar to the example above, this can be shortened to PBF-LB/CoCr.

- Powder bed fusion of glass filled polyamide-12 (PA12): PBF-LB/P/PA12GF.

The process category is powder bed fusion (PBF), a laser beam is used for consolidation (-LB), which can be used for both polymers and metals (/P), the specific material is glass filled polyamide (/PA12GF).

- Binder jetting on stainless steel with subsequent sintering and bronze infiltration: BJT-MSt/M/StS,BI.

The process category is binder jetting (BJT), a multi-step process (-MSt), for metallic materials (/M), in this case a composite consisting of stainless steel (/StS) with bronze infiltration (BI).

- Material extrusion of ABS plastic from a heated nozzle: MEX-TRB/P/ABS.

The process category is material extrusion (MEX), the material is joined by thermal reaction bonding (-TRB), it is a polymer (/P), in this case ABS (/ABS).

- Material extrusion of silicone: MEX-CRB/P/Silicone.

The process category is material extrusion (MEX), the material is joined by chemical reaction bonding (-CRB), it is a polymer (/P), in this case Silicone (/Silicone).

- Material extrusion of concrete: MEX-CRB/C/Concrete.

The process category is material extrusion (MEX), the material is joined by chemical reaction bonding (-CRB), it is a ceramic material (/C), in this case Concrete (/Concrete).

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Annex B (informative)

Basic principles

B.1 Additive shaping of materials

The functionality of a manufactured object is derived from the combination of the object's geometry and material properties. In order to achieve this combination, a manufacturing process is made up of a series of operations and sub-processes that brings the shape of the intended geometry to a material capable of possessing the desired properties. The shaping of materials into objects within a manufacturing process can be achieved by applying one or a combination of three basic principles.

- Formative shaping: the desired shape is acquired by application of pressure to a body of raw material.

EXAMPLES Forging, bending, casting, injection moulding, the compaction of green bodies in conventional powder metallurgy or ceramic processing, etc.

- Subtractive shaping: the desired shape is acquired by selective removal of material.

EXAMPLES Milling, turning, drilling, EDM, etc.

- Additive shaping: the desired shape is acquired by successive addition of material.

The objects, or parts, with the acquired shapes can be combined into more complex shaped products by joining different parts in a physical, chemical or mechanical operation, such as welding, soldering, adhesive, fasteners, etc.

Additive manufacturing technology applies the additive shaping principle and thereby builds physical 3D geometries by successive addition of material.

“Addition of material” means that units of feedstock material are brought together and joined (e.g. fused or bonded), most commonly layer by layer to build a part. The determining factor for each process is in the technique used for adding the materials. This determines, for example, what types of materials are possible in the process, since different materials have different principles of fusion or adhesion. Basically, for additive manufacturing processing, the products' fundamental properties are determined by

- a) type of material (polymer, metal, ceramic or composite),
- b) principle applied for fusion or bonding (melting, curing, sintering, etc.),
- c) feedstock used for adding material (liquid, powder, suspension, filament, sheet, etc.), and
- d) how the material is brought together, i.e. machine architecture.

The process of successively adding material to build a part makes the properties of the material in this part highly dependent on the machine type and the process parameters in the additive operation. Therefore, it is not possible to accurately predict these material properties without coupling them to a specific type of machine and process parameters.

A layered approach to the additive building of parts can also cause directional dependence in the material properties of that part. Material properties in an AM part can therefore depend on the part's orientation and position in the build space during processing.

B.2 Single-step and multi-step additive manufacturing processes

It is rare that the manufacturing of a finished product can be entirely completed with use of a single process principle. Normally, a series of operations and sub-processes are required to achieve the intended combination of geometrical shape and desired properties. However, in the context of AM, there is a distinction between which operations are indispensable to the additive process, and which are more product and application dependent preparations and post-processing operations. When additive manufacturing is applied within an industrial manufacturing system, this distinction is needed to clarify what part of the entire manufacturing process constitutes the actual additive manufacturing process as well as what part of the entire manufacturing system constitutes the actual additive manufacturing system, so that standards can be appropriately applied.

The fundamental principle of AM processes is forming three-dimensional parts by the successive addition of material. Depending on process, the parts can acquire the basic geometry and fundamental properties of the intended material in a single process step, i.e. a single-step process, or acquire the geometry in a primary process step, and then acquire the fundamental properties of the intended material (e.g. metallic properties for an intended metallic part and ceramic properties for an intended ceramic part) in a secondary process step, i.e. a multi-step process; see Figure B.1. For example, the object acquires the basic geometry by joining of powder with a binder in the primary process step, which is followed by material consolidation by sintering, with or without infiltration, in subsequent process steps. Depending on the final application, both single-step and multi-step can require one or more additional post-processing operations, such as heat treatments (including HIP), finishing machining and others (see further ISO 17296-2^[6]), to obtain all the intended properties in the final product.

AM technology can be used to produce tools, moulds, and casting patterns, which subsequently are used in the production of the intended products. However, in this scenario, it is the casting patterns, moulds or tools that are produced by the AM process, not the intended final product. Therefore, the manufacturing of the intended final products in these processes should be considered as being enabled by applications of AM technology rather than as one of the AM production processes.

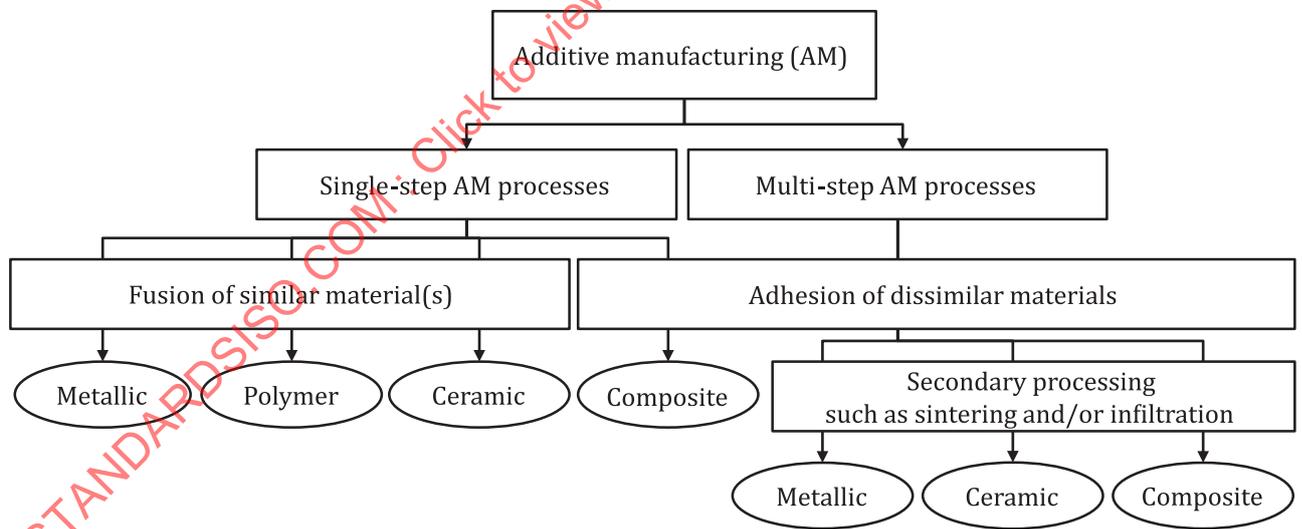


Figure B.1 — Single-step and multi-step AM process principles

B.3 Additive manufacturing processing principles

B.3.1 General

There are numerous ways in which units of material can be joined together to form a part. Different types of materials are being held together by different types of atomic bonds: metallic materials are typically held together by metallic bonds, polymer molecules typically by covalent bonds, ceramic materials typically by ionic- and/or covalent bonds, and composite materials by any combination of the

above mentioned. The type of bonding provides the most fundamental conditions for how that type of material can be joined in an additive process. Besides the type of material, the joining operation is also dependent on the form in which the material is delivered to the system and how it is distributed to the surface where it is to be added to the part. For additive manufacturing processes, the feedstock, the bulk raw material that is fed into the process, can typically come in the form of powder (dry, paste or slurry), filament, sheet, melted, and for polymers also in the shape of uncured liquid resin. Dependent on the form, the feedstock can then be distributed layer by layer in a powder bed, deposited by a nozzle, applied as layers in a sheet stack, deposited through a print head, or applied as a liquid, paste or slurry in a vat. With respect to the great possibilities for variation in different types of materials, different types of feedstock and means of distribution of the feedstock, there is a large number of possible principles that can be used for additive manufacturing processes. However, while there are significant research and development activities in this area worldwide, far from all potential solutions have been realized in a working process, and fewer still have reached the market. Figures B.2 to B.5 give an overview of process principles that are presently available on the market and have been proven viable in an industrial context.

B.3.2 Overview of AM single-step processing principles

The parts are fabricated in a single operation where the basic geometric shape and basic material properties of the intended product are achieved in a single operation simultaneously. Removal of the support structure and cleaning can be necessary. Figure B.2 to Figure B.4 represent overviews of single step AM processing principles for metallic materials, polymer materials and ceramic materials.

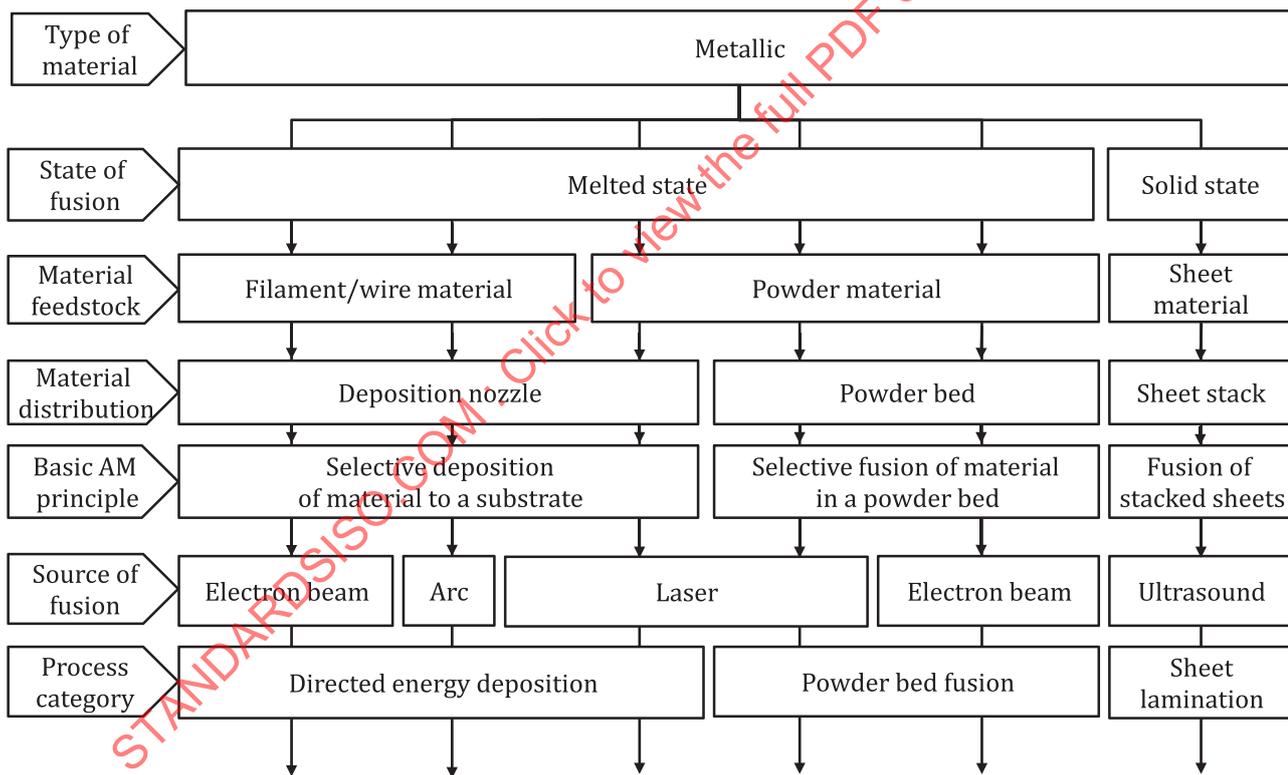


Figure B.2 — Overview of single-step AM processing principles for metallic materials