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Additive manufacturing — General principles — Overview of data processing

Fabrication additive — Principes généraux — Vue d'ensemble des échanges de données

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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 Technical Committee 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 first edition of ISO/ASTM 52950 replaces ISO 17296-4:2014, which has been technically revised and renumbered. The main changes compared to ISO 17296-4:2014 are as follows:

— change of the document number to ISO/ASTM 52950;

— removal of outdated or withdrawn standards ISO 17296-4 and DIN 66301 (VDA-FS);

— revisions to Figure 1.

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 is used to fabricate prototypes, tools, and production parts.

This document aims to offer recommendations and advice to users (customers) and manufactures (both external and internal service providers), to improve communication between customer and supplier, and to contribute to an authoritative performance design and a smooth handling of the project.

It assumes that the reader has a basic understanding of the process flow of different additive processes. It explains the processes used in practice in only as much detail as it necessary to understand the statements.

Additive manufacturing — General principles — Overview of data processing

1 Scope

This document covers the principal considerations which apply to data exchange for additive manufacturing. It specifies terms and definitions which enable information to be exchanged describing geometries or parts such that they can be additively manufactured. The data exchange method outlines file type, data enclosed formatting of such data and what this can be used for.

This document

— enables a suitable format for data exchange to be specified,

— describes the existing developments for additive manufacturing of 3D geometries,

— outlines existing file formats used as part of the existing developments, and

— enables understanding of necessary features for data exchange, for adopters of this document.

This document is aimed at users and producers of additive manufacturing processes and associated software systems. It applies wherever additive processes are used, and to the following fields in particular:

— producers of additive manufacturing systems and equipment including software;

— software engineers involved in CAD/CAE systems;

— reverse engineering systems developers;

— test bodies wishing to compare requested and actual geometries.

2 Normative reference

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 referenced document (including any amendments) applies.

ISO/ASTM 52900, *Additive manufacturing —General principles — Fundamentals and vocabulary*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in in ISO/ASTM 52900 and the following apply.

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 http://www.electropedia.org/

3.1
polygonization
triangulation
creating a digital model of a surface in the form of a multitude of connected polygons

Note 1 to entry: Creating a surface of connected triangular polygons is usually called triangulation.

Note 2 to entry: In additive manufacturing polygonization/triangulation is a software assisted operation used to generate a facet model from either a point cloud or a 3D CAD volume model.

4 Data exchange

4.1 Dataflow

4.1.1 General

A complete 3D data set of the part forms the basis of additive manufacturing. Most commonly, this is created by direct 3D CAD modelling. The data sets can also be generated by 3D scanned data if the parts exist in a physical form (see Figure 1).

A representation based on facets is then generated from the volume or area model through polygonization or triangulation (see 4.1.2.4) and transferred to the additive manufacturing process in a suitable data transfer format. This software-assisted process runs automatically as far as possible.

4.1.2 Explanation of the key terms used in Figure 1

4.1.2.1 3D CAD modelling (solid modelling)

3D CAD modelling is the process most commonly used during design to produce a digital 3D model. The starting point can be an idea for a product, which takes shape and becomes increasingly defined directly on the computer screen during the process, or a previously generated image of the object in the form of sketches, drawings, etc. which can be converted to 3D data through a modelling process in CAD systems. Volume can be described using two different techniques, or a combination of both. The object is either composed of basic volumes (shapes) (e.g. cuboid, wedge, cylinder, cone, sphere, and toroid) which generate the actual object via a sequence of Boolean operations, or the volume is described by its surrounding boundary surfaces and the location of the material relative to the boundary surfaces.

4.1.2.2 3D digitalization

3D digitalization is the process in which the surface geometry of a physical object is measured using appropriate hardware and software and recorded in a digital point cloud model. The objects can be manually produced or finished models which need to be copied in digital form. The use of 3D digitalization is particularly efficient if the model has empirically drafted, freeform surface areas, since these are difficult to reproduce through direct 3D CAD modelling.

4.1.2.3 Surface reconstruction

Surface reconstruction is a means of processing data generated through 3D digitalization. Starting from the computer-generated point cloud, mathematically described curves and surfaces are generated with sufficient topological information to adequately recreate the object surface. These data can then be stored separately or integrated into an existing CAD volume model. Surface reconstruction thus creates a bridge between 3D digitalization and CAD modelling.

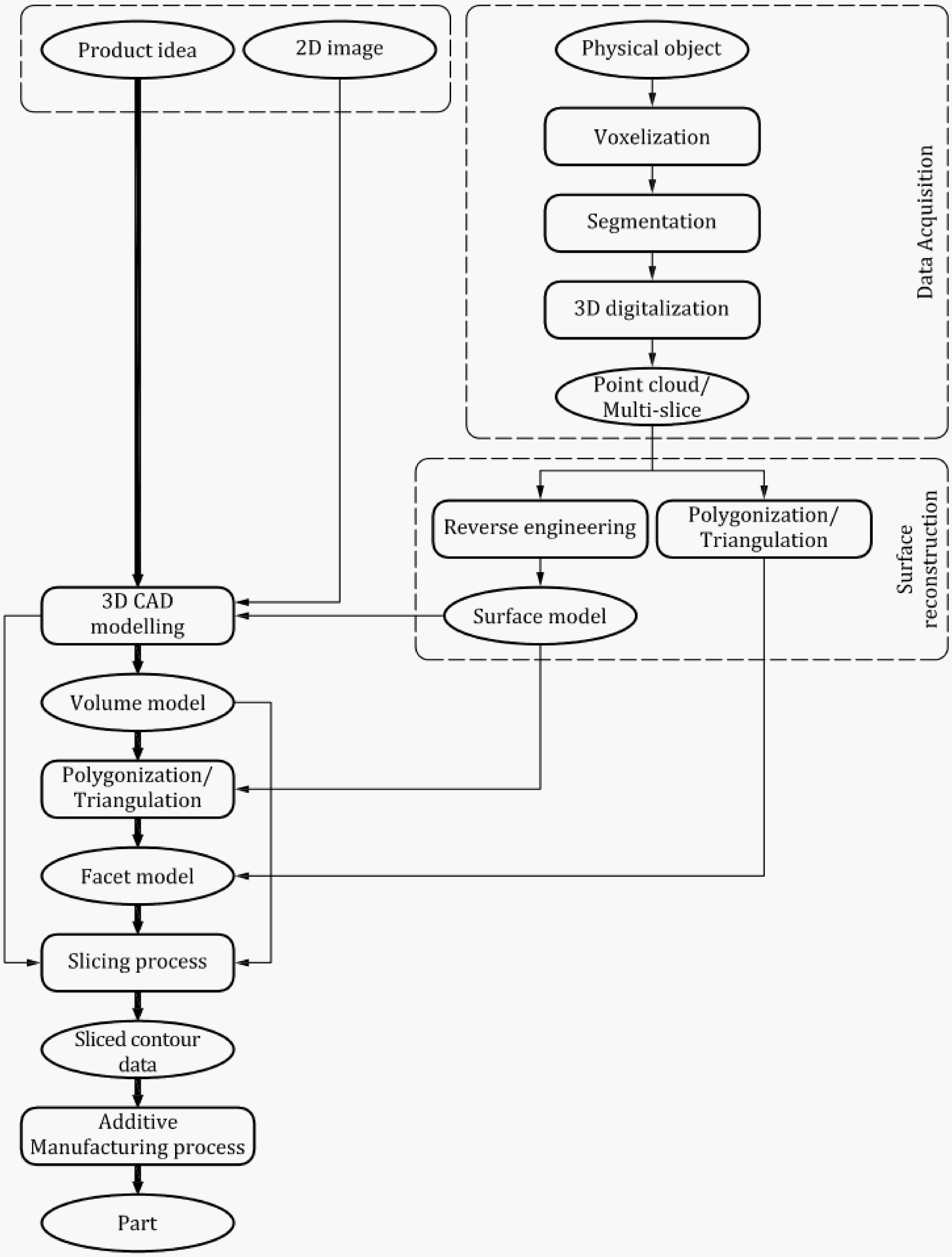

Figure 1 — General overview of traditional data flow from product idea to actual part (terminology)

4.1.2.4 Polygonization/triangulation

This software-assisted process is used to generate a volume-based facet model either from the point cloud following 3D digitalization or from the volume model after 3D CAD modelling. The object surface is represented by a multiplicity of tiny, planar facets, or polygons, which are stretched between the points. The number and size of the facets are one aspect which determines how accurately the actual surface geometry is reproduced. This process creates a data set.

4.1.2.5 Facet model

This method describes the solid geometry boundary and the calculation region. Each triangular facet is connected to an adjacent facet with shared edges to ensure that the surfaces are watertight. In a facet model, its accuracy is determined by the chordal deviation from the CAD model. More accuracy requires more calculation effort.

4.1.2.6 Slicing process

The slicing process is an essential pre-manufacturing stage in all additive manufacturing processes. It involves slicing the facet (volume) model into several successive layers and recording the information contained within each layer. The sliced contour data are no longer connected to one another in the z-axis, which means that subsequent scaling is no longer possible. With some technologies, this process is automatically performed by the software, once the necessary parameters (e.g. layer thickness) have been set. Other systems require separate software to prepare and store this layer data.

4.2 Data formats

4.2.1 General

The most common interface formats used within the dataflow are explained in 4.2.2 to 4.2.8. The STL format is the most commonly used data format for data transfer. If the STL format cannot be exported due to the absence of the interface module (not supplied as standard with all CAD software programs), the data can be transferred to other CAD programs via interface formats (e.g. STEP or IGES), which shall then enable an STL output.

NOTE Conversion problems can arise when transferring data through system-neutral interfaces, since interfaces capabilities (despite established standards) vary greatly and programs operate with varying degrees of accuracy (e.g. in the acceptance of the joining of two adjacent surfaces).

4.2.2 STL

The STL file format was originally developed as part of the CAD package for the early Stereolithography Apparatus, (thus referring to that process) but has overtime established itself as a commonly used format for transferring 3D model data to additive manufacturing technologies. It is a system-neutral data format for exchanging pure geometric coordinates. The boundary surfaces of volume models are described by triangles (planar facets) and their normal vectors. STL data sets can be stored using either ASCII or binary representations, the former being a more human-readable format, the latter substantially reducing the file size. The STL data format is unsuitable for exchanging data between CAD/CAM systems because the geometry is irreversibly faceted. (see ISO/ASTM 52900).

4.2.3 VRML (WRL)

VRML (virtual reality modelling language) ISO/IEC 14772-1 and ISO/IEC 14772-2, file extension “wrl” (world) or “wrz” (for compressed VRML files), is a platform-independent, three-dimensional image format supported by network functionality. VRML is not restricted to the input of point or edge data in the form of lists; it also describes 3D objects or scenarios in an object-orientated way in one type of computer language (plain text ASCII or UTF-8). The basic components of VRML are “node types” and communication channels: shape nodes (basic geometrical shapes such as cuboids, cylinders, cones, and spheres), appearance nodes [colour, texture (material properties), and geometric transformations], light nodes, camera nodes (parallel perspective projection), and group nodes to implement hierarchical structures, as well as prototypes to extend the existing range of node types. More recently the VRML format has become an XML format called “eXtensible 3D” by Web3D (Consortium see ISO/IEC 19775-1).

4.2.4 IGES

IGES (initial graphics exchange specification) is a neutral CAD data exchange format intended for exchange of product geometry and geometry annotation information. (see ISO/ASTM 52900). There are limitations of IGES when translating boundary representation models, which can lose their watertightness due to tolerance issues.

NOTE IGES is the common name for a United States National Bureau of Standards standard NBSIR 80-1978, Digital Representation for Communication of Product Definition Data, which was approved by ANSI first as ANS Y14.26M-1981 and later as ANS USPRO/IPO-100–1996. IGES version 5.3 was superseded by ISO 10303 STEP in 2006.

4.2.5 STEP

ISO 10303 STEP (standard for the exchange of product model data) is a system-neutral interface format to describe and exchange product model data between different CAD systems. STEP can be used to transfer product data (e.g. product assemblies, product lifecycle data, colours, text, etc.) in addition to geometric data (as with IGES). All forms of CAD data model can be integrated in the geometric representation (wireframe models, surface models, and volume models). (See ISO/ASTM 52900).

NOTE It is an ISO standard that provides a representation of product information, along with the necessary mechanisms and definitions to enable product data to be exchanged. ISO/TS 10303-1835 applies to the representation of product information, including components and assemblies; the exchange of product data, including storing, transferring, accessing and archiving.

4.2.6 AMF

The Additive Manufacturing Format (AMF) is an XML-based format for communicating additive manufacturing model data including a description of the 3D surface geometry with native support for colour, materials, lattices, textures and constellations. Metadata containing AM processing or post-processing information could be included in the AMF file type (see ISO/ASTM 52900). AMF can represent one of multiple objects arranged in a constellation. Similar to STL, 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 gives the standard specification of AMF.

4.2.7 OBJ

The OBJ file format encodes the surface geometry of a 3D model. It is able to store colour and texture information, either with a companion PNG file containing a texture map, or with a Material Template Library (MTL) file containing face attributes. The format is open source, neutral and in an ASCII file format. OBJ files achieved a more precise mesh, since surface encoding in OBJ is not limited to triangular segments but also various polygons, such as quadrilaterals or hexagons is possible.

4.2.8 3MF

The 3D Manufacturing Format (3MF) is an open-source project developed by the 3MF consortium. It is an XML-based platform. It contains the 3D model and property information. The file is also able to contain support structures attached to the part data and multiple material support.

4.3 Data preparation

4.3.1 The importance of data quality for part quality

A faultless reproduction of the geometry in the data set is a prerequisite for ensuring high-quality, trouble-free production of parts using additive manufacturing technologies. Attention shall be paid to the following:

— all surfaces of surface models shall be smoothly blended together and trimmed (a perfectly sealed, watertight model);

— all surfaces shall be oriented in such a manner that the volume can be clearly identified[1];

— when performing triangulation, no construction aids (layers, cylinders, axes, hidden elements, etc.) shall be selected;

— surface models shall be converted to solid volumes before performing polygonization/triangulation.

The generation or supply of poor quality data can call for data set repairs, which in some cases can be very time-consuming and costly and therefore require individual approval.

For this reason, and due to tolerance problems, it is advisable to supply dimensioned drawings.

4.3.2 Export parameters

The setting of export parameters when inputting the data set and thus the accuracy of polygonization/triangulation determines how accurately the desired geometry is approximated. A too coarse resolution affects the accuracy and appearance of the finished prototype. However, a very high resolution demands a large storage capacity (excessive file size) and increases preparation time (see Table 1).

Various export parameters can be set depending on the CAD program:

— chord height, aspect ratio and resolution;

— surface tolerance, absolute surface smoothing, absolute facet deviation, maximum deviation distance, conversion tolerance, adjacency tolerance;

— triangle tolerance, angular tolerance, angle control, surface plane angle.

For a few programs which do not allow the setting of individual parameters during export, the output parameters are adjusted to the display parameters. In this case, care shall be taken to ensure that an adequate and high display resolution in the program has been selected by prior adjustment.

Increasing the number of facets retrospectively to increase the image quality cannot be achieved without considerable expense. In contrast, it is generally possible to subsequently reduce the number of facets without causing problems.

Table 1 — Potential formatting errors in the data set and their impact on the manufacturing process and part

Formatting error	Process effect	Part effect	Possible measures
Too coarse triangulation	none	Poor approximation of the actual geometry	file generation with adjusted resolution
Too fine triangulation	Excessive computing time, long construction times Process errors due to large volumes of data	Defects caused by process errors	file generation with adjusted resolution
Uneven and/or un-trimmed surfaces in the CAD model	Process errors caused by undefined parts definition	Geometric distortion defects	Repair = clean cut "closed volumes"
Improper orientation of the surfaces in the CAD model	Process errors caused by empty layers or undefined parts definition	Geometric distortion defects Delamination and loss of strength in z-direction (axis)	Check normal vectors "Closed volumes"

1) All surface orientations need to be consistent so that the inside of the CAD model is always well defined. If this is not achieved, triangles in the STL or AMF file may face the wrong way, forming a hole in the part surface. Orientation is determined by the direction of the outward pointing normal vector to the CAD model surface in the location of interest.

4.3.3 Special considerations in data processing

4.3.3.1 Machining allowances

Depending on the component or the chosen method, manufacturing can require post processing. In this case, it is essential to allow for appropriate oversizing or undersizing in the areas concerned when generating the CAD model. The contractor/fabricator should be additionally informed of the machining areas.

4.3.3.2 Volume reduction

Some additive manufacturing technologies can be very lengthy and expensive when fabricating large volumes. It is possible to reduce the volume in the CAD model stage such as by creating entirely hollow regions or low-density internal regions with lattices. Volume reduction of the part shall be agreed in advance for build-to-order manufacturing.

4.3.3.3 Part alignment and supports

Depending on the process, built part accuracy and other characteristics are sensitive to part orientation and material deposition sequence. This shall be taken into account when aligning the part in the build space. In addition, manufacturing times often depend on the positioning.

Some additive manufacturing processes require the use of additional structures to support overhanging geometries, and anchor them to a solid structure, such as the build plate below. These supports are applied to the build file prior to the build operation and generally removed manually after the part has been completed.

The system user creates the supports using either the options in the system software or separate software tools.

It is not always possible to avoid damaging the surface finish entirely when attaching the supports. For this reason, it is essential to mark those areas where it is imperative that no supports are attached (see ISO/ASTM 52915).

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