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Additive manufacturing — General principles — Part positioning, coordinates and orientation

Fabrication additive — Principes généraux — Positionnement, coordonnées et orientation de la pièce

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Foreword

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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).

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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 ISO/TC 261, *Additive manufacturing*, 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).

The first edition of ISO 17295 cancels and replaces ISO/ASTM 52921:2013, which has been technically revised.

The main changes are as follows:

— terms and definitions that are included in ISO/ASTM 52900 have been removed from this document and instead referred to ISO/ASTM 52900;

— since the list of terms and definitions have been removed from this edition, it is therefore not a standard terminology anymore, and therefore it has been renamed so that the title describes the actual content of the standard;

— the remaining normative content of the document including the annex have been consolidated into one single normative document;

— specifications of some aspects of initial build orientation and orthogonal orientation notation have been integrated in the text body of the document.

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

Although many additive manufacturing systems are based heavily upon the principles of computer numerical control (CNC), the coordinate systems and nomenclature specific to CNC are not sufficient to be applicable across the full spectrum of additive manufacturing equipment. This document expands upon the principles of ISO 841 and applies them specifically to additive manufacturing.

Additive manufacturing — General principles — Part positioning, coordinates and orientation

1 Scope

This document provides specifications and illustrations for the positioning and orientation of parts with regards with coordinate systems and testing methodologies for additive manufacturing (AM) technologies in an effort to standardize the method of representation used by AM users, producers, researchers, educators, press/media, and others, particularly when reporting results from testing of parts made on AM systems. Included specifications cover coordinate systems and the location and orientation of parts. It is intended to be in accordance with the principles of ISO 841 and to clarify the specific adaptation of those principles for additive manufacturing.

2 Normative references

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 841, *Industrial automation systems and integration — Numerical control of machines — Coordinate system and motion nomenclature*

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 ISO/ASTM 52900 and ISO 841 apply.

ISO and IEC maintain terminology 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/
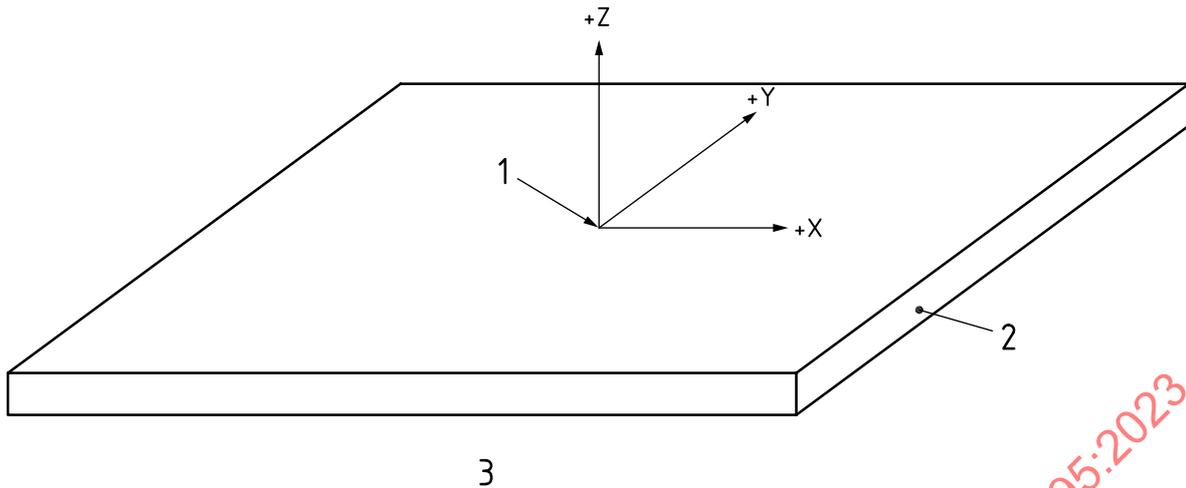
4 Machine coordinate systems for additive manufacturing machines with different build directions

4.1 General

The location and orientation of a part within the build volume shall be specified using coordinates in a three-dimensional machine coordinate system. Examples of different machine coordinate systems for different types of additive manufacturing machines are illustrated in Figures 1, 2 and 3.

4.2 Machine coordinate system for additive manufacturing machines with upwards Z-positive build direction

A three-dimensional Cartesian coordinate system located at the build origin for a generic additive manufacturing process using upwards Z-positive building direction, is illustrated as seen from the front of the machine in Figure 1. This is the most common type of machine coordinate system and is used for processes within all defined additive manufacturing process categories, though other types of coordinate systems can be used for specific process solutions within some process categories.
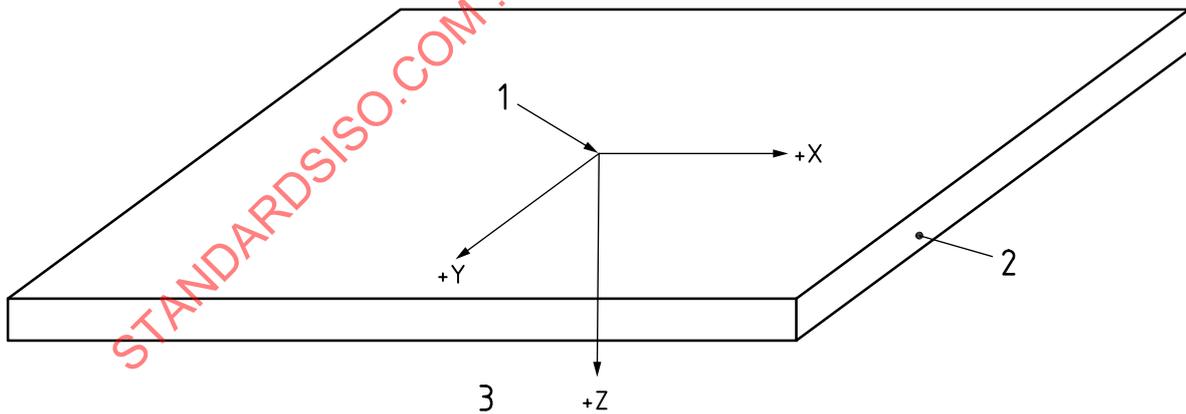
Key

1 build origin (0,0,0)

2 build platform

3 front of the machine

Figure 1 — Cartesian coordinate system for additive manufacturing with upward Z-positive building direction

4.3 Machine coordinate system for additive manufacturing machines with downwards Z-positive build direction

A three-dimensional Cartesian coordinate system located at the build origin for a generic additive manufacturing process using downwards Z-positive building direction, is illustrated as seen from the front of the machine in Figure 2. This type of machine coordinate system is mostly used for certain vat photopolymerisation process solutions.

Key

1 build origin (0,0,0)

2 build platform

3 front of the machine

Figure 2 — Cartesian coordinate system for additive manufacturing with downward Z-positive building direction

5 Rule for positive direction of axes of rotation

A, B and C define the designation of rotary axes about linear axes X, Y and Z respectively. Positive A, B and C are in the direction to advance right-hand screws in the positive X, Y and Z directions respectively (see Figure 3).

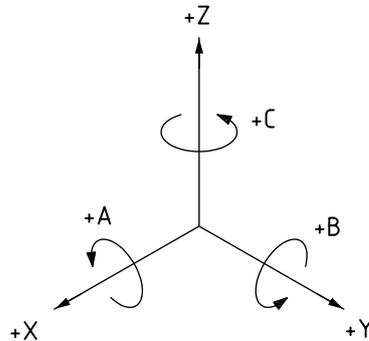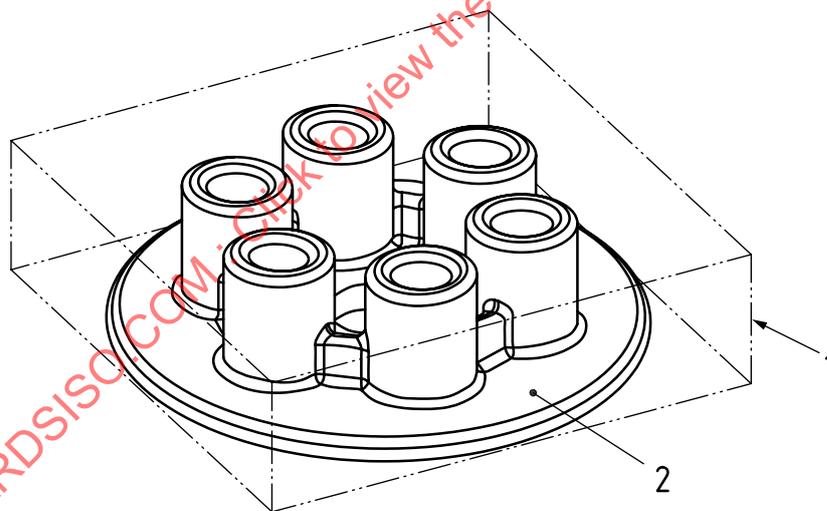**Figure 3 — Right-hand coordinate system (extracted from ISO 841:2001, Figure A.1)**

6 Bounding box

An example of part geometry, in this case a pressure plate, enclosed by its bounding box is illustrated in Figure 4.

Key
1   bounding box
2   part geometry

Figure 4 — Example of a part geometry and its bounding box

Different bounding boxes with respect to their orientation and the part geometry's orientation are illustrated in Figure 5. Figure 5 a) shows an arbitrarily oriented part geometry enclosed by a bounding box that is aligned to the machine coordinate system Figure 5 b) shows the same part geometry in the same orientation, but this time enclosed by its arbitrarily oriented bounding box. In this case, the bounding box is aligned to the part coordinate system. Figure 5 c) shows the same part geometry now re-oriented so that its bounding box is aligned to the part coordinate system and to the machine coordinate system.
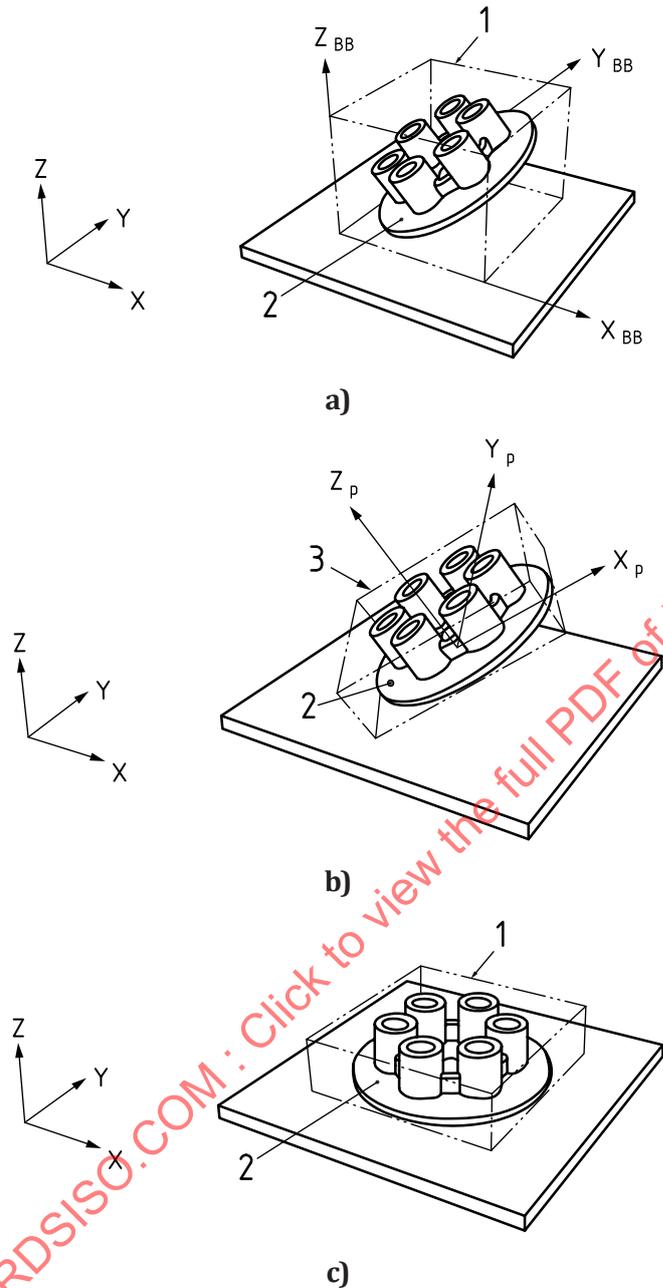
Key

|	
1	bounding box aligned to the machine coordinate system
2	part geometry
3	arbitrarily oriented bounding box
X, Y, Z	machine coordinate system
X_{BB}, Y_{BB}, Z_{BB}	bounding box coordinate system
X_P, Y_P, Z_P	part coordinate system

Figure 5 — Examples of part orientation and different types of bounding boxes

7 Initial build orientation

The initial build orientation is the orientation of the part as it is first placed in the build volume and is most commonly used as a reference for any further reorientation of the part. The initial build orientation

shall be communicated either by 3D computer models, with the possibility to be interrogated for part position and orientation relative to the build origin, as agreed between the supplier and the user of the oriented part geometry, or by image(s) of the part(s) within the build volume and the orientation relative to the build origin.

Figure 6 show the part geometry with its intended build orientation (the positive Z-direction) relative to the build origin. The overall dimensions of its bounding box are provided so that the geometric centre can be calculated. The alignment of the major features, in this example the bolt circle, has been made apparent by the centre lines. Alternative orientations of the same part are illustrated in Figure 7.
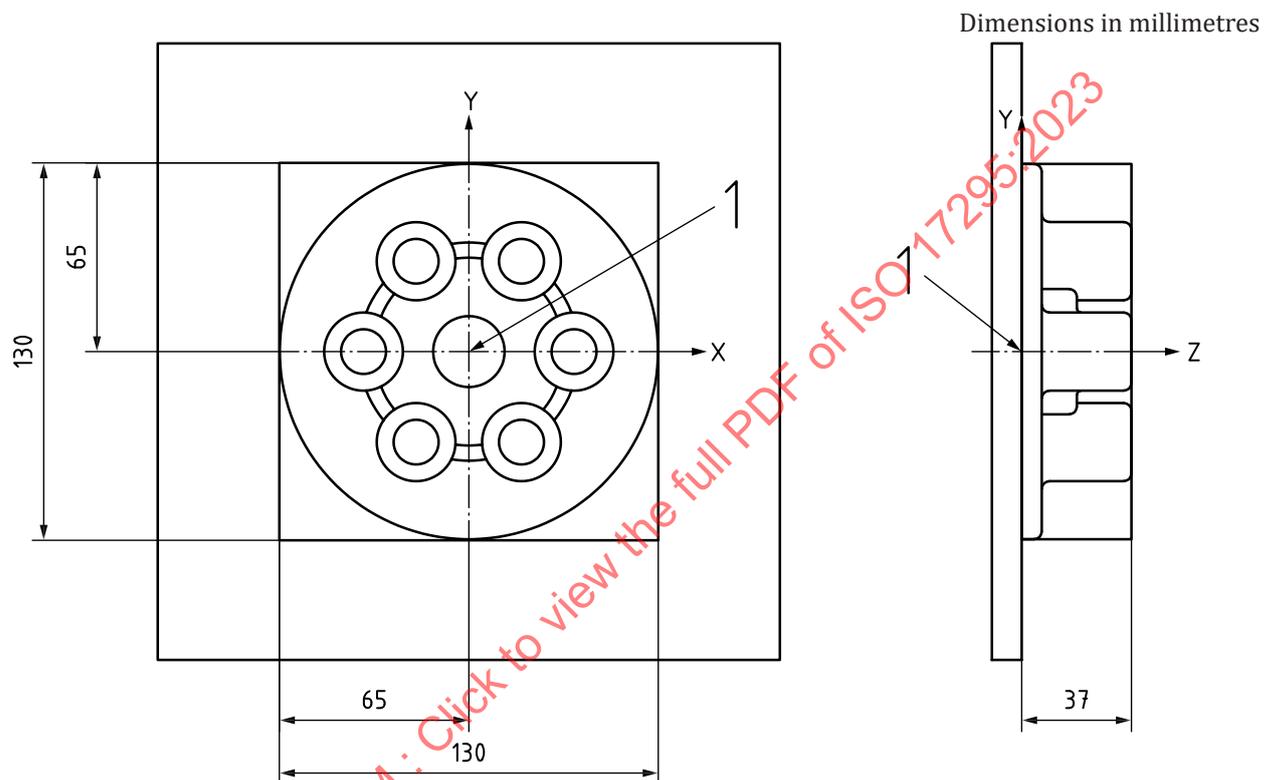
Key

1   build origin

Figure 6 — Initial build orientation

The initial build orientation of the part in Figure 6 has positioned the part directly over the build origin such that the Z-axis pass through the geometric centre of the bounding box. The sides of the bounding box are aligned parallel to the X-, and Y-axes of the coordinate system, while the part geometry is rotated such that the X-, and Y-axis intersect the part symmetrically. This is a convenient orientation, especially when specifying multiple occurrences of the part geometry with reorientation, but it is not a requirement for the initial build orientation. For example, if thoroughly dimensioned, the orientation of this part as shown in Figure 5 a) could be used as an initial build orientation as well. In practice, the more complicated the part geometry and increased number of orientations, the more advantageous it will be to communicate the initial build orientation using three-dimensional computer models, rather than methods for 2D reporting.

Orthogonal orientation notation describes the orientation of the bounding box according to overall length in decreasing magnitude parallel to the axis of the machine coordinate system. However, this only provides the orientation of the bounding box, and does not provide a full description of the orientation of the part within the bounding box. Figure 7 illustrate different orientations of a part with the same orthogonal orientation notation.
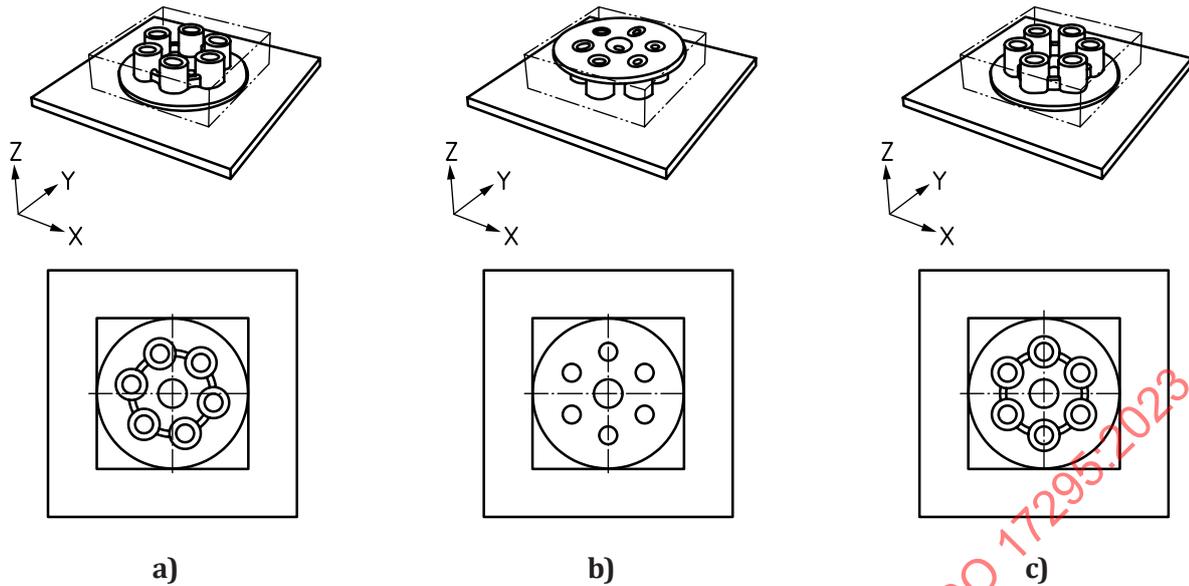
a)   **b)**   **c)**

Figure 7 — Different orientations of a part with the same bounding box orientation notation

NOTE   Even though they share the same orthogonal orientation notation for their bounding box, the part coordinate system orientations in a), b) and c) are not identical.

Even if the bounding box is identically aligned, such as in Figure 7, there are still multiple orientations possible for many part geometries. The example illustrated in Figure 7 show the part geometry, a pressure plate with a 60° rotated bolt circle in several alternative orientations. For communication of the initial build orientation of most complex geometries, a visual depiction is needed in order to clarify which orientation is intended.

8 Orthogonal orientation notation

8.1 General

Orthogonal orientation notation of a part's initial build orientation can be used when the intended build orientation for a part is such that its bounding box is aligned parallel to the X, Y, and Z directions of the build origin as shown in Figure 5 c). The orientation of the bounding box is described by listing which axis is parallel to the longest overall dimension of the bounding box first, followed by the axis which is parallel to the second longest overall dimension of the bounding box second, followed by the axis which is parallel to the third longest overall dimension of the bounding box. Figure 8 shows the possible alignments for a bounding box with reference to the build volume origin and their notations.

EXAMPLE   A part and its bounding box which is placed so that its longest dimension is parallel to the Z-axis, the second longest dimension is parallel to the X-axis, and its shortest overall dimension is parallel to the Y-axis shall be defined as having a ZXY orientation. See Figure 8 e).

Where symmetry allows unambiguous designation of orientation by listing fewer than three axes in descending order of length, orthogonal orientation notation may be further abbreviated, see 8.2 and 8.3.

Some combinations of symmetry in the geometry of a part can make the orthogonal orientation notation of the initial build orientation fully specify only one possible orientation and therefore no image is required to communicate the initial build orientation for this type of geometries. This is the case for parts like the dog bone specimen (ASTM D638 or ISO 527-1) as illustrated in Figure 9, which are bilaterally symmetrical (see 8.2) through its geometric centre in the XY, XZ, YZ planes and have no rotational symmetry. This is also the case for parts like the round tension bar illustrated in Figure 10 which have 360° rotational symmetry through a centre axis and are also bilaterally symmetrical across

the plane bisecting the part perpendicular to the axis of rotational symmetry. However, an image is normally required to identify initial build orientation when parts have features with less than 360° rotational symmetry as illustrated in Figure 9.
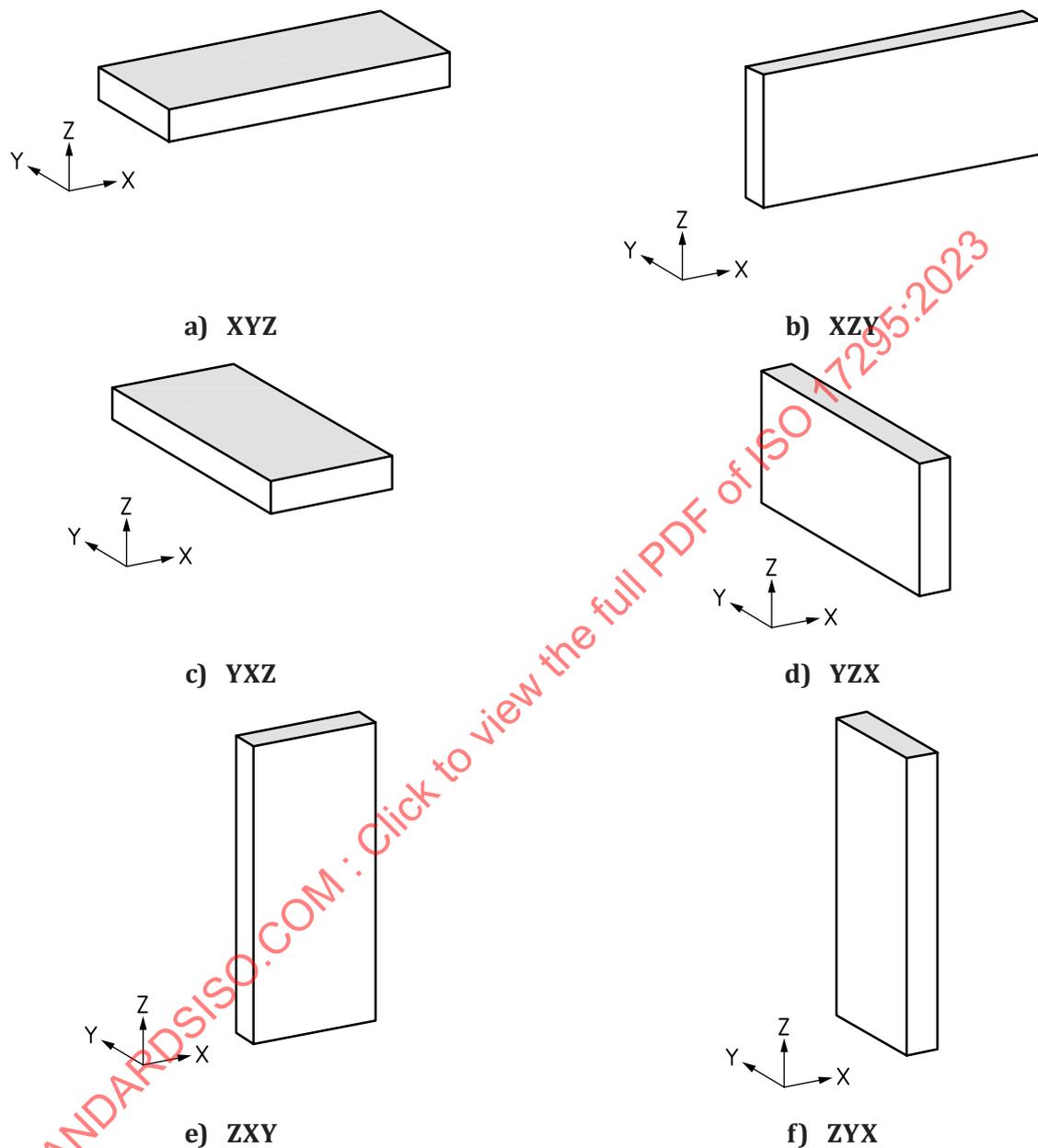

a) XYZ

b) XZY

c) YXZ

d) YZX

e) ZXY

f) ZYX

Figure 8 — Orthogonal orientation notation

8.2 Bilateral symmetry

Bilateral symmetry is present when geometry is mirrored across a centre plane. Parts with radial and other types of symmetry are often bilaterally symmetric as well, such as the round tension test specimen. Different geometries with bilateral symmetry are illustrated in Figure 9.
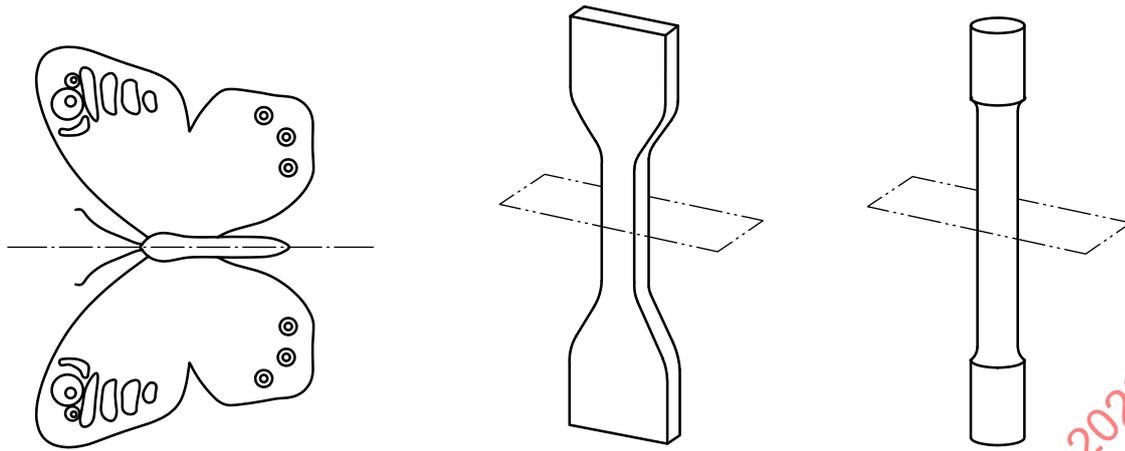
Figure 9 — Examples of bilateral symmetry

8.3 Abbreviation of orthogonal orientation notation

Orthogonal orientation notation can be abbreviated based on the part's geometric symmetry. For example, the orientation of parts with bilateral symmetry, such as a dog bone-shaped tensile specimen illustrated in Figure 11, can be described by listing the axes parallel to the longest and second longest dimensions. This makes the orthogonal orientation notation for the tensile specimen geometry in Figure 11 be ZY. Additionally, the orientation of a rotational symmetric geometry such as a round tensile bar can unambiguously be described by listing only the axis to which the longest dimension runs parallel as illustrated in Figure 11.


a) ZX

b) Z

Figure 10 — Examples where symmetry allows abbreviation of orthogonal orientation notation

9 Representation of part location and initial build orientation

Figure 12 illustrates a set of five tensile test bars (ASTM E8/E8M or ISO 6892-1) positioned in the build volume of a generic type of additive manufacturing machine. The geometry of the test bars is bilateral and rotational symmetric, see 8.2.

The geometry of these parts meets the criteria for describing their initial build orientation using abbreviated orthogonal orientation notation (see 8.3) and therefore are labelled with "Z" rather than ZXY. The location of each part is the position (in X-, Y-, and Z-coordinates) of the geometric centre of the bounding box for the part. Since the parts are bilateral and radial symmetric, the communication of the orientation of the parts does not require a visual depiction of the parts in the build volume. Their positions can therefore unambiguously be described as in Table 1.

Dimensions in millimetres

Key
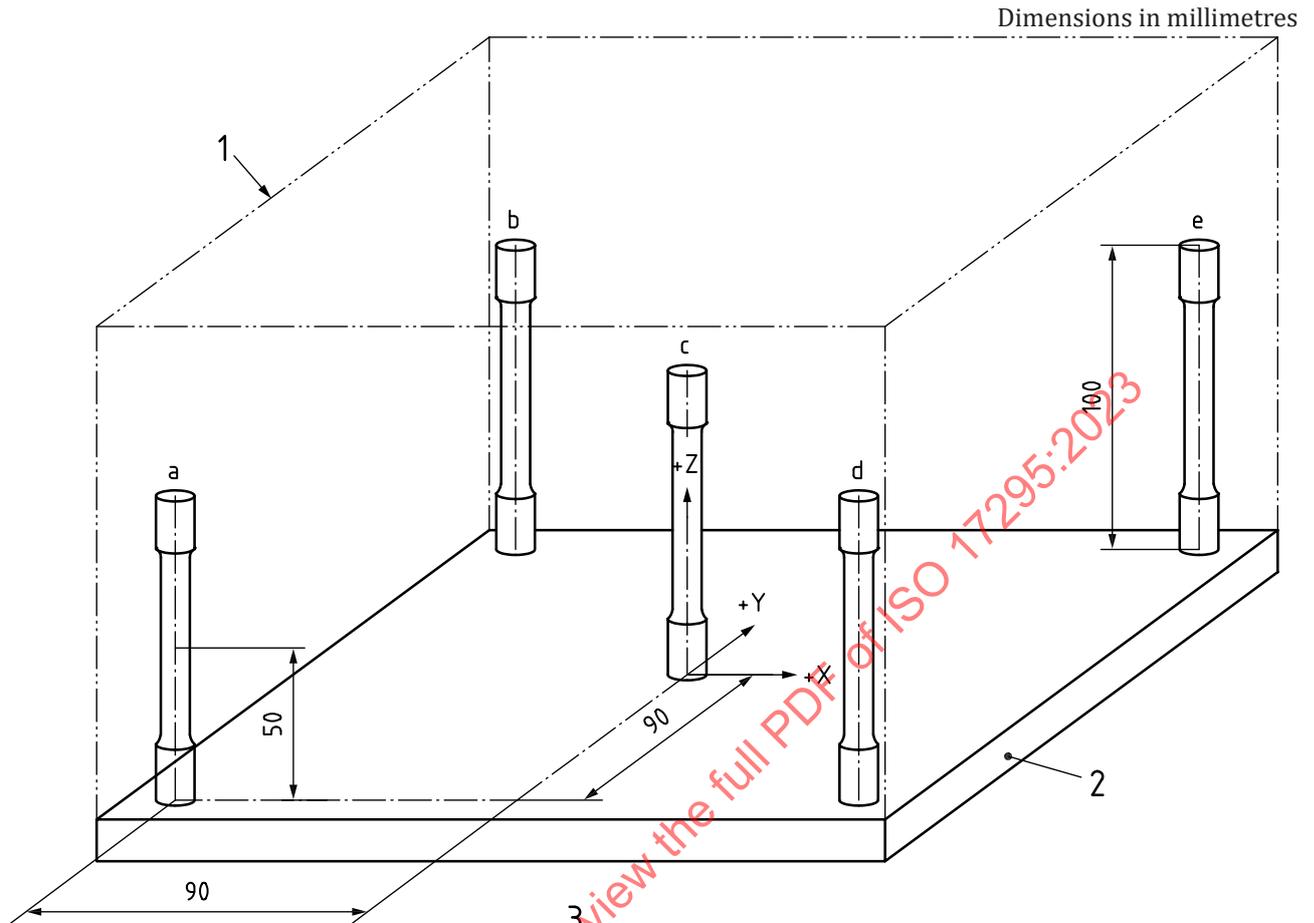
a, b, c, d, e   samples

1   build volume

2   build platform

3   front of the machine

Figure 11 — Part location and initial build orientation: five round bar specimens with Z orientation

Table 1 — Description of part locations and orientations

Sample name	Location (X, Y, Z) mm	Reorientation (A, B, C) °	Initial orientation
Sample a	0, 0, 50	None	Z
Sample b	90, 90, 50	None	Z
Sample c	−90, 90, 50	None	Z
Sample d	−90, −90, 50	None	Z
Sample e	90, −90, 50	None	Z

10 Representation of part location and reorientation

When parts have been reoriented in the build volume it is many times more practical to specify the initial build orientation and list the deviations. Figure 12 show a set of six tensile test bars positioned in a build volume as seen from the front of the machine. The initial orientation was Z, but the parts in

the front row have been rotated 45° around the Y-axis (B = 45), and the parts in the back row have been rotated -45° around the Y-axis (B = -45). See Figure 12.

Dimensions in millimetres

Key
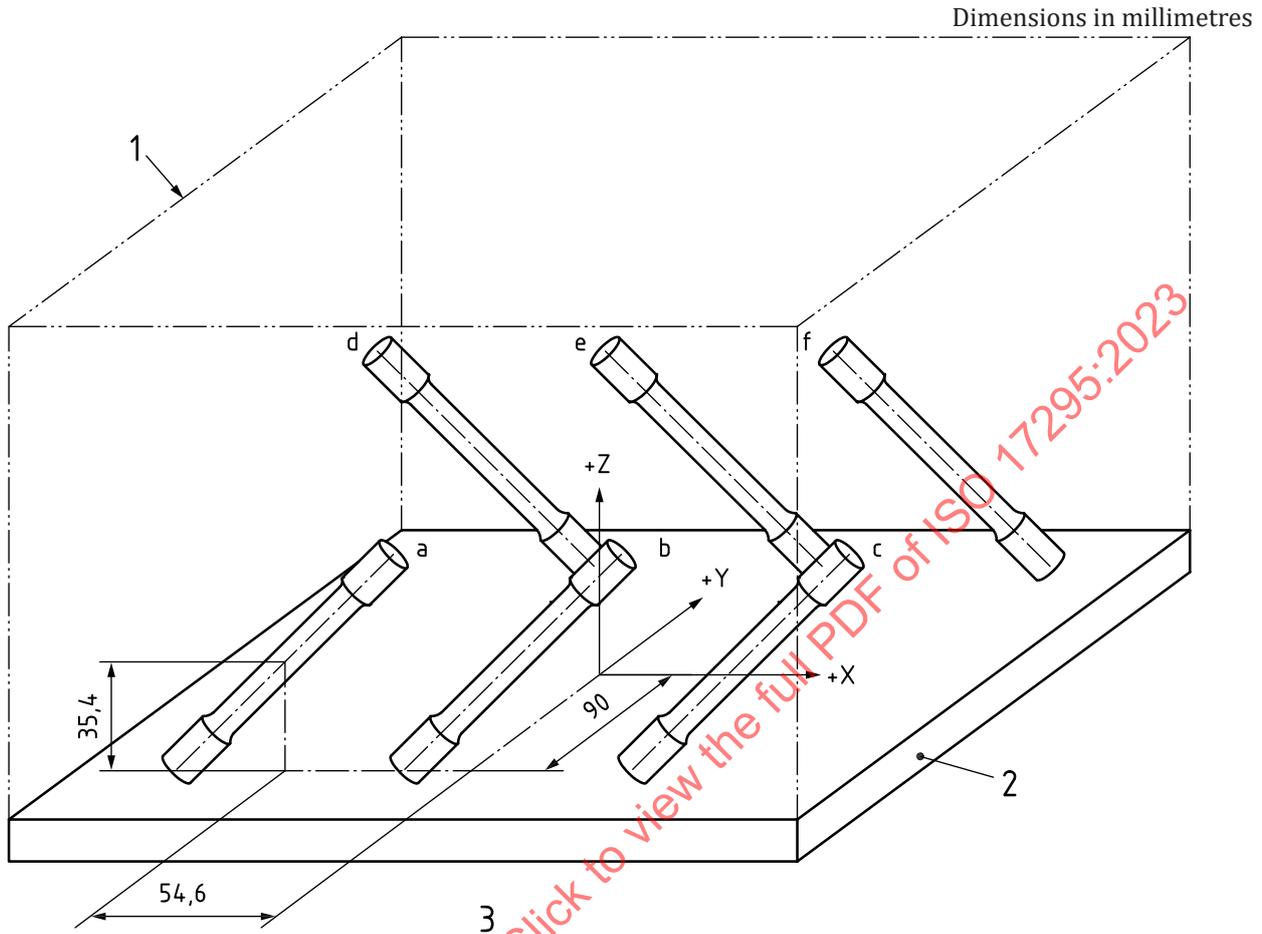
a, b, c, d, e   samples

1   build volume

2   build platform

3   front of the machine

Figure 12 — Part location and reorientation: round tensile test bars reoriented at (front row) B+45 from Z and (back row) B−45 from Z

Since the parts are bilateral and radial symmetric, the communication of the orientation of the parts does not require a visual depiction of the parts in the build volume. However, since they have been reoriented it is a practical approach to specify the deviation from their initial build orientation. Their positions can therefore unambiguously be described as in Table 2.

Table 2 — Description of part locations and reorientations

Sample name	Location (X, Y, Z) mm	Reorientation (A, B, C) °	Initial orientation
Sample a (front row)	−54,6, −90, 35,4	0, 45, 0	Z
Sample b (front row)	0, −90, 35,4	0, 45, 0	Z
Sample c (front row)	54,6, −90, 35,4	0, 45, 0	Z
Sample d (back row)	−54,6, 90, 35,4	0, −45, 0	Z