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Second edition
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Geometrical product specifications (GPS) — Dimensional tolerancing —

Part 2: Dimensions other than linear or angular sizes

Spécification géométrique des produits (GPS) — Tolérancement dimensionnel —

Partie 2: Dimensions autres que tailles linéaires ou angulaires

Reference number
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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 Committee ISO/TC 213, *Dimensional and geometrical product specifications and verification.*

This second edition cancels and replaces the first edition (ISO 14405-2:2011), which has been technically revised.

The main changes compared to the previous edition are as follows:

— the addition of angular sizes to reflect ISO 14405-3;

— clarifications around specification ambiguity and the use of geometrical tolerancing;

— a review and update of all normative references and other ISO GPS standards referenced in the text.

A list of all parts in the ISO 14405 series can be found on the ISO website.

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

This document is a geometrical product specification (GPS) standard and is to be regarded as a general GPS standard (see ISO 14638). It influences chain link A of the chain of standards on distance.

The ISO GPS Matrix model given in ISO 14638 gives an overview of the ISO GPS system of which this document is a part. The fundamental rules of ISO GPS given in ISO 8015 apply to this document and the default decision rules given in ISO 14253-1 apply to specifications made in accordance with this document, unless otherwise indicated.

For dimensions other than linear or angular sizes, the requirement is ambiguous when applied to the real workpiece. It is the presence of form and angular deviations on all real workpieces that makes these requirements ambiguous, i.e. there is a specification ambiguity.

This specification ambiguity can only be avoided for features of size toleranced in accordance with ISO 14405-1 or ISO 14405-3. For all other dimensions, geometrical specifications should be used in order to control the specification ambiguity.

For more detailed information on the relation of this document to other standards and to the GPS matrix model, see Annex B.

Geometrical product specifications (GPS) — Dimensional tolerancing —

Part 2: Dimensions other than linear or angular sizes

1 Scope

This document illustrates the ambiguity caused by the use of dimensional specifications to control properties other than linear or angular size and the benefit of using geometrical specifications instead.

Dimensional tolerancing can be indicated by ± tolerancing or geometrical specifications.

The ambiguity caused by using ± tolerances for dimensions other than linear or angular sizes (for individual tolerances and general tolerances according to, e.g. ISO 2768-1 and ISO 8062-3) is explained in Annex A.

NOTE 1 The figures, as shown in this document, merely illustrate the text and are not intended to reflect actual usage. The figures are consequently simplified to indicate only the relevant principles.

NOTE 2 For indications of dimensional specifications, see the following:

— ISO 14405-1 for linear size;

— ISO 14405-3 for angular size;

— ISO 2538-1 and ISO 2538-2 for wedges;

— ISO 3040 for cones.

NOTE 3 The rules for geometrical specifications are given in ISO 1101.

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 129-1, *Technical product documentation (TPD) — Presentation of dimensions and tolerances — Part 1: General principles*

ISO 1101, *Geometrical product specifications (GPS) — Geometrical tolerancing — Tolerances of form, orientation, location and run-out*

ISO 8015, *Geometrical product specifications (GPS) — Fundamentals — Concepts, principles and rules*

ISO 13715, *Technical product documentation — Edges of undefined shape — Indication and dimensioning*

ISO 14405-1, *Geometrical product specifications (GPS) — Dimensional tolerancing — Part 1: Linear sizes*

ISO 14405-3, *Geometrical product specifications (GPS) — Dimensional tolerancing — Part 3: Angular sizes*

ISO 17450-1, *Geometrical product specifications (GPS) — General concepts — Part 1: Model for geometrical specification and verification*

ISO 17450-2, *Geometrical product specifications (GPS) — General concepts — Part 2: Basic tenets, specifications, operators, uncertainties and ambiguities*

ISO 17450-3, *Geometrical product specifications (GPS) — General concepts — Part 3: Toleranced features*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 129-1, ISO 1101, ISO 8015, ISO 13715, ISO 14405-1, ISO 14405-3, ISO 17450-1, ISO 17450-2, ISO 17450-3 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/

The term “drawing” is used in this document as a synonym for the 2D drawing, the 3D model and other representations of the workpiece.

3.1
± tolerancing
tolerancing using dimension and indication of limit deviations, dimension limit values or unilateral dimension limit

Note 1 to entry: The sign ± should not be understood in a way that the limit deviations are always symmetrical to the nominal size.

3.2
linear size
dimension in length units characterizing a feature of size

3.3
angular size
dimension in angle units characterizing a feature of size

3.4
distance
dimension between two geometrical features which are not considered as a feature of size

Note 1 to entry: Distance can be between two integral features or an integral feature and a derived feature or two derived features.

Note 2 to entry: *Linear distance* (3.4.1) and *angular distance* (3.4.2) exist.

3.4.1
linear distance
distance (3.4) in length units

3.4.2
angular distance
distance (3.4) in angle units

4 Principles and rules for indication of dimensions and related tolerances

The general rules and principles for indicating ± tolerances given in ISO 14405-1 and ISO 14405-3 apply to this document and are the basis for tolerancing on mechanical engineering drawings. In all other cases, special rules apply.

For rules on the indication of units, see Clause 5.

For dimensions other than linear or angular sizes, a requirement with ± tolerancing is ambiguous (specification ambiguity) when applied to a real workpiece. This type of specification is not recommended; see Annex A.

Specification ambiguity of dimensional specifications can be avoided for linear features of size when specified in accordance with ISO 14405-1 and for angular features of size when specified in accordance with ISO 14405-3. In order to minimize specification ambiguity, geometrical specifications shall be used for the cases illustrated in Table 1.

Unless otherwise specified, e.g. by using CZ according to ISO 1101 or Ⓜ according to ISO 2692, tolerances on mechanical engineering drawings are independent requirements without any relationships to other requirements for the same feature(s). This is the independency principle (see ISO 8015).

Table 1 — Types of dimensions which are not sizes

<table>
<tr><th colspan="2"></th><th colspan="3">Characterization, type and number of features</th><th>Type of dimension</th><th>Details in</th></tr>
<tr><td rowspan="11">Dimension</td><td rowspan="8">Linear dimension
(length units)</td><td rowspan="2">One feature</td><td colspan="2">Integral or derived</td><td>Radius dimension</td><td>7.5, A.6, A.7</td></tr>
<tr><td colspan="2">Integral or derived</td><td>Arc length</td><td>A.12</td></tr>
<tr><td rowspan="4">Two features</td><td rowspan="2">Integral — integral</td><td>Facing the same direction</td><td>Linear distance or step height</td><td>7.2, A.2</td></tr>
<tr><td>Facing the opposite direction</td><td>Linear distance</td><td>7.2, 7.6, A.3, A.8</td></tr>
<tr><td colspan="2">Integral — derived</td><td>Linear distance</td><td>7.3, 7.7, A.4, A.9</td></tr>
<tr><td colspan="2">Derived — derived</td><td>Linear distance</td><td>7.4, A.5</td></tr>
<tr><td rowspan="2">Edge (transition region between two integral features)</td><td rowspan="2">Integral</td><td>Chamfer shape</td><td>Chamfer height and angle</td><td>A.11</td></tr>
<tr><td>Rounding shape</td><td>Edge radius</td><td>A.11</td></tr>
<tr><td rowspan="3">Angular dimension
(angle units)</td><td rowspan="3">Two features</td><td colspan="2">Integral — integral</td><td>Angular distance</td><td>8.1
ISO 14405-3
ISO 2538-1
ISO 2538-2</td></tr>
<tr><td colspan="2">Integral — derived</td><td>Angular distance</td><td>8.2, A.10</td></tr>
<tr><td colspan="2">Derived — derived</td><td>Angular distance</td><td>—</td></tr>
</table>

5 Units used in drawings for dimensions

The default units for dimensions are the following.

— For linear dimensions and associated tolerance limits, the unit is the millimetre (mm).

— For angular dimensions and associated tolerance limits, the unit is the degree (360°). Decimal degrees or degrees, minutes and seconds can be used.

For a linear dimension, the unit is not indicated; it is implied.

For an angular dimension, the unit shall be indicated for the nominal value and for the tolerance limit indication.

If a unit other than the default is used, the unit shall be indicated in or near the title block of the drawing.

6 Indication of tolerances for linear or angular dimensions

Indication of tolerances for linear dimensions shall be in accordance with the indication rules in ISO 14405-1.

Indication of tolerances for angular dimensions shall be in accordance with the indication rules in ISO 14405-3.

7 Illustrations of ambiguous ± tolerancing vs. unambiguous geometrical specifications

7.1 General

This clause shows examples of the use of geometrical specifications for dimensions which are not linear sizes or angular sizes. Geometrical specifications can be used to avoid the ambiguity of dimensions with ± tolerances. Generally, requirements based on geometrical specifications have no, or very low, specification ambiguity.

The ambiguity caused by using ± tolerances is described in Annex A.

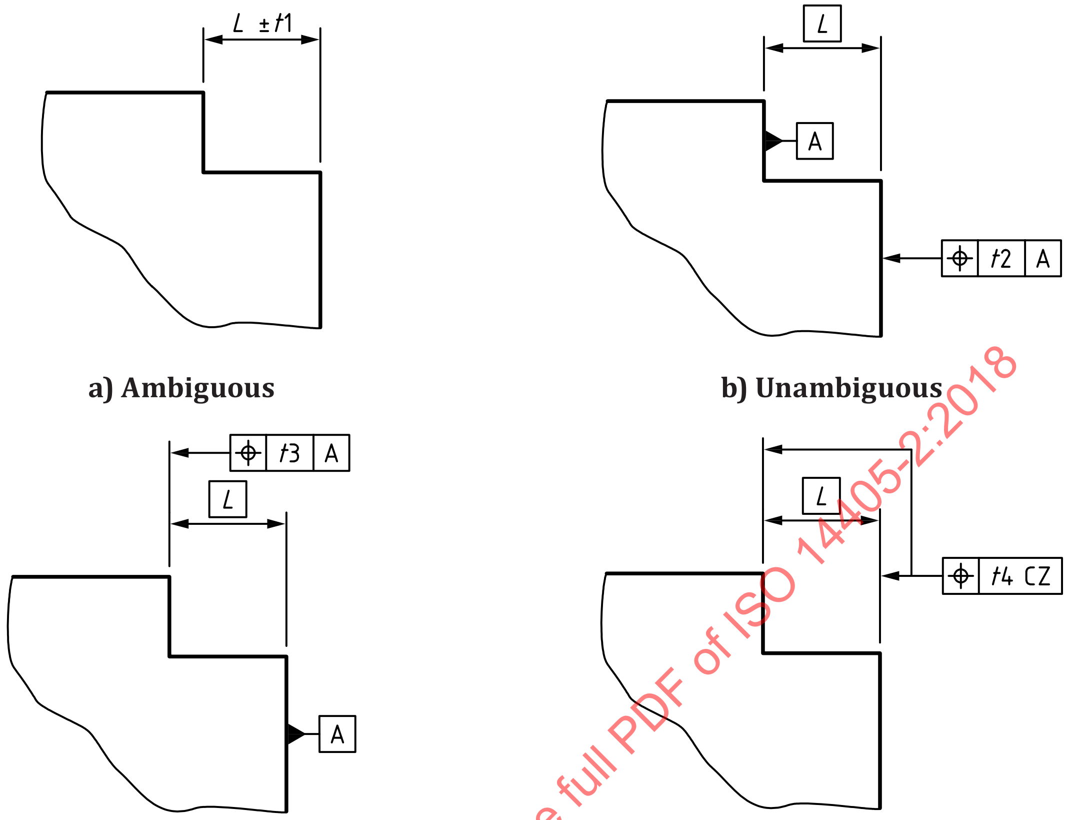
If geometrical specifications are used, several different solutions are normally possible. The examples in this clause show some of these possibilities.

Each example is accompanied by a figure illustrating the use of ± tolerancing, which is ambiguous and therefore has high specification ambiguity. (See Annex A for explanations and examples of the ambiguity associated with ± tolerancing for dimensions other than linear or angular sizes.)

For more details about geometrical specifications, see ISO 1101.

7.2 Linear distance between two integral features

See Figure 1.



a) Ambiguous

b) Unambiguous

c) Unambiguous

d) Unambiguous

Figure 1 — Example of a linear step dimension, a) and three different solutions using geometrical specifications, b), c) and d)

NOTE 1 Figure 1 a) shows an example of the use of ± tolerances for a dimension. This is ambiguous and can result in high specification ambiguity; see Annex A.

NOTE 2 Figure 1 b), c) and d) show different solutions using geometrical specifications. These are unambiguous and can result in no, or very low, specification ambiguity.

NOTE 3 In Figure 1 b), a datum plane A is established on datum feature A, the left-hand vertical nominal flat surface. Datum A aligns the workpiece in space. The right-hand vertical flat surface is toleranced by a position tolerance zone at a theoretically exact dimension (TED) distance *L*.

NOTE 4 In Figure 1 c), a datum plane A is established on datum feature A, the right-hand vertical nominal flat surface. Datum A aligns the workpiece in space. The left-hand vertical flat surface is toleranced by a position tolerance zone at a TED distance *L*.

NOTE 5 In Figure 1 d), no datum is indicated. The workpiece is aligned in space considering simultaneously the two vertical flat surfaces. The two flat surfaces are toleranced in relation to each other by position tolerance zones at a distance *L* apart.

Figure 2 shows an example with two integral features facing opposite directions. However, the principle is the same as in Figure 1.

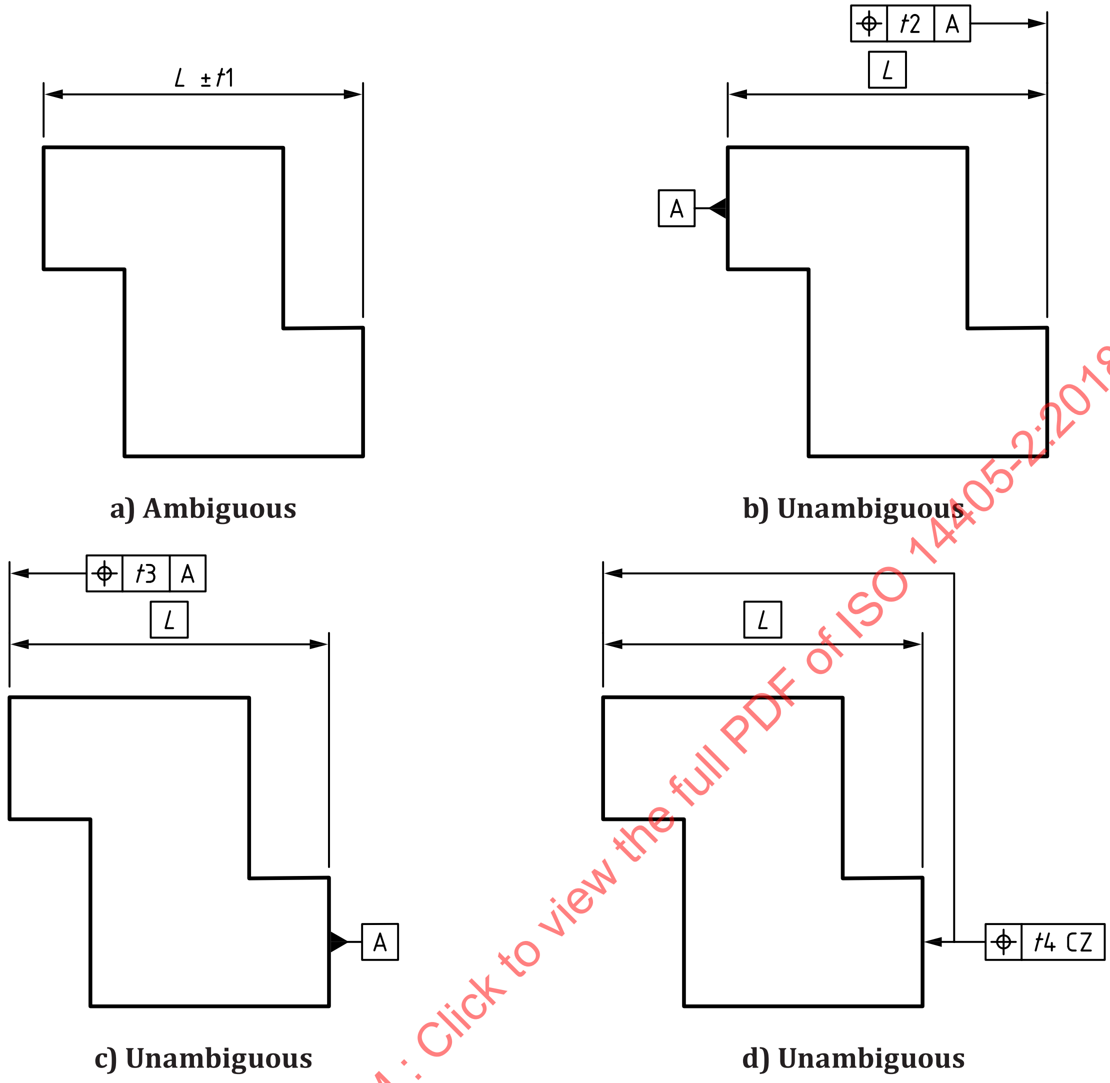
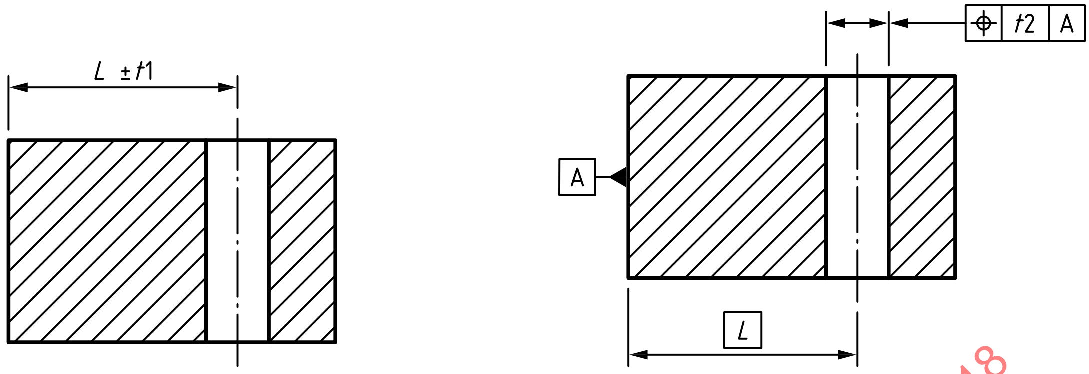


Figure 2 — Example of a linear distance between two integral features facing opposite directions – not a feature of size – a), and three different solutions using geometrical specifications, b), c) and d)

7.3 Linear distance between an integral and a derived feature

See Figure 3.



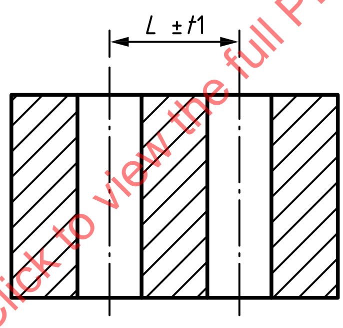
a) Ambiguous

b) Unambiguous

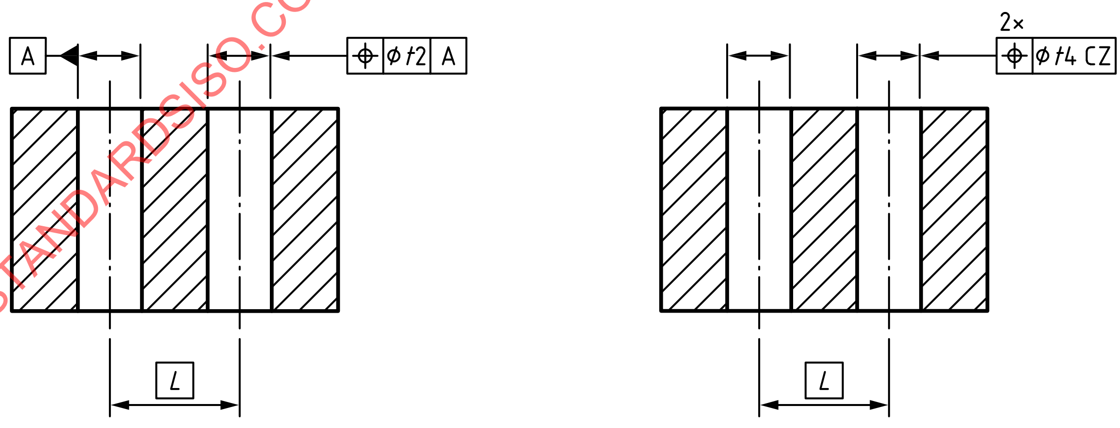
Figure 3 — Example of a linear distance between an integral feature and a derived feature, a) and one solution using geometrical specifications, b)

7.4 Linear distance between two derived features

See Figure 4.



a) Ambiguous



b) Unambiguous

c) Unambiguous

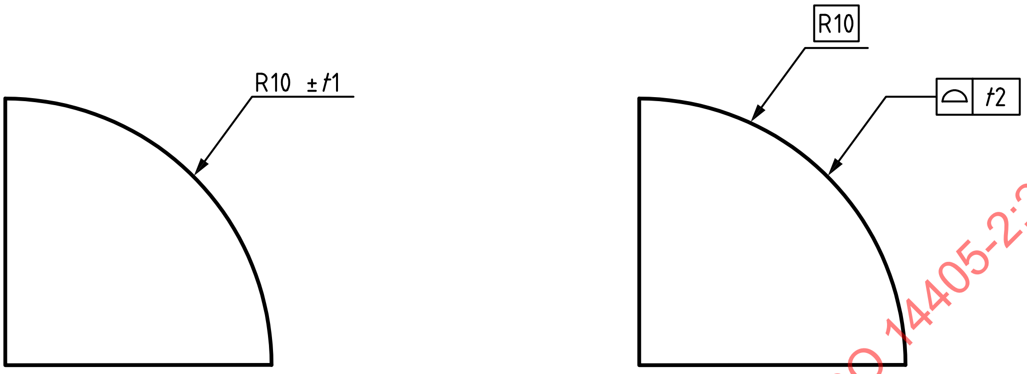
Figure 4 — Example of a linear distance between two derived features, a) and two solutions using geometrical specifications, b) and c)

NOTE 1 Figure 4 b) shows a solution with geometrical specifications where one of the holes is used as a datum and a position tolerance for the other hole is given in relation to this datum.

NOTE 2 Figure 4 c) shows a solution with geometrical specifications with a position tolerance for the two holes in relation to each other. No datum is indicated.

7.5 Radius dimension

See Figure 5.



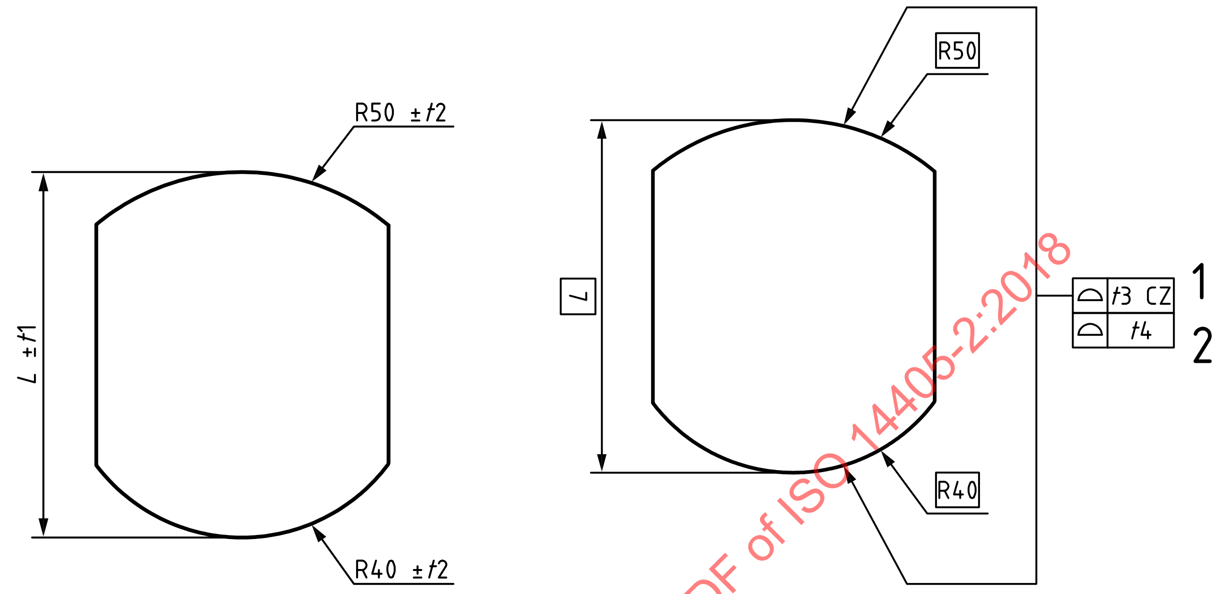
a) Ambiguous

b) Unambiguous

Figure 5 — Example of a radius dimension for an integral feature, a) and a solution using geometrical specifications, b)

7.6 Linear distance between non-planar integral features

See Figure 6.



a) Ambiguous

b) Unambiguous

Key

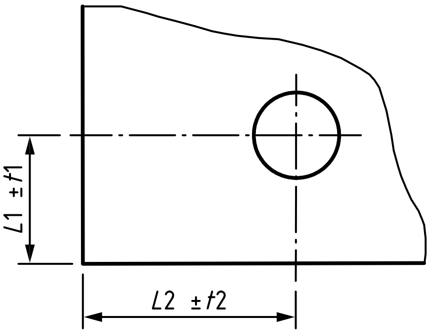
1 tolerance zone indicator of a location requirement

2 tolerance zone indicator of a form requirement

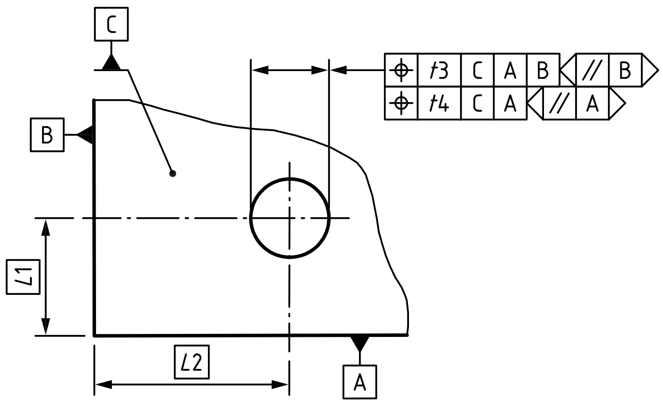
Figure 6 — Example of a linear distance between two non-planar integral features, a) and one solution using geometrical specifications, b)

7.7 Linear distance in two directions

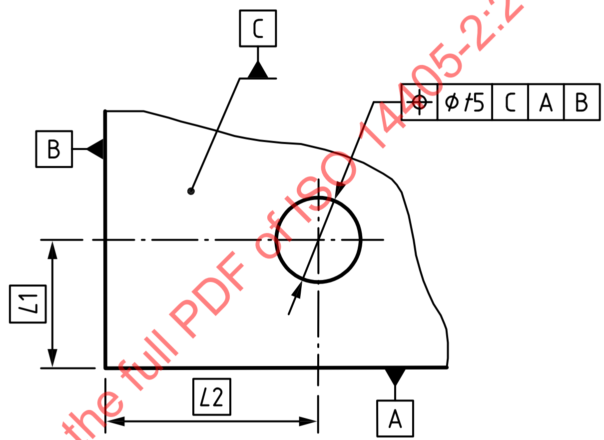
See Figure 7.



a) Ambiguous



b) Unambiguous



c) Unambiguous

Figure 7 — Example of a linear distance in two directions, a) and two solutions using geometrical specifications, b) and c)

NOTE 1 Figure 7 b) shows a solution with geometrical specifications and a position requirement for each direction. It is possible to give different tolerance values in the two directions indicated on the drawing. The use of datum C orientates the tolerance zone to be perpendicular to datum C.

NOTE 2 Figure 7 c) shows a solution with geometrical specifications and a position requirement with a cylindrical tolerance zone. The use of datum C orientates the tolerance zone to be perpendicular to datum C.

8 Angular tolerancing

8.1 Examples of geometrical specifications applied to angular distance between two integral features

See Figure 8.

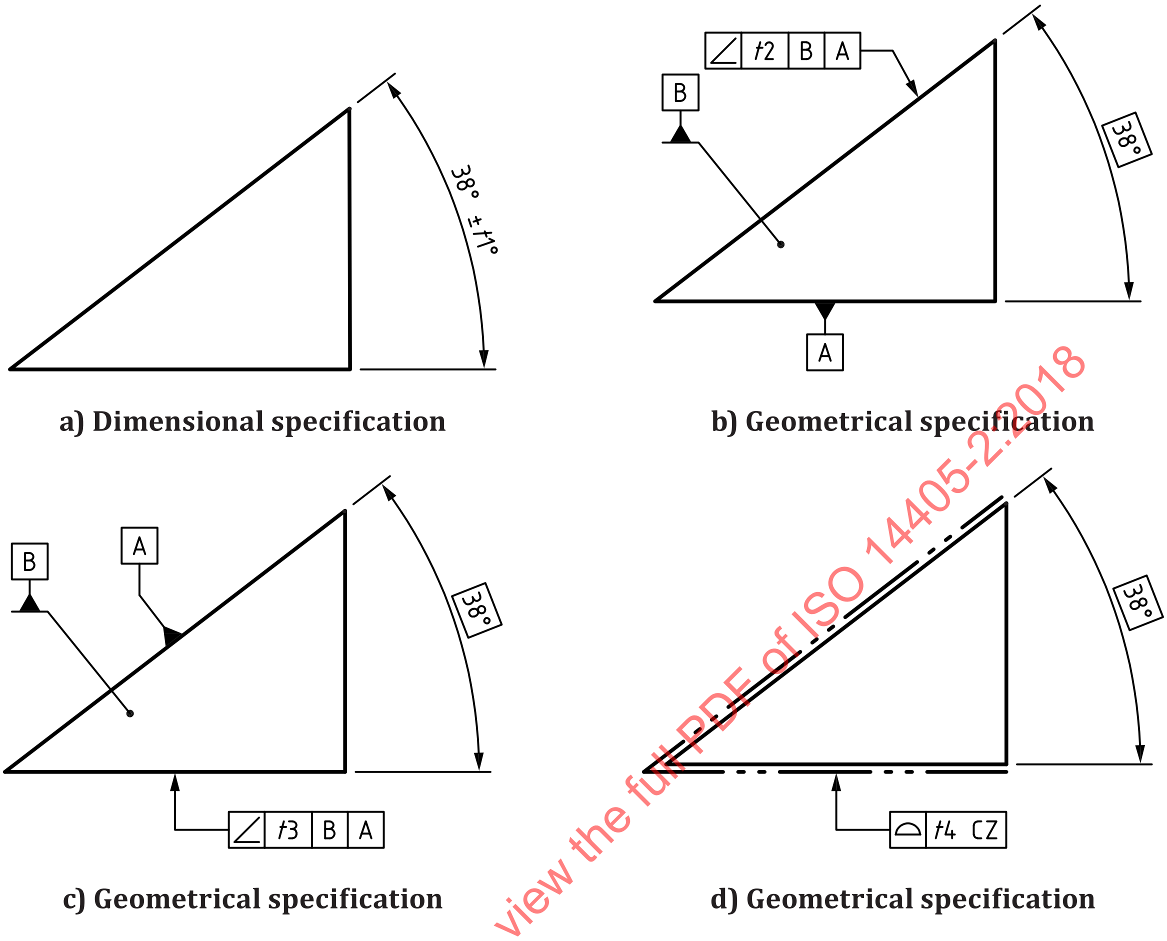
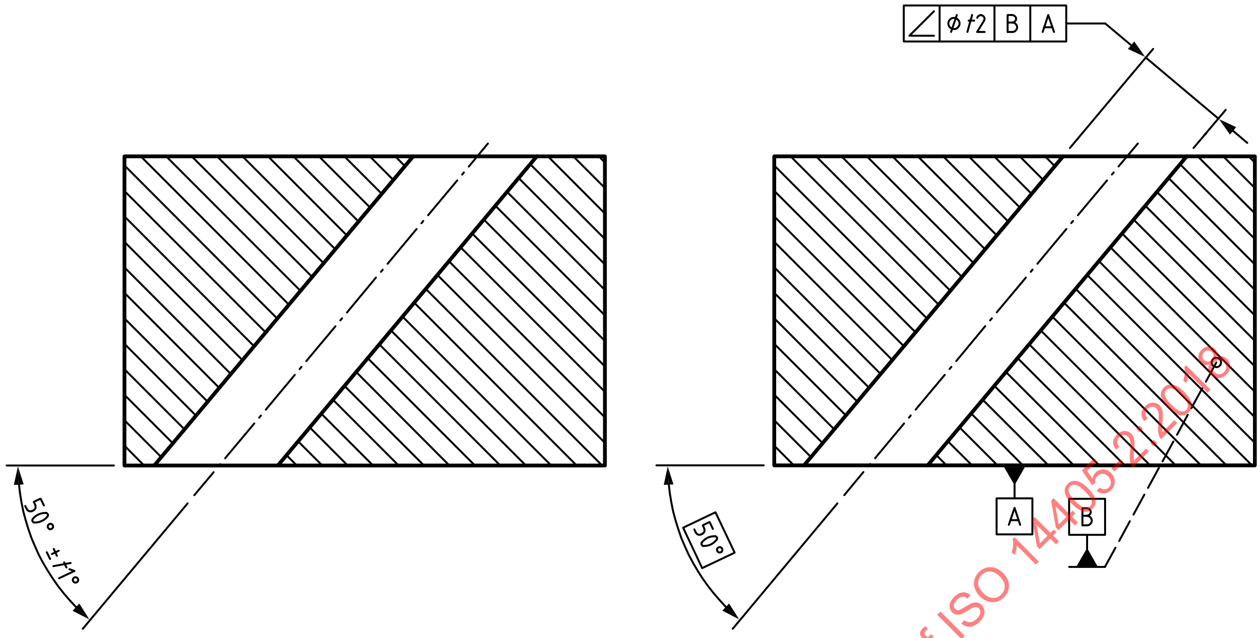


Figure 8 — Example of an angular size for an angular feature of size, a) and three different solutions using geometrical specifications between two integral features, b), c) and d)

8.2 Angular distance between an integral feature and a derived feature

See Figure 9.



a) Ambiguous **b) Unambiguous**

Figure 9 — Example of an angular distance between an integral feature and a derived feature, a) and one solution using geometrical specifications, b)

Annex A
(informative)

Explanations and examples of the ambiguity caused by using ± tolerances for dimensions other than linear size or angular size

A.1 Introduction

This annex provides explanations and examples on the ambiguity caused by using ± tolerances for dimensions other than linear or angular sizes.

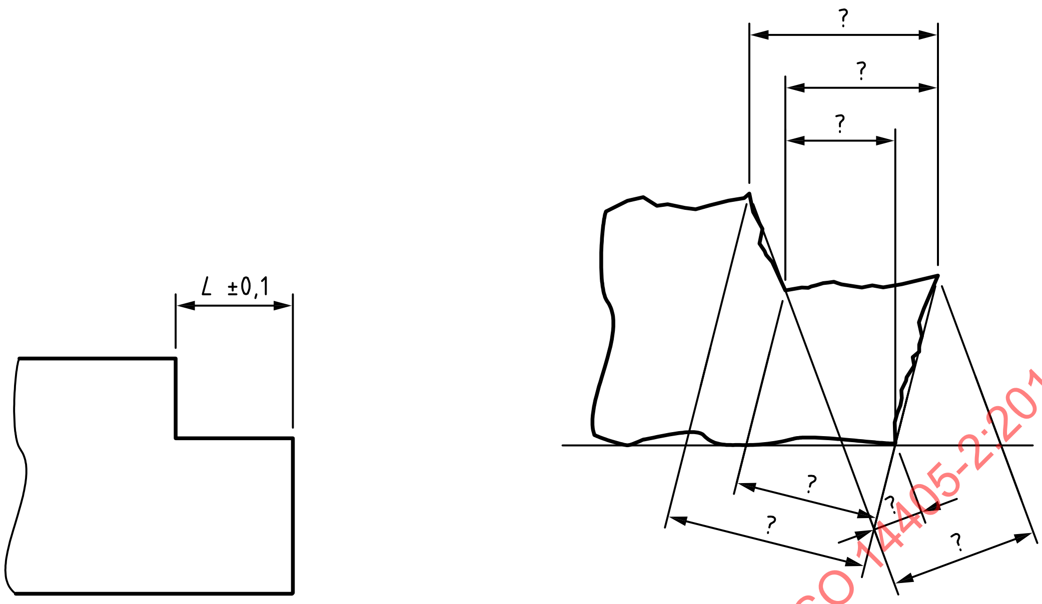
For dimensions other than sizes, the requirement is ambiguous when applied to a real workpiece. There is no universal solution to solve this ambiguity. It is the presence of form and angular deviations on all real workpieces that makes these requirements ambiguous. These deviations are not limited by the ± tolerancing, but they influence the result of the evaluation of the dimension. This specification ambiguity means that more than one interpretation of the requirement is possible. Any one of these interpretations can be used to prove conformance with the requirement. The ambiguity of the dimensional specification is not predictable and quantifiable in advance; therefore, in most functional cases it is not possible to exclude parts that are not functioning. This ambiguity is due to the geometrical deviations of the real workpiece (see Figure A.1).

The first example in this annex shows several possible interpretations and associated explanations. The other examples only show where the use of ± tolerances causes ambiguity.

The ambiguity is illustrated with a question mark for the dimension on the real workpiece.

A.2 Linear distance between two parallel integral features facing the same direction

See Figure A.1.



a) b)

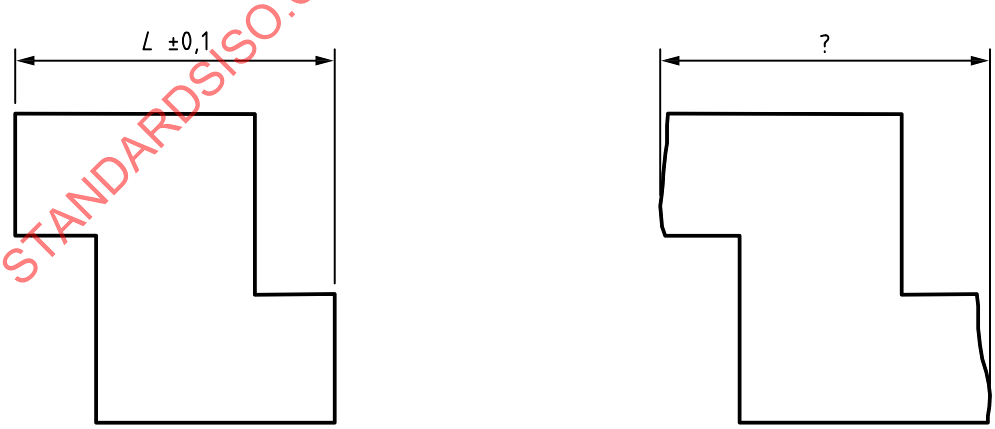
Figure A.1 — Example of a linear distance used between two integral features facing the same direction

NOTE The ambiguity of the drawing indication in Figure A.1 a) is shown in Figure A.1 b). The ambiguity arises because the position and the orientation of the toleranced dimension is not defined on the real workpiece with form and orientation deviations.

Figure A.1 b) shows some of the possible ways to interpret the requirement on the real workpiece.

A.3 Linear distance between two parallel integral features facing the opposite direction

See Figure A.2.



a) b)

Figure A.2 — Example of a linear distance used between two integral features facing the opposite direction

NOTE The ambiguity of the drawing indication in Figure A.2 a) is shown in Figure A.2 b).

A.4 Linear distance between an integral and a derived feature

See Figure A.3.

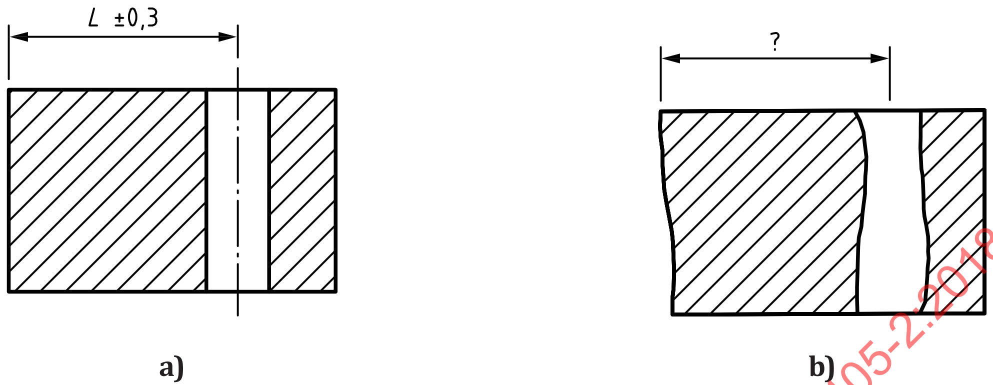


Figure A.3 — Example of a linear distance between an integral and a derived feature

NOTE The ambiguity of the drawing indication in Figure A.3 a) is shown in Figure A.3 b).

A.5 Linear distance between two derived features

See Figure A.4.

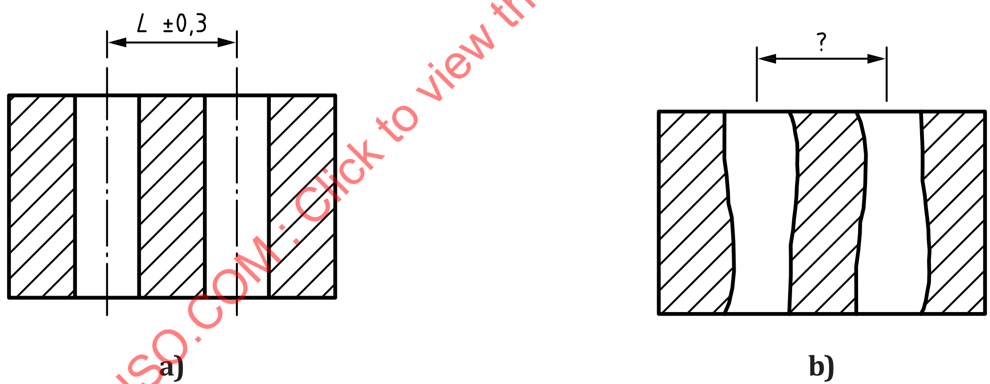
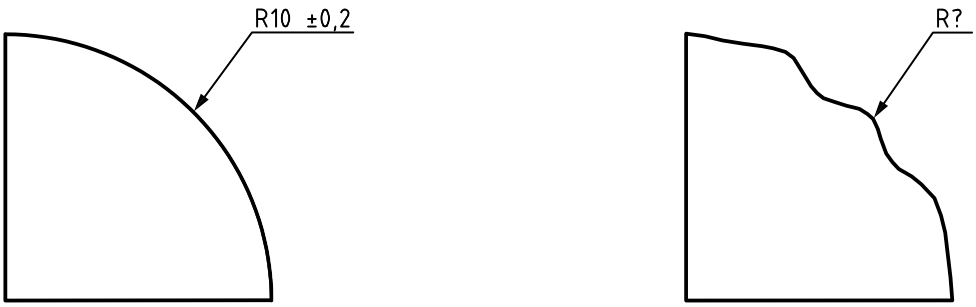


Figure A.4 — Example of a linear distance between two derived features

NOTE The ambiguity of the drawing indication in Figure A.4 a) is shown in Figure A.4 b).

A.6 Radius dimension for an integral feature

See Figure A.5.



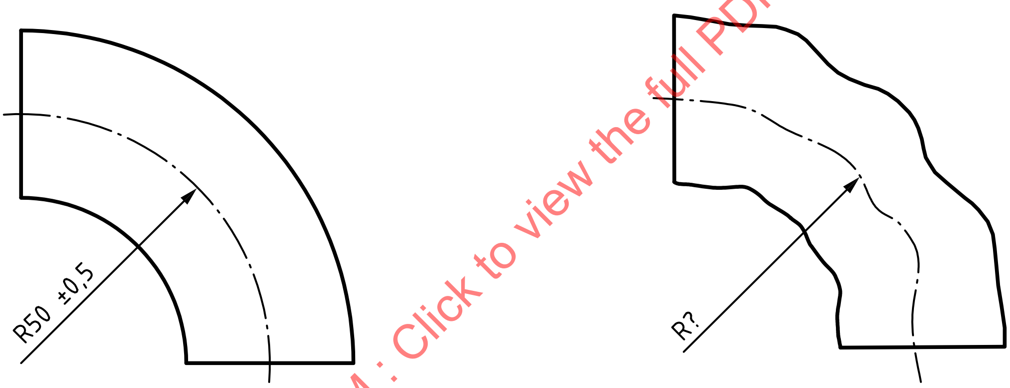
a) b)

Figure A.5 — Example of a radius dimension for an integral feature

NOTE The ambiguity of the drawing indication in Figure A.5 a) is shown in Figure A.5 b).

A.7 Radius dimension for a derived feature

See Figure A.6.



a) b)

Figure A.6 — Example of a radius dimension for a derived feature

NOTE The ambiguity of the drawing indication in Figure A.6 a) is shown in Figure A.6 b).

A.8 Linear distance between two non-planar integral features

See Figure A.7.

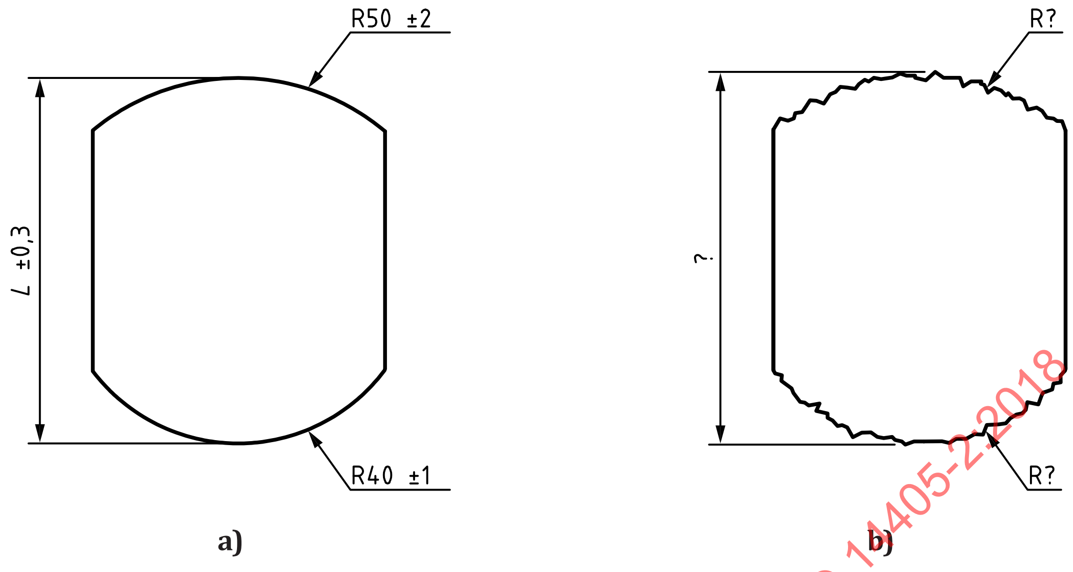


Figure A.7 — Example of a linear distance between two non-planar integral features

NOTE The ambiguity of the drawing indication in Figure A.7 a) is shown in Figure A.7 b).

A.9 Linear distance in two directions

See Figure A.8.

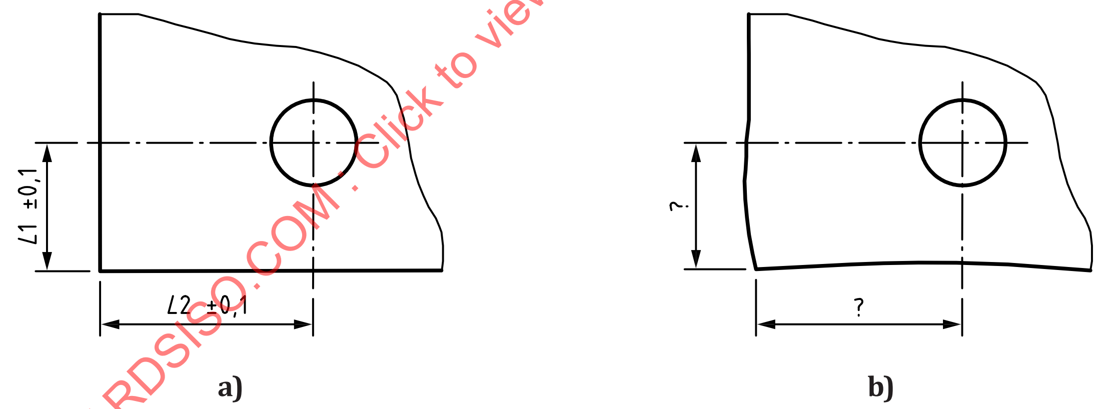
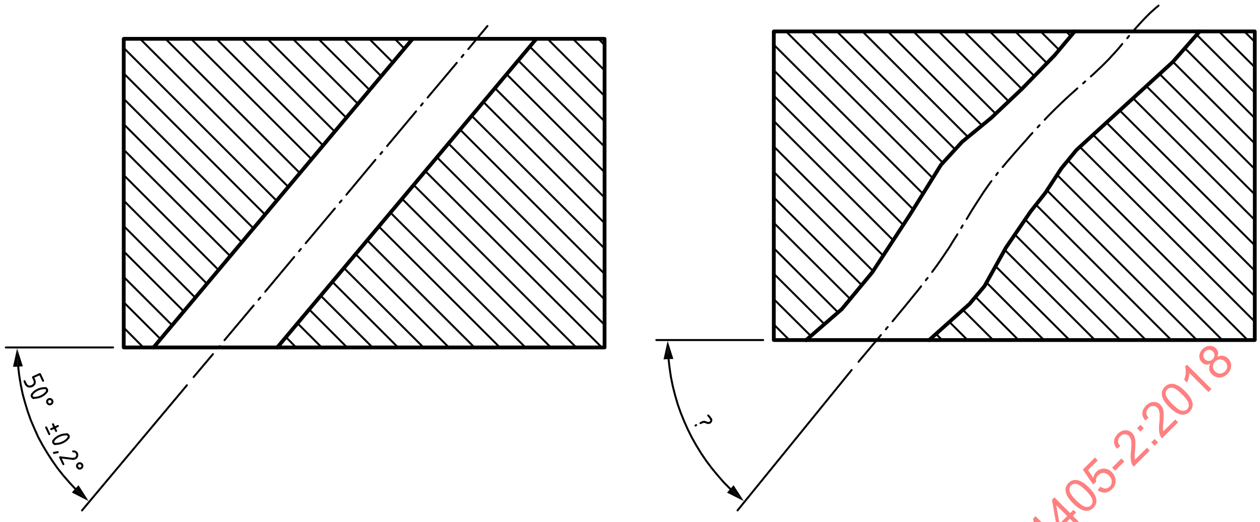


Figure A.8 — Example of linear distance in two directions

NOTE The ambiguity of the drawing indication in Figure A.8 a) is shown in Figure A.8 b).

A.10 Angular distance between an integral feature and a derived feature

See Figure A.9.



a) b)

Figure A.9 — Example of an angular distance between an integral feature and a derived feature

NOTE The ambiguity of the drawing indication in Figure A.9 a) is shown in Figure A.9 b).

A.11 Rounding and chamfers

See Figure A.10.

