INTERNATIONAL
STANDARD

ISO
14405-2

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

Part 2:
Dimensions other than linear sizes

Spécification géométrique des produits (GPS) — Tolérancement dimensionnel —

Partie 2: Dimensions autres que tailles linéaires

Reference number
ISO 14405-2:2011(E)

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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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.

ISO 14405-2 was prepared by Technical Committee ISO/TC 213, *Dimensional and geometrical product specifications and verification*.

This first edition of ISO 14405-2 cancels and replaces ISO 406:1987.

ISO 14405 consists of the following parts, under the general title *Geometrical product specifications (GPS) — Dimensional tolerancing*:

- *Part 1: Linear sizes*
- *Part 2: Dimensions other than linear sizes*

Introduction

This part of ISO 14405 is a geometrical product specification (GPS) standard and is to be regarded as a general GPS standard (see ISO/TR 14638). In the general GPS matrix, it influences chain link 1 in the distance and radius chains of standards and chain links 1, 2 and 3 in the angle chain of standards.

The ISO/GPS Masterplan given in ISO/TR 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 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.

It has to be realized that this specification ambiguity can only be avoided for features of size toleranced in accordance with ISO 14405-1. For all other dimensions, geometrical tolerancing should be used in order to control the specification ambiguity.

For more detailed information on the relation of this part of ISO 14405 to other standards and to the GPS matrix model, see Annex B.

INTERNATIONAL STANDARD **ISO 14405-2:2011(E)**

Geometrical product specifications (GPS) — Dimensional tolerancing —

Part 2:
Dimensions other than linear sizes

1 Scope

This part of ISO 14405 illustrates the use of geometrical tolerancing for dimensions that are not linear sizes to avoid the ambiguity that the use of ± tolerances on these dimensions causes. Both linear and angular dimensions, except size of features of size are covered.

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

The ambiguity caused by using ± tolerances for dimensions other than linear 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 part of ISO 14405, 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 size tolerances, see the following:

- ISO 14405-1 for linear size;
- ISO 2538 for wedges;
- ISO 3040 for cones.

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

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the cited editions apply. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 129-1:—[1], *Technical drawings — Indication of dimensions and tolerances — Part 1: General principles*

ISO 286-1:2010, *Geometrical product specifications (GPS) — ISO code system for tolerances on linear sizes — Part 1: Basis of tolerances, deviations and fits*

ISO 2538:1998, *Geometrical Product Specifications (GPS) — Series of angles and slopes on prisms*

ISO 1101:—[2], *Geometrical Product Specifications (GPS) — Geometrical tolerancing — Tolerances of form, orientation, location and run-out*

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[1] To be published. (Revision of ISO 129-1:2004)

[2] To be published. (Revision of ISO 1101:2004)

ISO 8015:2011, *Geometrical product specifications (GPS) — Fundamentals — Concepts, principles and rules*

ISO 13715:2000, *Technical drawings — Edges of undefined shape — Vocabulary and indications*

ISO 14405-1:2010, *Geometrical product specifications (GPS) — Dimensional tolerancing — Linear sizes*

ISO 14660-1:1999, *Geometrical Product Specifications (GPS) — Geometrical features — Part 1: General terms and definitions*

ISO 14660-2:1999, *Geometrical Product Specifications (GPS) — Geometrical features — Part 2: Extracted median line of a cylinder and a cone, extracted median surface, local size of an extracted feature*

ISO 17450-1:—[3], *Geometrical product specifications (GPS) — General concepts — Part 1: Model for geometrical specification and verification*

ISO 17450-2:—[4], *Geometrical product specifications (GPS) — General concepts — Part 2: Basic tenets, specifications, operators, uncertainties and ambiguities*

3 Terms and definitions

For the purpose of this document, the terms and definitions given in ISO 129-1, ISO 1101, ISO 8015, ISO 13715, ISO 14405-1, ISO 14660-1, ISO 14660-2, ISO 17450-1, ISO 17450-2 and the following apply.

The term “drawing” is used in this part of ISO 14405 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 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 Distance can be between two integral features or an integral feature and a derived feature or two derived features.

NOTE 2 Linear distance and angular distance exist.

3.4.1
linear distance
distance in length units

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[3] To be published. (Revision of ISO/TS 17450-1:2005)

[4] To be published. (Revision of ISO/TS 17450-2:2002)

3.4.2
angular distance
distance 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 apply to this part of ISO 14405 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 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 can only be avoided for linear sizes toleranced in accordance with ISO 14405-1. In order to control specification ambiguity, geometrical tolerancing shall be used.

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).

Several types of dimensions exist in the nominal model of the workpiece (see Table 1).

Table 1 — Types of dimensions

		Characterization, type and number of features			**Type of dimension**	**Details in**
Dimension	Linear dimension (length units)	One feature	Integral – only features of size		Linear size	ISO 14405-1
			Integral or derived		Radius dimension	7.5, A.6, A.7
			Integral or derived		Arc length	A.12
		Two features	Integral – integral	Facing the same direction	Linear distance or step height	7.2, A.2
				Facing the opposite direction	Linear distance	7.2, 7.6, A.3, A.8
			Integral – derived		Linear distance	7.3, 7.7, A.4, A.9
			Derived – derived		Linear distance	7.4, A.5
		Edge (transition region between two integral features)	Integral	Chamfer shape	Chamfer height and angle	A.11
				Rounding shape	Edge radius	A.11
	Angular dimension (angle units)	One feature	Integral – only features of size		Angular size, cones	ISO 3040
		Two features	Integral – integral		Angular distance	8.1, 8.2, ISO 2538
			Integral – derived		Angular distance	8.3, A.10
			Derived – derived		Angular distance	—

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 and angular dimensions

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

For the indication of tolerances for angular dimensions, the same indication rules apply with the addition that the angle unit shall be specified on both the dimension value and the tolerance value.

7 Illustrations of ambiguous ± tolerancing vs. unambiguous geometrical tolerancing

7.1 General

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

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

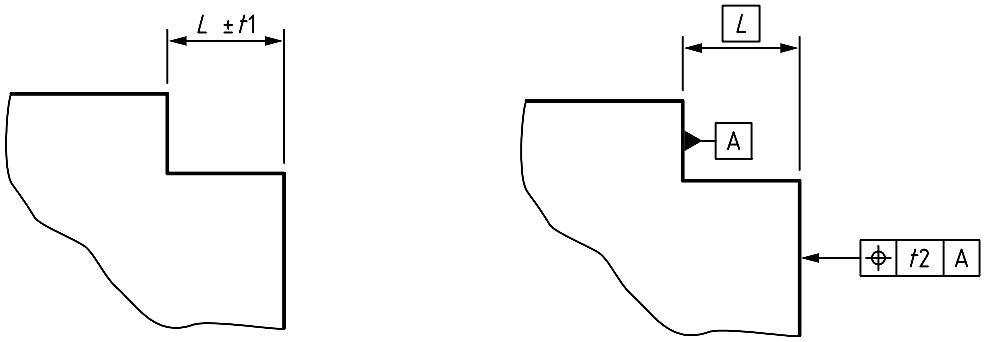
If geometrical tolerances are used, several different solutions are normally possible. The examples in this clause show some of these possibilities.

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

For more details about geometrical tolerances, see ISO 1101.

7.2 Linear distance between two integral features

See Figure 1.

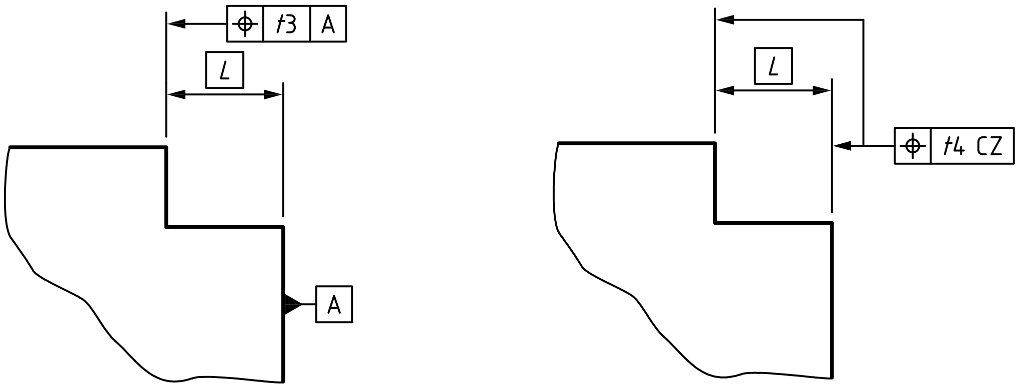


Ambiguous

a)

Unambiguous

b)



Unambiguous

c)

Unambiguous

d)

Figure 1 — Example of a linear step dimension (a) and three different solutions using geometrical tolerances (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.

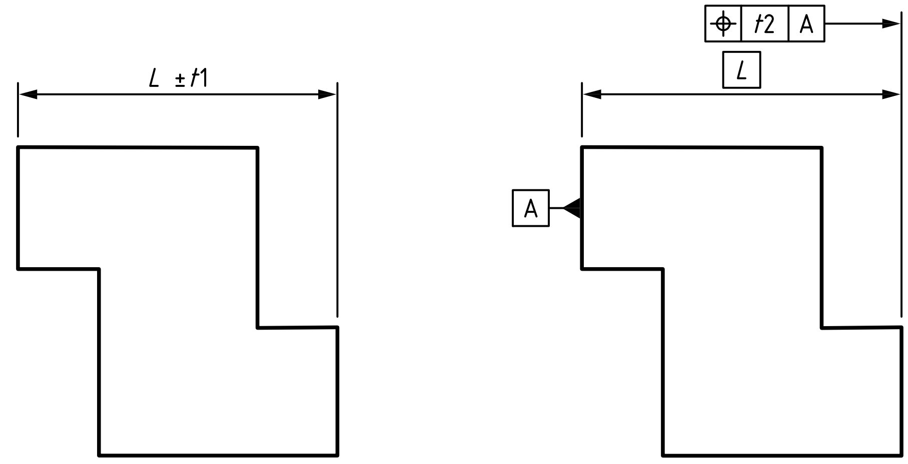
NOTE 2 Figures 1 b), 1 c) and 1 d) show different solutions using geometrical tolerances. This is unambiguous and can result in no, or a very low, specification ambiguity.

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 TED (Theoretically Exact Dimension) 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 the 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.

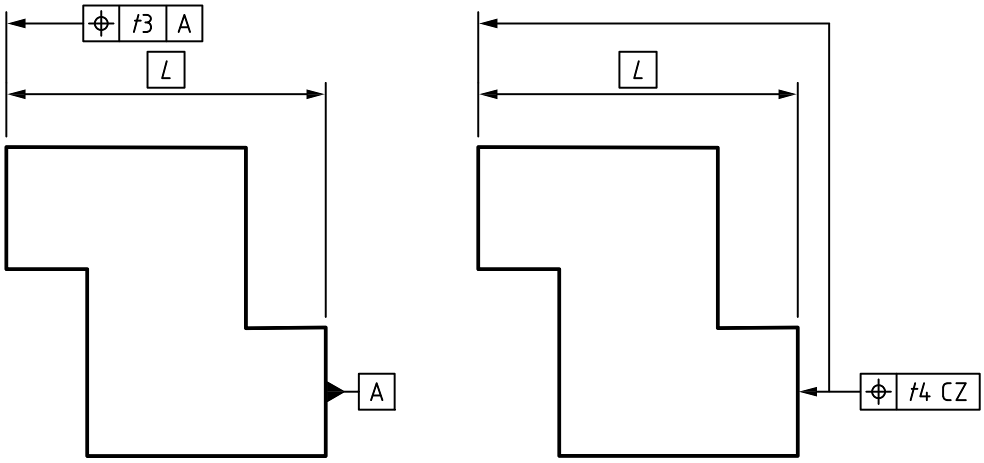


Ambiguous

a)

Unambiguous

b)



Unambiguous

c)

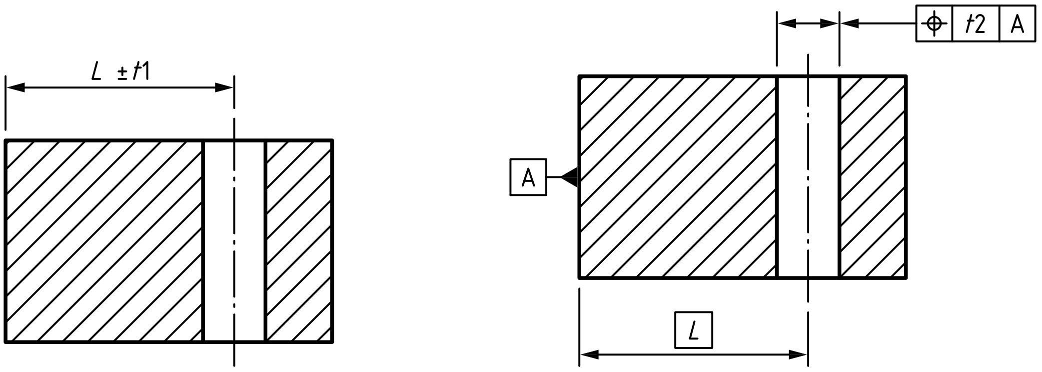
Unambiguous

d)

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

7.3 Linear distance between an integral and a derived feature

See Figure 3.



Ambiguous

a)

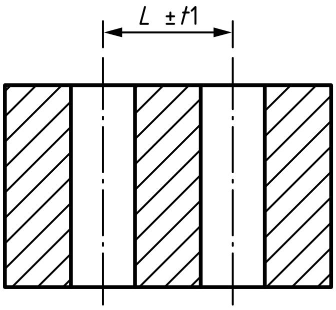
Unambiguous

b)

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

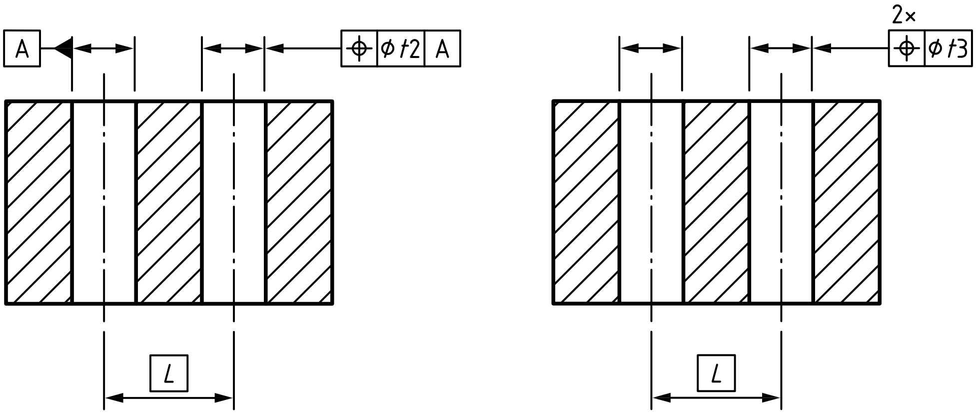
7.4 Linear distance between two derived features

See Figure 4.



Ambiguous

a)



Unambiguous

b)

Unambiguous

c)

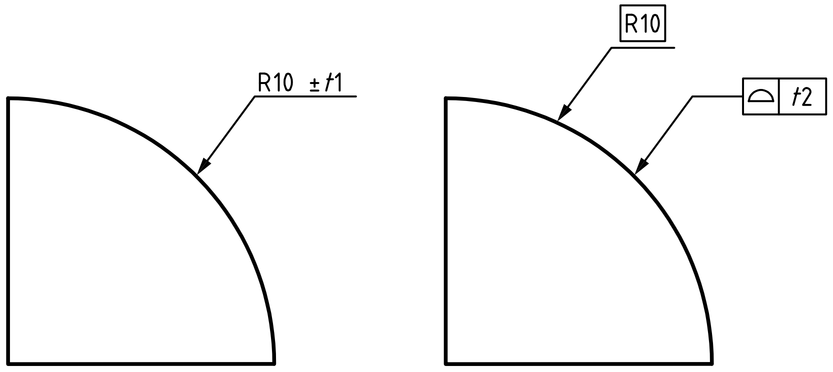
Figure 4 — Example of a linear distance between two derived features (a) and two solutions using geometrical tolerances (b) and (c)

NOTE 1 Figure 4 b) shows a solution with geometrical tolerances 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 tolerances with a position tolerance for the two holes in relation to each other. No datum is indicated.

7.5 Radius dimension

See Figure 5.



Ambiguous

a)

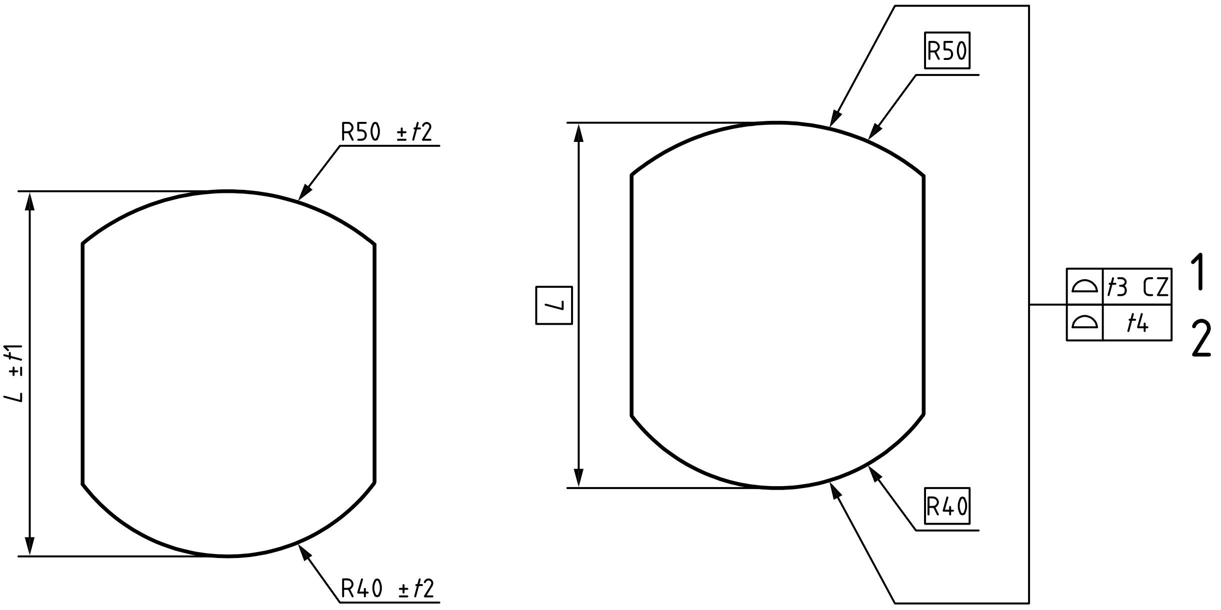
Unambiguous

b)

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

7.6 Linear distance between non-planar integral features

See Figure 6.



Ambiguous

a)

Unambiguous

b)

Key

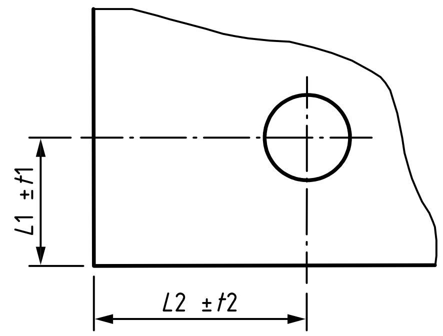
1 tolerance zone indicator of a location requirement

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 tolerances (b)

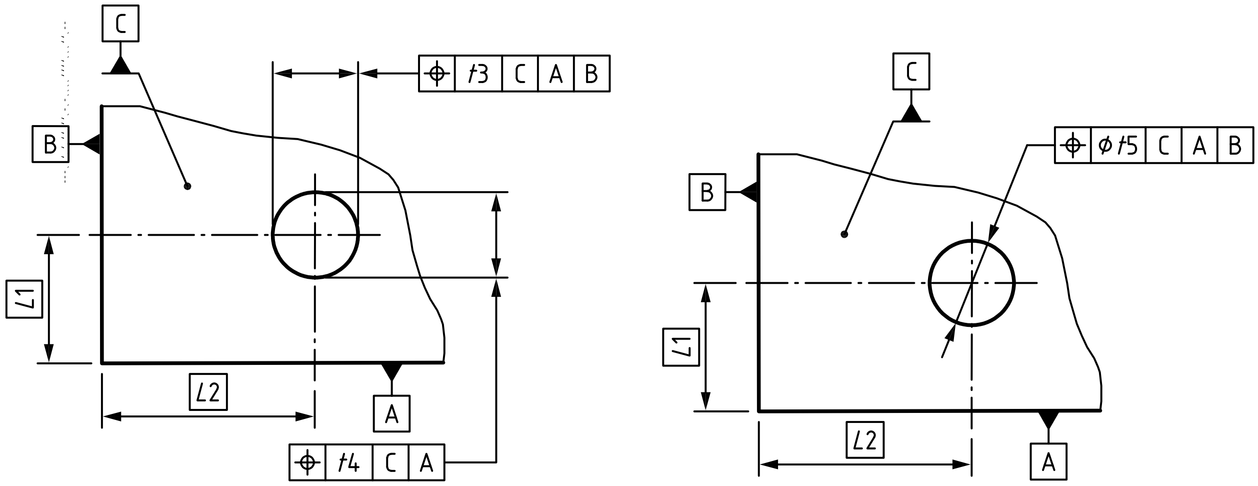
7.7 Linear distance in two directions

See Figure 7.



Ambiguous

a)



Unambiguous

b)

Unambiguous

c)

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

NOTE 1 Figure 7 b) shows a solution with geometrical tolerances 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 tolerances 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 Plus/minus tolerancing applied to angular distance

See Figures 8 and 9.

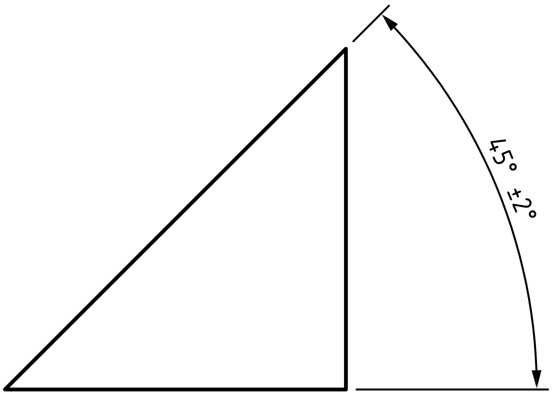
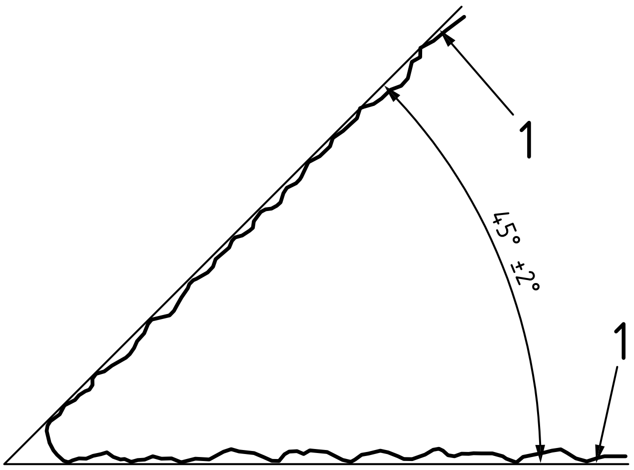


Figure 8 — Indication



Key

1 contacting line

Figure 9 — Interpretation

Angular ± tolerance controls only the general relative orientation between two real integral lines but not their form deviations (see Figure 9).

The tolerance applies to all cross sections where an angle exists along the two real integral surfaces and all such angles shall be contained within the tolerance interval. The orientation of each cross section is defined by maximizing the angle between two contacting straight lines.

Each contacting straight line is the result of an association of a straight line to the real integral line with the constraint of being external to the material by minimizing the maximum distance between the associated straight line and the real integral line.

Figure 9 shows the definition of the angle tolerance in Figure 8. However, the definition does not ensure that all the individual angles exist in parallel planes, as shown in Figure 10.

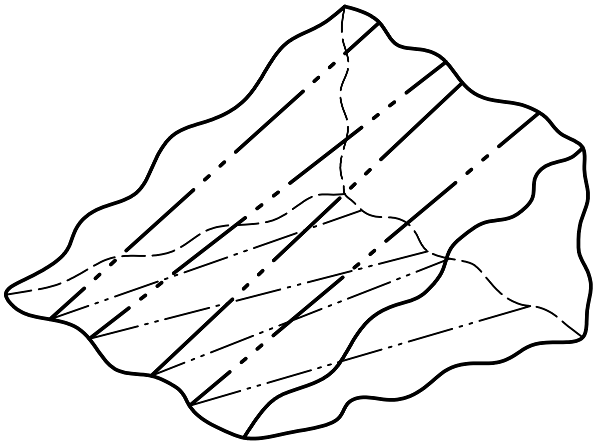
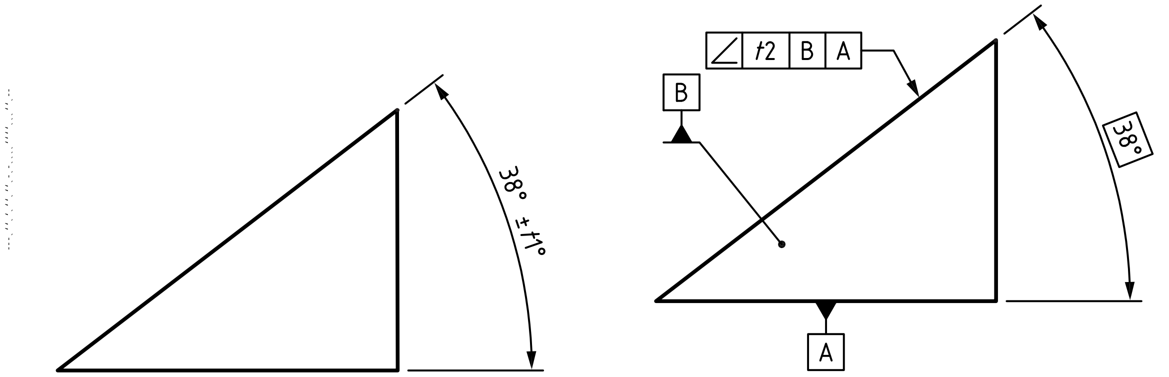


Figure 10 — The angles in Figure 9 do not exist in parallel planes

8.2 Examples of geometrical tolerancing applied to angular distance between two integral features

See Figure 11.

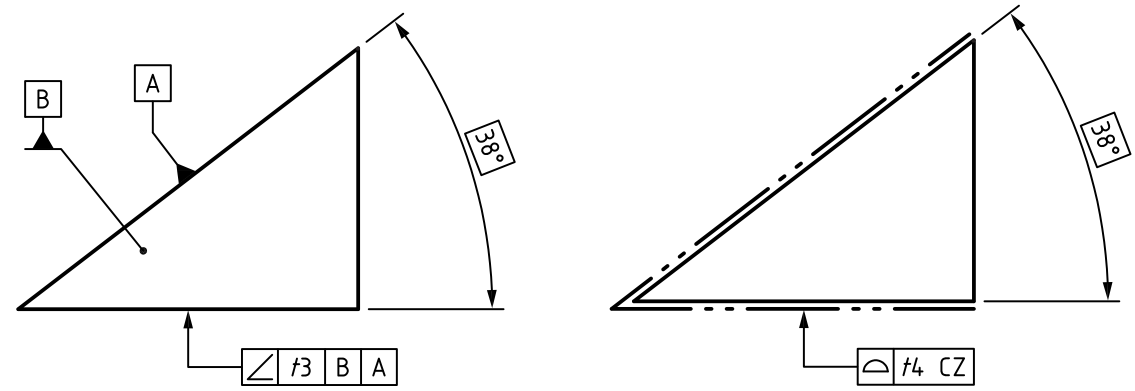


Ambiguous

a)

Unambiguous

b)



Unambiguous

c)

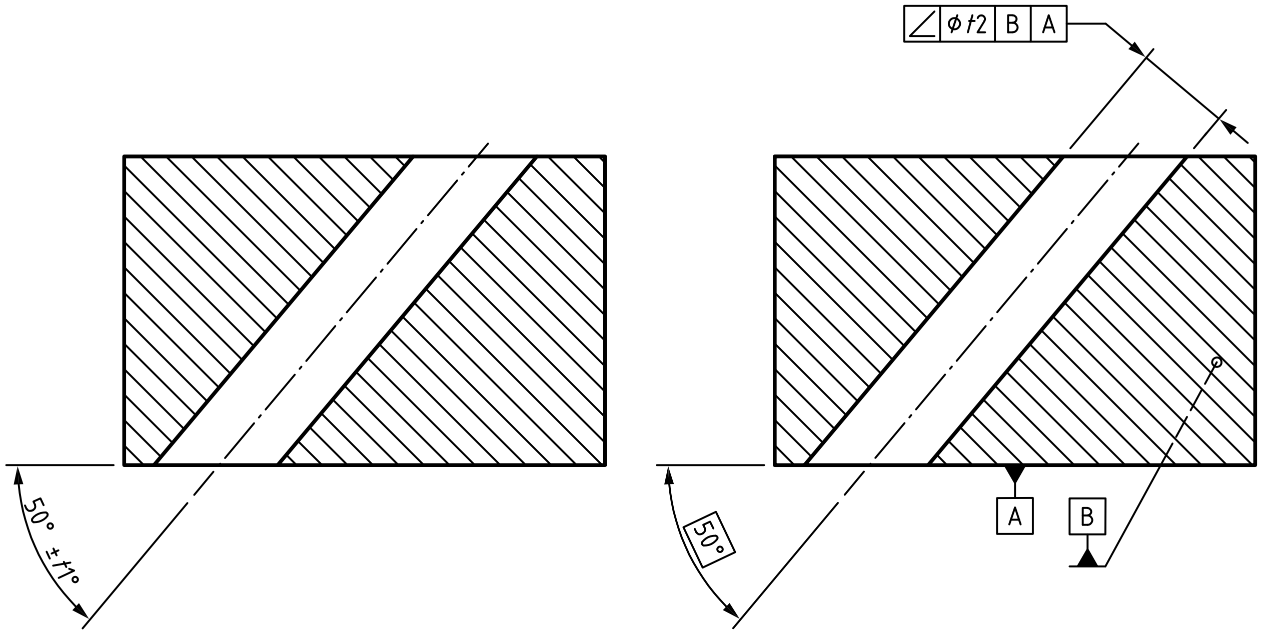
Unambiguous

d)

Figure 11 — Example of an angular distance between two integral features (a) and three different solutions using geometrical tolerances (b, c and d)

8.3 Angular distance between an integral feature and a derived feature

See Figure 12.



Ambiguous

a)

Unambiguous

b)

Figure 12 — Example of an angular distance between an integral feature and a derived feature (a) and one solution using geometrical tolerances (b)

Annex A
(informative)

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

A.1 Introduction

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

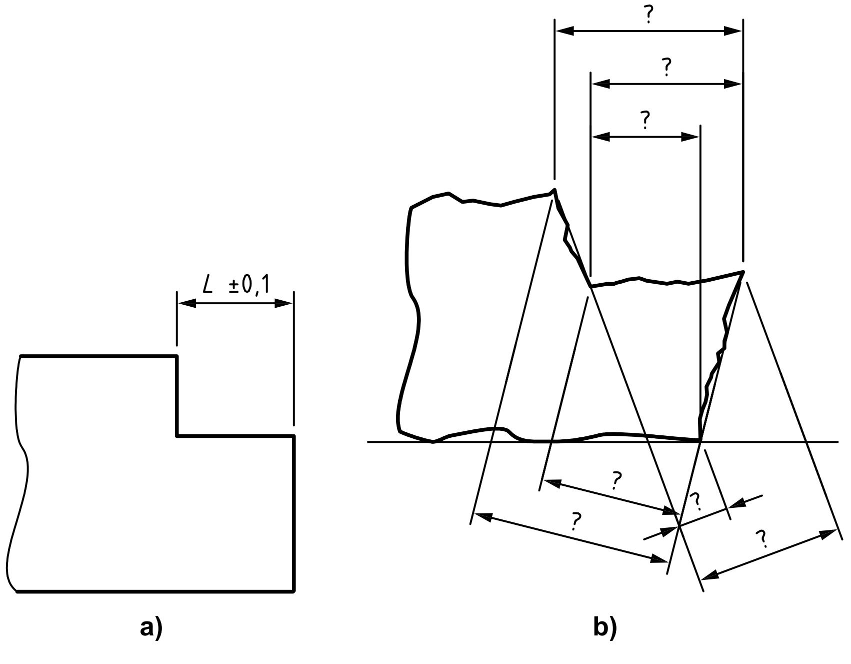
For dimensions other than sizes, the requirement is ambiguous when applied to a real workpiece. There is no universal solution to solve this ambiguity. It is the presence of form and angular deviations on all real workpieces that makes these requirements ambiguous. These deviations are not limited by 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)**

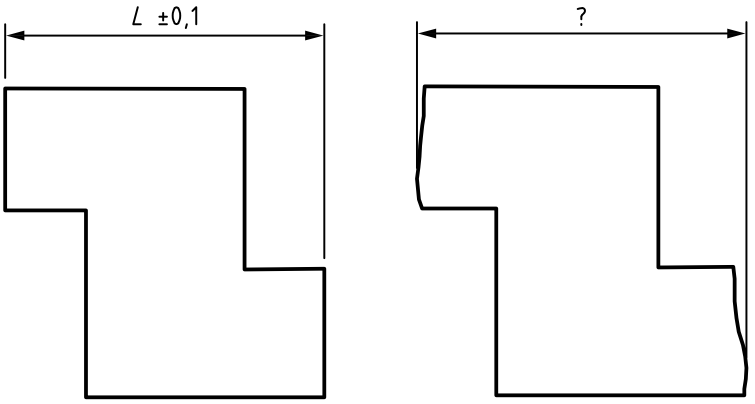
Figure A.1 — Example of a linear distance used between two integral features facing the same direction

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.



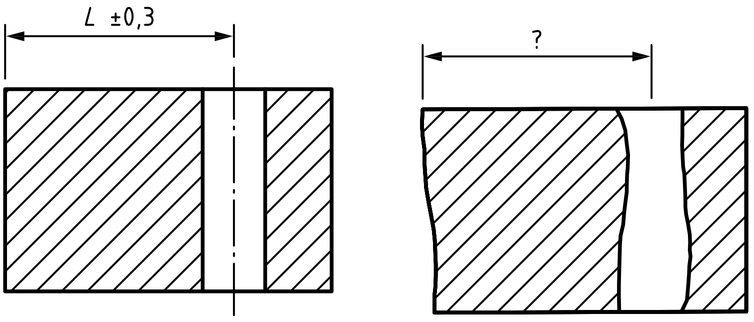
a) **b)**

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.



a) **b)**

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.

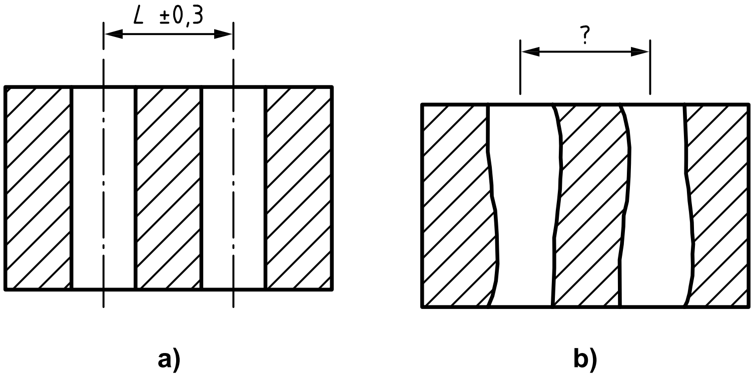


Figure A.4 — Example of a linear distance between two derived features

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.

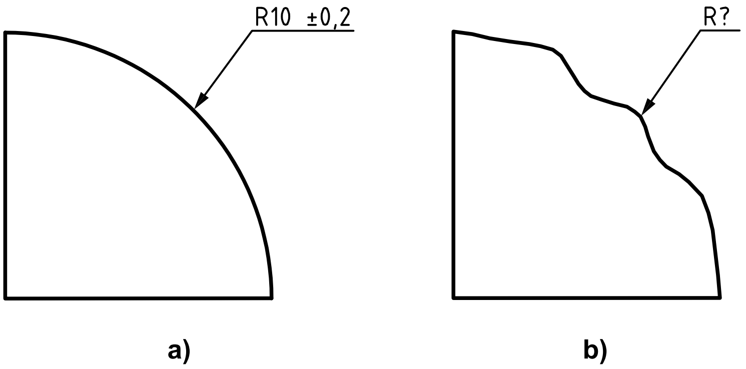
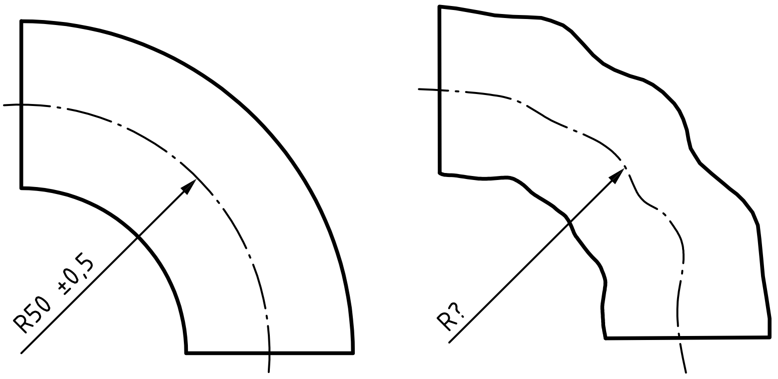


Figure A.5 — Example of a radius dimension for an integral feature

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.



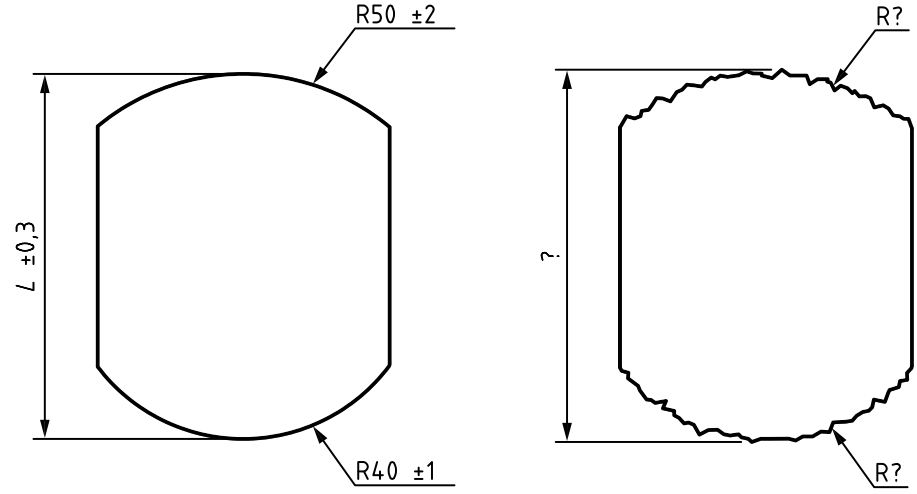
a) b)

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.



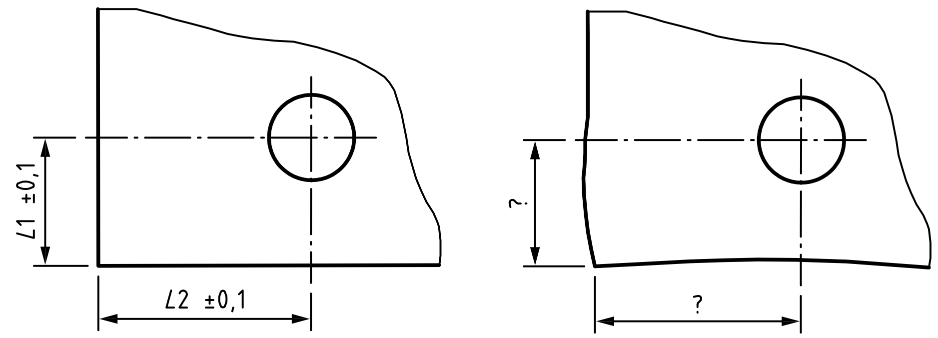
a) b)

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.



a)

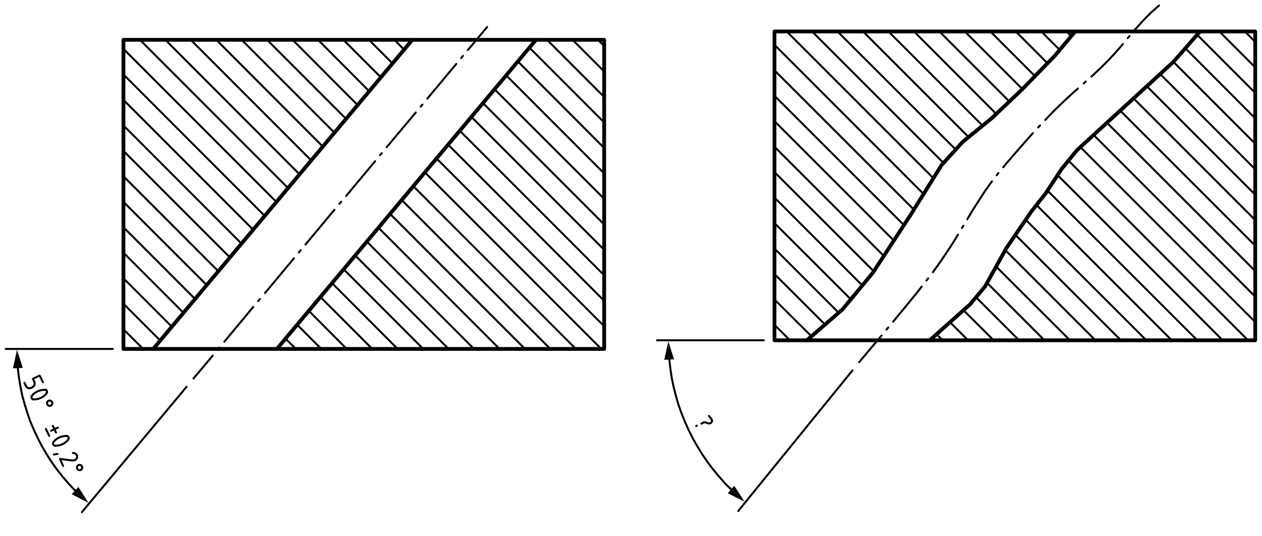
b)

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)

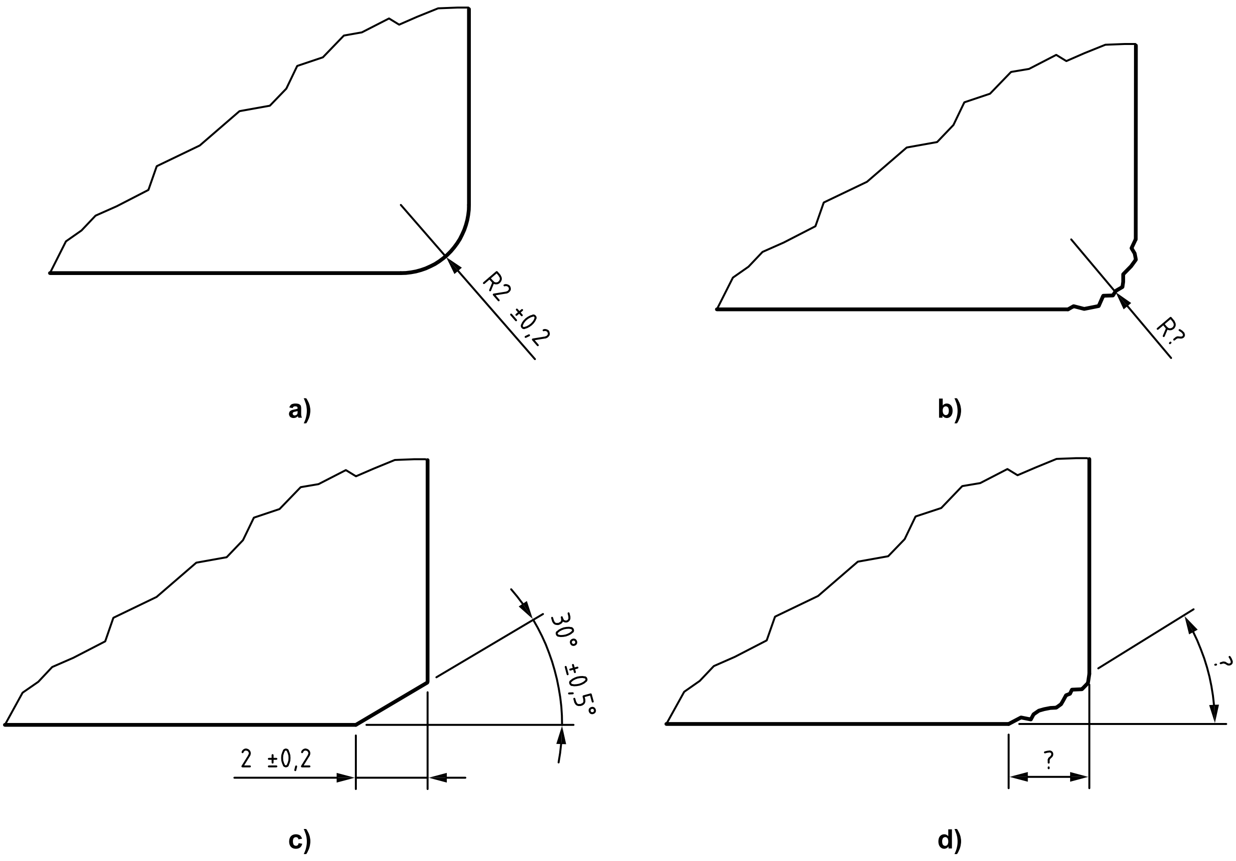
b)

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.



a) b) c) d)

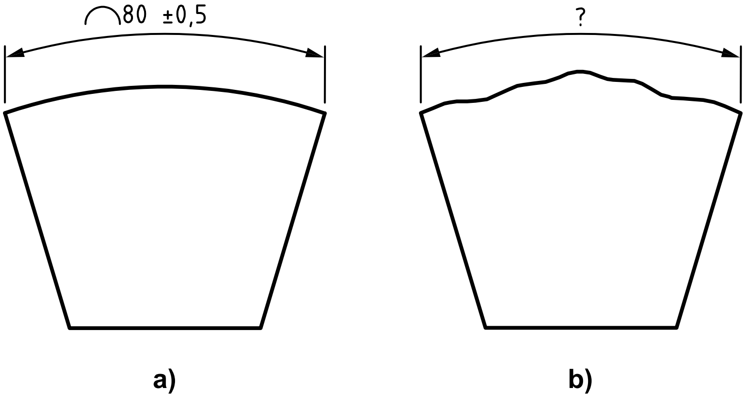
Figure A.10 — Examples of drawing indications for rounding and chamfer with the use of ± tolerances

NOTE The ambiguity of the drawing indication in Figures A.10 a) and c) is shown in Figures A.10 b) and d).

Using ± tolerances for rounding and chamfers can be ambiguous on a real workpiece with form and angular deviations. If this specification ambiguity is not acceptable, geometrical tolerancing shall be used.

A.12 Arc length

See Figure A.11.



a) b)

Figure A.11 — Examples of an arc length with the use of ± tolerances

NOTE The ambiguity of the drawing indication in Figure A.11 a) is shown in Figure A.11 b).

Arc length dimensions using ± tolerances are ambiguous on a real workpiece with form and angular deviations.

It is preferable to use a combination of specifications, e.g. a theoretically exact radius dimension and a geometrical tolerance, for form of a line or form of a surface, instead of a ± tolerance for arc length.

Annex B
(informative)

Relation to the GPS matrix model

B.1 General

For full details about the GPS matrix model, see ISO/TR 14638.

The ISO/GPS masterplan given in ISO/TR 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.

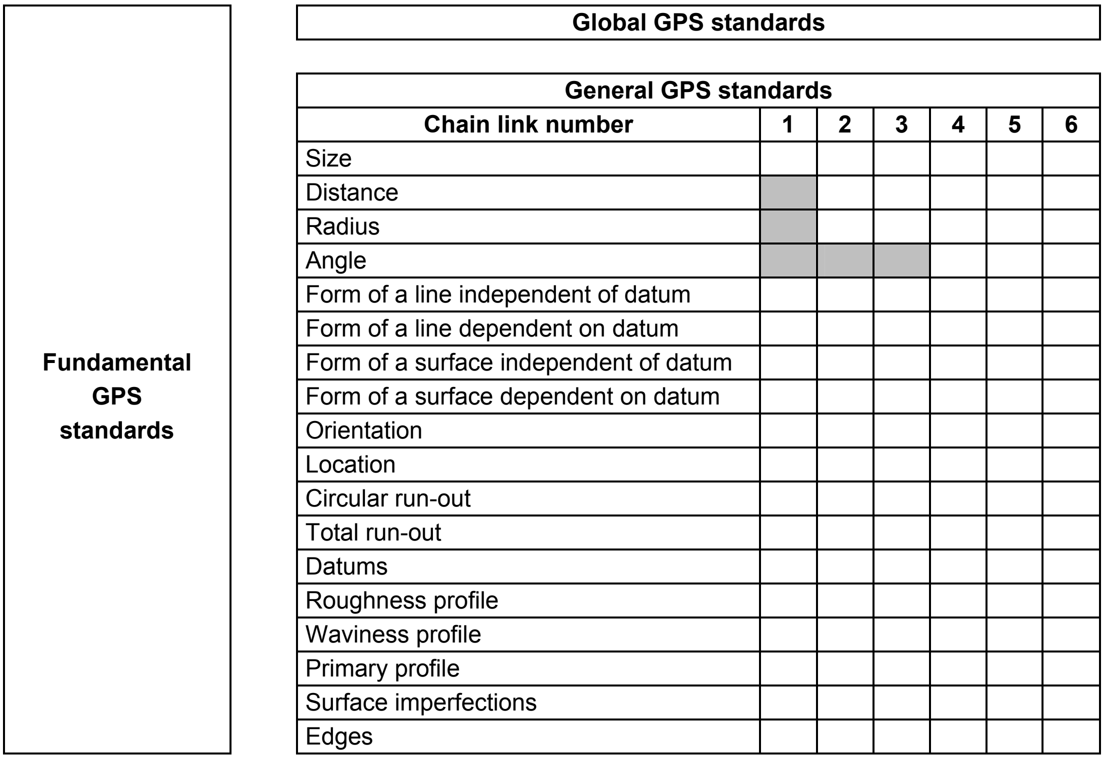
B.2 Information about this part of ISO 14405 and its use

This part of ISO 14405 shows how geometrical tolerances can be used for dimensions that are not linear sizes to avoid the ambiguity that the use of ± tolerances on this type of dimensions causes.

It also explains the ambiguity caused by using ± tolerances for dimensions other than linear sizes.

B.3 Position in the GPS matrix model

This part of ISO 14405 is a general GPS standard, which influences chain link 1 in the distance and radius chains of standards and chain links 1, 2 and 3 in the angle chain of standards, as graphically illustrated in Figure B.1.



Fundamental GPS standards

Global GPS standards

General GPS standards						
Chain link number	**1**	**2**	**3**	**4**	**5**	**6**
Size						
Distance	▨					
Radius	▨					
Angle	▨	▨	▨			
Form of a line independent of datum						
Form of a line dependent on datum						
Form of a surface independent of datum						
Form of a surface dependent on datum						
Orientation						
Location						
Circular run-out						
Total run-out						
Datums						
Roughness profile						
Waviness profile						
Primary profile						
Surface imperfections						
Edges						

Figure B.1 — Position in the GPS matrix model

B.4 Related standards

The related standards are those of the chains of standards indicated in Figure B.1.

Bibliography

[1] ISO/R 1938:1971, *ISO system of limits and fits — Part II: Inspection of plain workpieces*

[2] ISO 2692, *Geometrical product specifications (GPS) — Geometrical tolerancing — Maximum material requirement (MMR), least material requirement (LMR) and reciprocity requirement (RPR)*

[3] ISO 2768-1, *General tolerances — Part 1: Tolerances for linear and angular dimensions without individual tolerance indications*

[4] ISO 3040, *Geometrical product specifications (GPS) — Dimensioning and tolerancing — Cones*

[5] ISO 5458, *Geometrical Product Specifications (GPS) — Geometrical tolerancing — Positional tolerancing*

[6] ISO 5459, *Geometrical product specifications (GPS) — Geometrical tolerancing — Datums and datum systems*

[7] ISO 8062-3, *Geometrical product specifications (GPS) — Dimensional and geometrical tolerances for moulded parts — Part 3: General dimensional and geometrical tolerances and machining allowances for castings*

[8] ISO 14253-1, *Geometrical Product Specifications (GPS) — Inspection by measurement of workpieces and measuring equipment — Part 1: Decision rules for proving conformance or non-conformance with specifications*

[9] ISO 14253-2, *Geometrical product specifications (GPS) — Inspection by measurement of workpieces and measuring equipment — Part 2: Guidance for the estimation of uncertainty in GPS measurement, in calibration of measuring equipment and in product verification*

[10] ISO/TR 14638, *Geometrical product specifications (GPS) — Masterplan*

[11] ISO 81714-1, *Design of graphical symbols for use in the technical documentation of products — Part 1: Basic rules*

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