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Geometrical product specifications (GPS) — Dimensional tolerancing —

Part 3: Angular sizes

Spécification géométrique des produits (GPS) — Tolérancement dimensionnel —

Partie 3: Tailles angulaires

Reference number
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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 on 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 the following URL: www.iso.org/iso/foreword.html.

The committee responsible for this document is Technical Committee ISO/TC 213, *Dimensional and geometrical product specifications and verification.*

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

— *Part 1: Linear sizes*

— *Part 2: Dimensions other than linear sizes*

— *Part 3: Angular 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 14638). In the general GPS matrix, it influences chain links “Symbols and indications”, “Feature requirements” and “Feature properties” of the size chain of standards.

The ISO/GPS Masterplan given in ISO 14638 gives an overview of the ISO/GPS system of which this part of ISO 14405 is a part. The fundamental rules of ISO/GPS given in ISO 8015 apply to this part of ISO 14405 and the default decision rules given in ISO 14253-1 apply to specifications made in accordance with this part of ISO 14405, unless otherwise indicated.

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

Geometrical product specifications (GPS) — Dimensional tolerancing —

Part 3: Angular sizes

1 Scope

This part of ISO 14405 establishes the default specification operator for angular size and defines a number of special specification operators for features of angular size: cone (truncated, i.e. frustum, or not), wedge (truncated or not), two opposite straight lines (intersection of a wedge/truncated wedge and a plane perpendicular to the intersection straight line of the two planes of the wedge/truncated wedge, intersection of a cone/frustum and a plane containing the axis of revolution of the cone/frustum). See Figure 1 and Figure 2.

This part of ISO 14405 also defines the specification modifiers and the drawing indications for these angular sizes.

This part of ISO 14405 covers the following angular sizes:

- local angular size:
  - angular size between two lines;
  - portion angular size;
- global angular size:
  - direct global angular size:
    - least squares angular size;
    - minimax angular size;
  - rank order angular size/indirect global angular size:
    - maximum angular size;
    - minimum angular size;
    - average angular size;
    - range of angular sizes;
    - mid-range angular size;
    - median angular size;
    - standard deviation of angular size.

This part of ISO 14405 defines the meaning of tolerances of angular sizes indicated as

- + and/or - limit deviations, e.g. 0°/-0,5°, or
- indicated with upper limit of size (ULS) and/or lower limit of size (LLS), e.g. 35° max. or 15° min., 34°/36°,

— with or without modifiers.

This part of ISO 14405 provides a set of tools to express several types of angular size characteristics. It does not give any information on the relationship between a function or a use and an angular size characteristic.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

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 specification (GPS) — General concepts — Part 3: Toleranced Features*

ISO 14405-1:2016, *Geometrical product specifications (GPS) — Dimensional tolerancing — Part 1: Linear sizes*

ISO 14405-2, *Geometrical product specifications (GPS) — Dimensional tolerancing — Part 2: Dimensions other than linear sizes*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 8015, ISO 17450-1, ISO 17450-2, ISO 17450-3, ISO 14405-1, ISO 14405-2 and the following apply.

For association criteria, it is assumed that the terms “least squares” and “Gaussian” are equivalent, as well as “minimax” and “Chebyshev”. In this document, the terms “least squares” and “minimax” are retained. The least squares criterion is understood without material constraint throughout this part of ISO 14405.

3.1
angular size
angular dimension of a cone or between two coplanar opposite straight lines or between two opposite non parallel planes

Note 1 to entry: The angular size is defined from nominal features or from associated features which are angular features of size.

Note 2 to entry: See example of angular size on Figure 1 and Figure 2.

Note 3 to entry: Definition of “angular feature of size (feature of angular size)” is given in ISO 17450-1, the angle dimension cannot be 0° or 180°.

Note 4 to entry: Angular features of size are of two types.

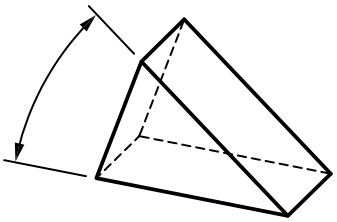
— Revolute angular feature of size: a cone or a frustum. Two opposite straight lines are established from a longitudinal section of a cone/frustum with a plane containing the associated axis of revolution of the cone/frustum.

— Prismatic angular feature of size: a wedge (truncated or not). Two opposite straight lines are established from a cross section of a wedge/truncated wedge with a plane perpendicular to the intersection straight line of the two associated planes of the wedge/truncated wedge.

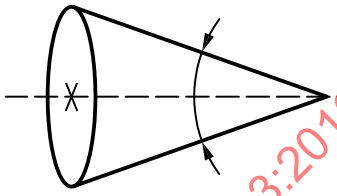
Note 5 to entry: Figure 1 and Figure 2 illustrate angular features of size type wedge, cone, frustum and two lines.

Note 6 to entry: Figure 3a and Figure 3b illustrate the case of an angular feature of size and an angular distance between two planes which is not an angular feature of size and shows that an angular feature of size exists when the material directions are opposed (when one of the features is rotated around their intersection line to coincide with the other feature, then the material is on the opposite sides for the two features). See also Annex B.

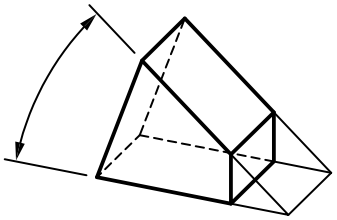
Note 7 to entry: Envelope requirement cannot be applied for angular features of size.



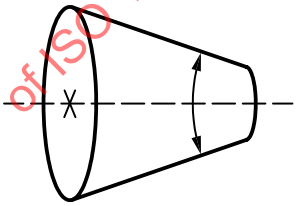
a) Wedge



b) Cone

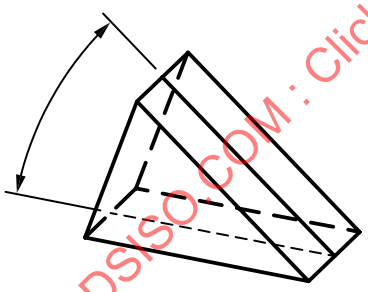


c) Truncated wedge

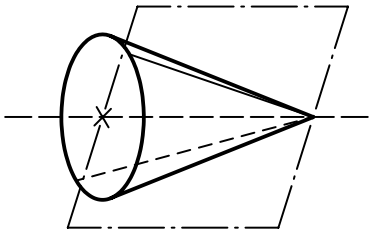


d) Frustum

Figure 1 — Examples of areal angular features of size

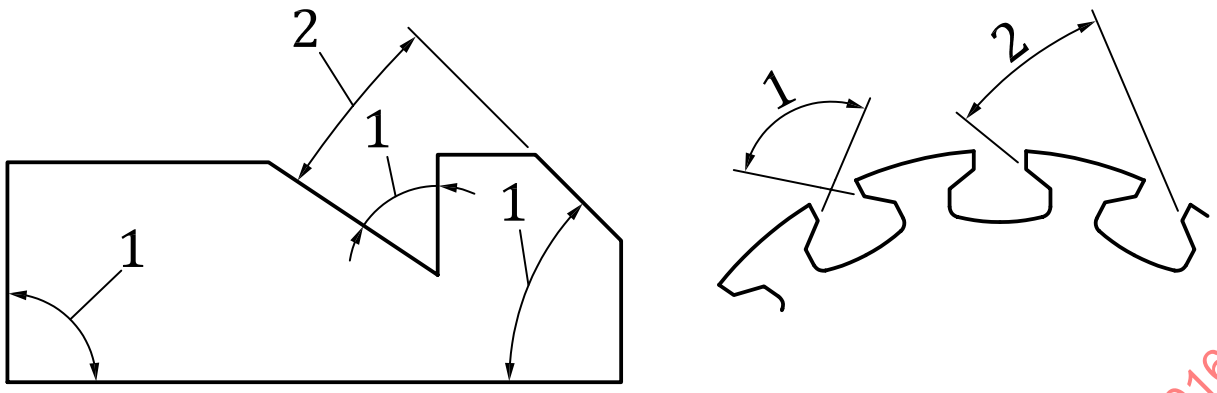


a) Two opposite lines of a wedge



b) Two opposite generatrix lines of a cone

Figure 2 — Examples of angular features of size



a) Example # 1 b) Example # 2

Key

1 Feature of angular size

2 Non-feature of angular size

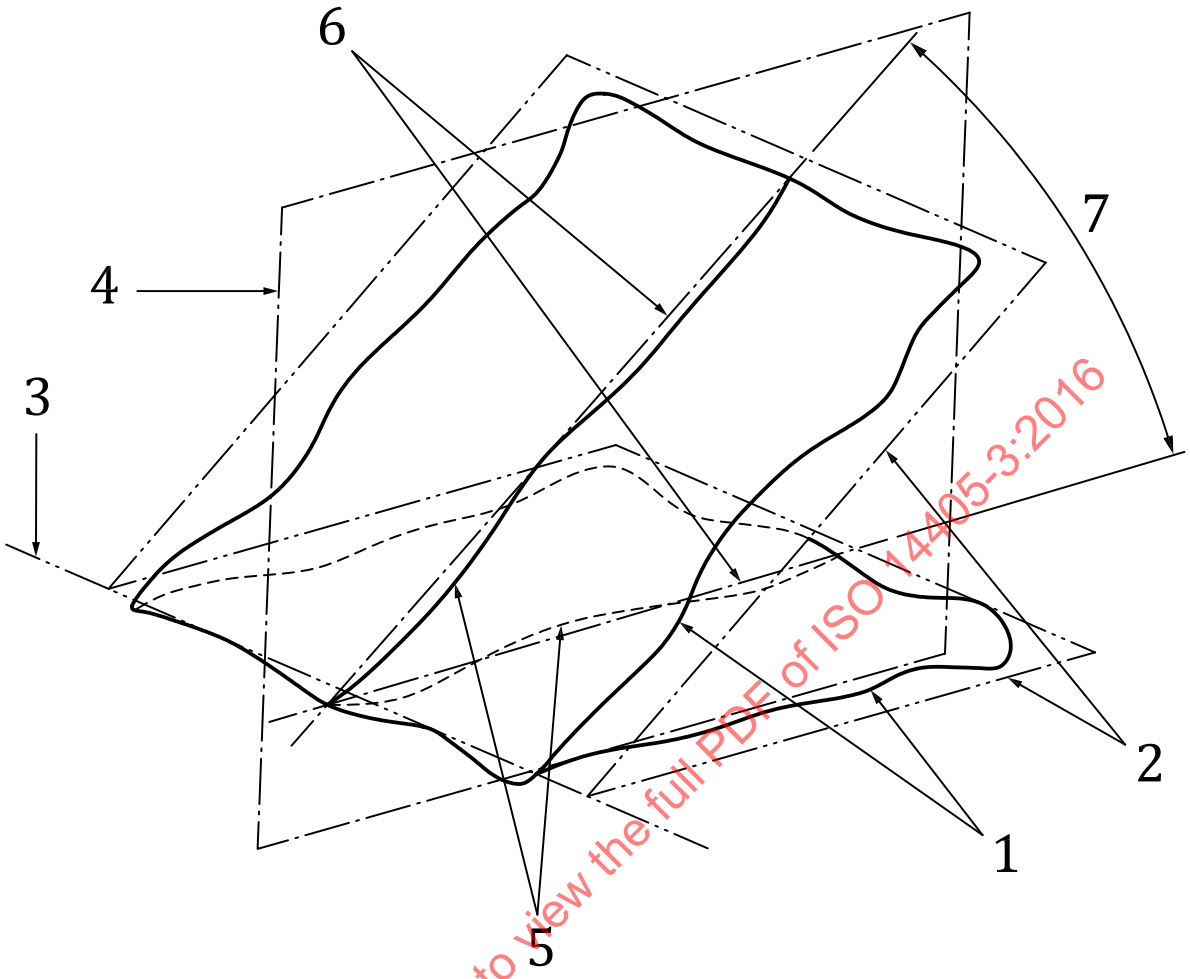
Figure 3 — Examples of possible angular features of size

3.2
local angular size
local angular size characteristic
angular size characteristic having a unique value for a specific location and a non-unique value along and/or around the angular feature of size

Note 1 to entry: For a given feature, an infinite number of local angular sizes exists.

Note 2 to entry: In Figure 4, an example of local angular size is shown.

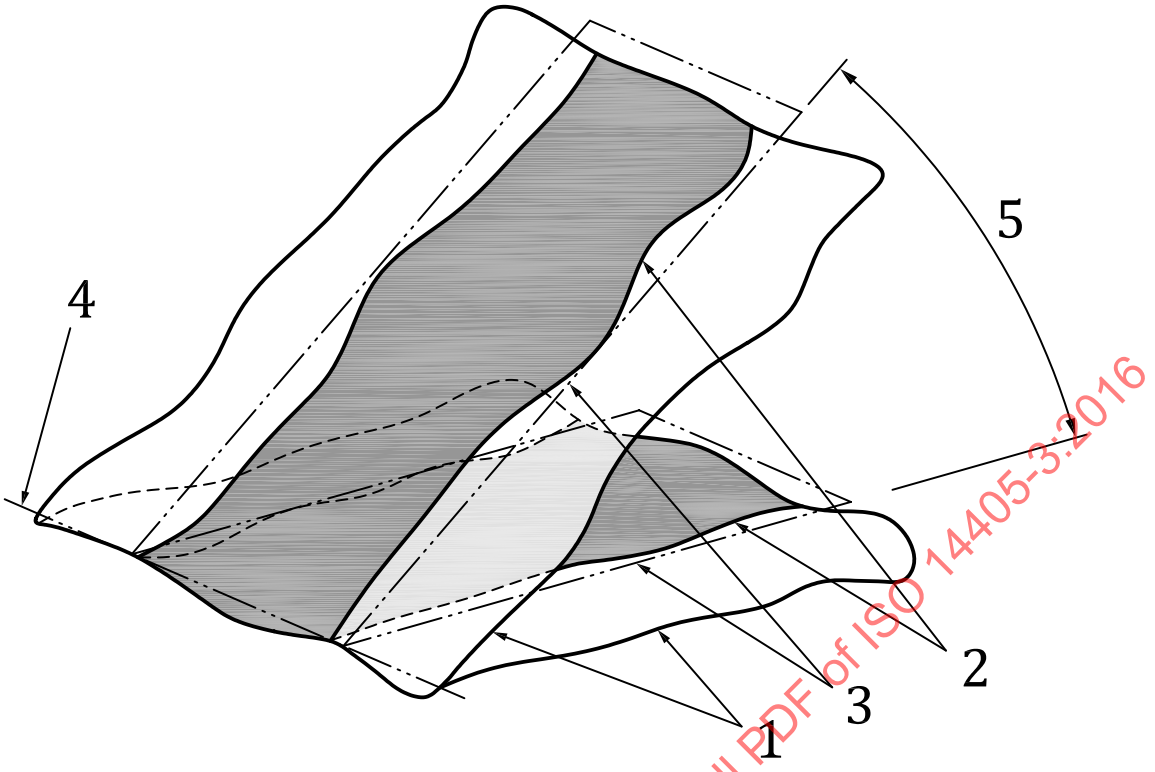
Note 3 to entry: Two local angular size associations can be specified: least squares local angular size and minimax local angular size. See Annex A.



Key

1 real angular feature of size
2 associated planes with (1)
3 intersection straight line of (2)
4 perpendicular cross section to (3)
5 two extracted lines
6 two associated straight lines
7 two-line angular size

Figure 4 — Two-line angular size



Key

1 real angular feature of size
2 portion of (1)
3 associated planes with (2)
4 intersection straight line of (3)
5 portion angular size

Figure 5 — Portion angular size

3.2.1
two-line angular size
local angular size between two lines
angle between two associated straight lines established from two extracted lines obtained from the intersection with an intersection plane defined from the associated angular feature of size

Note 1 to entry: See Figure 4.

Note 2 to entry: The process for establishing the two-line angular size depends on the invariance class of the feature: revolute surface or prismatic surface.

Note 3 to entry: The default specification operator defining the two-line angular size is described in Annex A.

3.2.1.1
two-line revolute angular size
two-line angular size (3.2.1) where the straight lines are associated with two extracted lines resulting from the intersection of an extracted revolute feature with a plane containing its associated axis

Note 1 to entry: The axis of the associated revolute feature is the "directly associated median line" described in ISO 22432:2011, 3.5.1.2.4.

3.2.1.2
two-line prismatic angular size
two-line angular size (3.2.1) where the straight lines are associated with two extracted lines resulting from the intersection of two extracted surfaces with a plane perpendicular to their associated straight line of intersection

3.2.2
portion angular size
global angular size (3.3) for a given portion of the extracted angular feature of size

Note 1 to entry: A portion angular size is a local angular size when taking into account the complete angular feature of size and a global angular size when taking into account only the specific portion.

Note 2 to entry: See Figure 5.

Note 3 to entry: A portion angular size can be a *direct global angular size* (3.3.1) or an *indirect global angular size* (3.3.2).

Note 4 to entry: The operator for defining a portion is not covered by this part of ISO 14405.

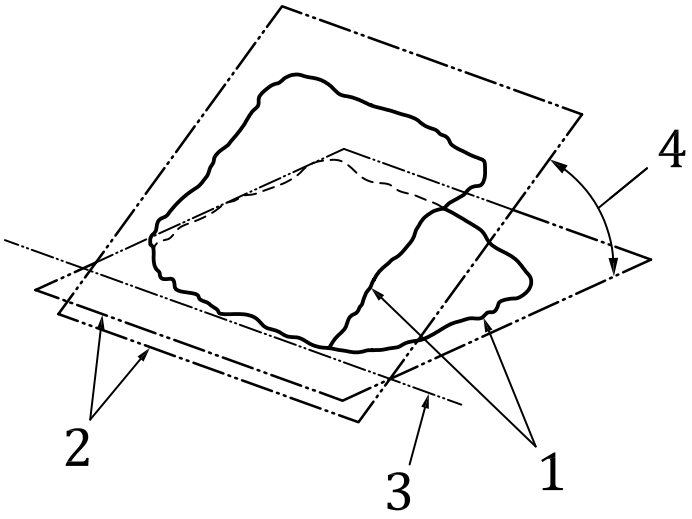
3.3
global angular size
global angular size characteristic
angular size characteristic having one unique value for the entire toleranced angular feature of size

3.3.1
direct global angular size
direct global angular size characteristic
global angular size defined from one association on the angular feature of size

Note 1 to entry: If the angular feature of size is a cone, the associated feature is a cone. If the angular feature of size is a wedge, the associated features are a pair of planes. One plane is associated independently to each side of the wedge.

Note 2 to entry: See Figure 6.

Note 3 to entry: Different association criteria lead to different results. The association criteria described in this part of ISO 14405 are the least squares criterion and minimax criterion.



Key

1 real angular features of size
2 associated planes with (1)
3 intersection straight line of (2)
4 direct global angular size defined in a plane perpendicular to the intersection straight line

Figure 6 — Direct global angular sizes

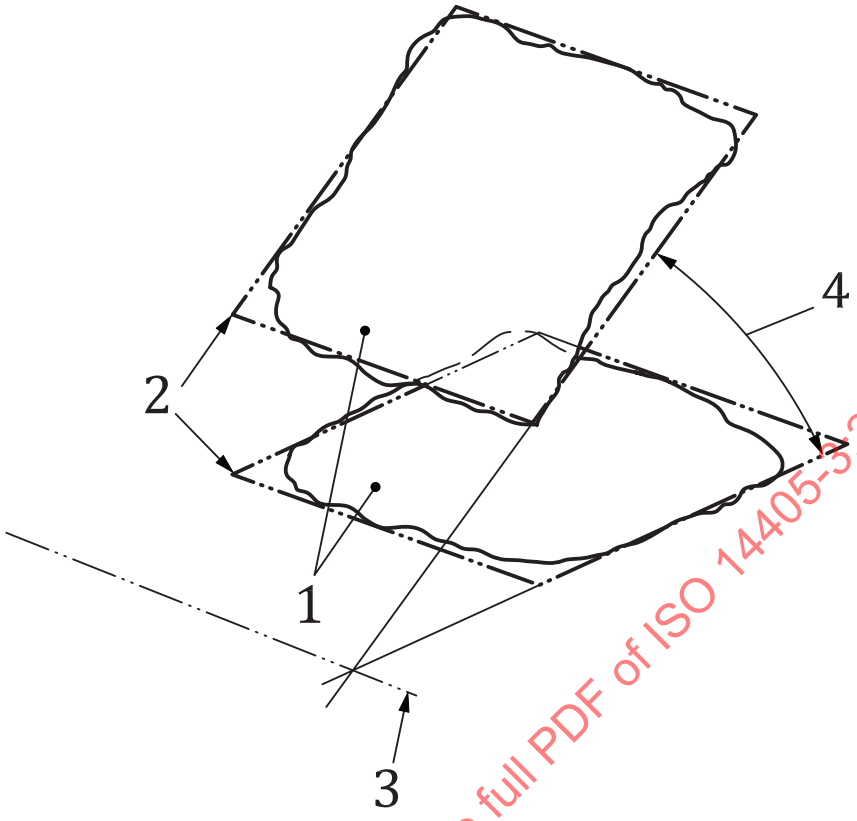
3.3.1.1
least squares global angular size
direct global angular size using the least squares association criterion

Note 1 to entry: See Figure 7 and Figure 9.

3.3.1.2
minimax global angular size
direct global angular size using the minimax association criterion

Note 1 to entry: See Figure 8 and Figure 10.

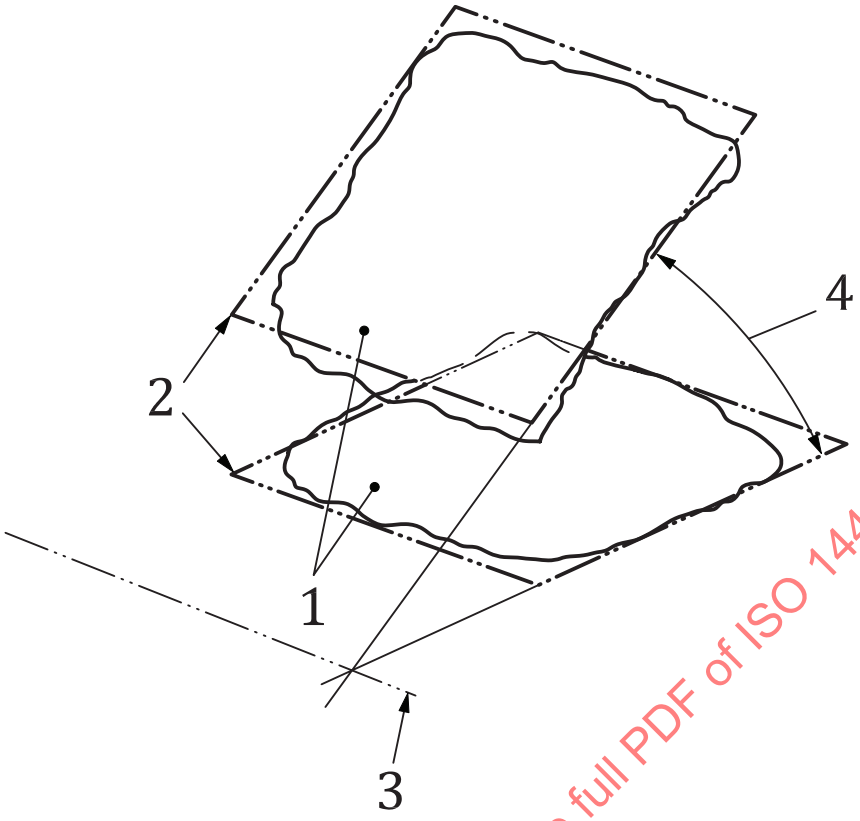
Note 2 to entry: Figure 7 to Figure 10 are the illustrations of two global angular sizes defined on the same real angular feature of size.



Key

1 real angular features of size
2 associated planes with (1)
3 intersection straight line of (2)
4 least squares global angular size

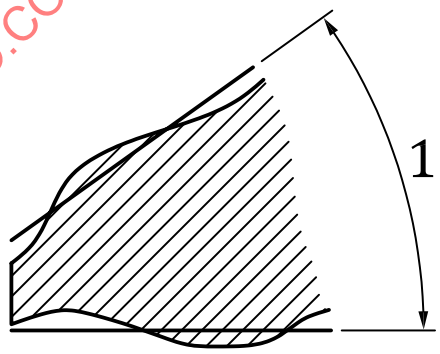
Figure 7 — Least squares global angular size 3D view



Key

1 real angular features of size
2 associated planes with (1)
3 intersection straight line of (2)
4 minimax global angular size

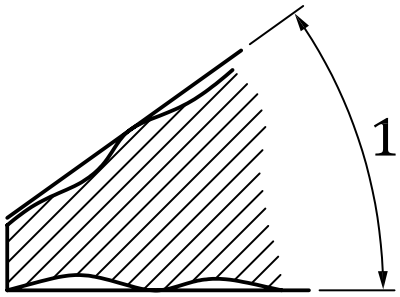
Figure 8 — Minimax global angular size 3D view



Key

1 least squares global angular size

Figure 9 — Least squares global angular size 2D view



Key

1 minimax global angular size

Figure 10 — Minimax global angular size 2D view

3.3.2
indirect global angular size
indirect global angular size characteristic
rank-order angular size
rank order angular size characteristic
global angular size defined mathematically from a homogeneous set of local size values obtained along and/or around the angular feature of size

Note 1 to entry: A rank-order angular size can define a unique value along and/or around the angular feature of size from a local angular size for a portion or for the entire angular feature of size.

Note 2 to entry: A rank-order angular size can define a local angular size from another local angular size (for example a rank order angular size from a two-line angular size taken in any portion).

Note 3 to entry: For further details on the subtypes of rank order size, see ISO 14405-1.

Note 4 to entry: A rank-order angular size can be, for example, the average of all two-line angular size values on an extracted conical surface.

4 Specification modifiers and symbols

For the purposes of this part of ISO 14405, the specification modifiers and symbols given in Table 1 and Table 2 apply. To define in a dimensional specification a specific type of angular size characteristic available for upper and/or lower limit specification, modifiers or symbols shall be used in the sequence given in Table 3 (see also Annex C).

The combination of these modifiers and symbols is described in Clause 5 and Clause 6.

Rules for the presentation of graphical symbols are given in ISO 14405-1:2016, Annex A and Annex E.

Table 1 — Specification modifiers for angular size

Modifier	Description
(LC)	Two-line angular size with minimax association criterion
(LG)	Two-line angular size with least squares association criterion
(GG)	Global angular size with least squares association criterion
(GC)	Global angular size with minimax association criterion
(SX)	Maximum angular size[a]
(SN)	Minimum angular size[a]
(SA)	Average angular size[a]
(SM)	Median angular size[a]
(SD)	Mid-range angular size[a]
(SR)	Range of angular sizes[a]
(SQ)	Standard deviation of angular size[a] [b]

[a] Rank-order angular size can be used as a supplement to portion angular size or global portion angular size or local angular size.

[b] SQ from root mean square.

Table 2 — General specification modifiers for angular size

Description	Symbol	Examples of indication	
		Prismatic angular feature of size	Revolute angular feature of size
Any restricted portion of angular feature of size	/linear distance	35° ±1°/15[a]	35° ±1°/15[a]
Any restricted portion of angular feature of size	/angular distance	**Not applicable**	35° ±1°/15°[a]
Specific fixed cross section	SCS	45° ±2° SCS	**Not applicable**
More than one angular feature of size	Number ×	2× 45° ±2°	2× 45° ±2°
Common toleranced feature of angular size	CT	2× 45° ±2° CT	2× 45° ±2° CT
Free-state condition	Ⓕ[b]	35° ± 1° Ⓕ	35° ± 1° Ⓕ
Between	←→	35° ± 1° A←→B	35° ± 1° A←→B

[a] /linear distance applies to prismatic features of size and to revolute features of size along the axis of the revolute feature. /angular distance applies to revolute feature of size.

[b] See ISO 10579.

Table 3 — Sequence of modifiers to refer to a specific angular size characteristic

Type of angular size characteristic	Subtype	Additional definition	Associated modifiers
Local angular size	Two-line angular size		(LC) or (LG)
	Portion angular size of length L	With least squares association criterion[a]	Example: (GG)/25
		With minimax association criterion[a]	Example: (GC)/20
		Rank order angular size of local angle ; angular size established on a portion	Example: (LG)/20 (SN)
Global angular size	Direct global angular size	With least squares association criterion	Example (GG)
		With minimax association criterion	Example (GC)
	Indirect global angular size	Rank order angular size based upon local angular size	Examples (LG) (SD) (GG)/10 (SD)

[a] For the second association operation, the first association operation is always defined by the least squares criterion.

5 Default specification operator for angular size

5.1 General

When the basic GPS indication is used for angular size, the default specification operator for angular size applies. The default specification operator for angular size can be as follows:

— the ISO default GPS specification operator (see 5.2 and ISO 8015);

— the drawing-specific default GPS specification operator (see 5.3);

— the altered default GPS specification operator (see ISO 8015).

The basic GPS specification for angular size has no specification modifier attached and can be one of four types; see Table 4.

Table 4 — Different basic GPS specifications for angular size

GPS basic specification for angular size	Examples
Nominal angular size ± deviation limits[a]	35° ±1° +1° 35°–2°
Values of upper and lower limits of angular size[a]	36° 34°
Values of upper or lower limits of angular size[a]	45° max 32° min
A nominal angular size which is neither indicated in brackets nor as a theoretically exact dimension (TED) and a reference to general tolerancing in or near the drawing title block[b].	45° and ISO 2768-f (in or near the drawing title block)

[a] Nominal angular size and deviation limit should be indicated with the unit indication (decimal degrees or degrees/minutes/seconds).

[b] See ISO 2768-1 for information on general tolerancing.

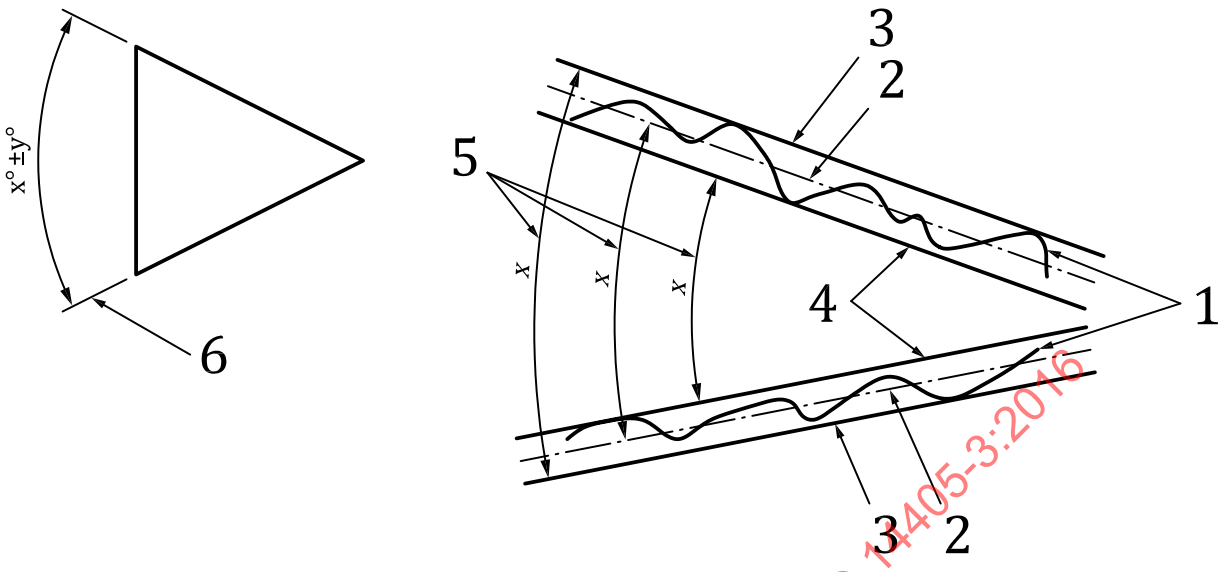
5.2 ISO default specification operator for angular size

The ISO default specification operator for angular size is the "two-line angular size" with minimax association criterion, see also Annex A.

The ISO default specification operator for angular size applies when there is no indication on the drawing referring to another default specification for angular size as defined in 5.3.

If the two-line angular size is applied for both specified limits, the modifier (LC) can be omitted.

See Figure 11 a) and Figure 11 b).



a) Indication **b) Interpretation**

Key

1 real feature
2 associated feature with minimax criterion without material constraint
3 associated feature with minimax criterion with outside material constraint
4 associated feature with minimax criterion with inside material constraint
5 two-line angular size
6 angular dimension

Figure 11 — ISO default specification operator for angular size

In case of minimax criterion, there is no impact on the result of evaluation of angular size when material constraint is used or not. See also Figure 11.

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.

5.3 Drawing-specific default specification operator for angular size

When a drawing-specific default specification operator for angular size applies, it shall be indicated on the drawing in or near the title block in the following order:

— reference to ISO 14405;

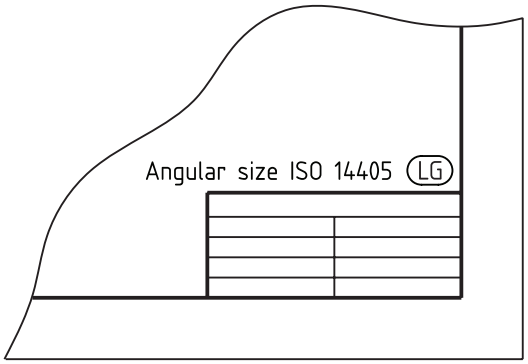
— the specification modifier(s) for the chosen default specification definition of angular size.

See also Figure 12.

In order to specify different default specification operators for linear and/or angular size, it shall be indicated before the reference to this International Standard by adding the words “linear size” and/or “angular size”.

EXAMPLE “Angular size ISO 14405”.

See also Figure 12 and Figure 13.



NOTE 1 The default specification operator for angular size for this drawing is changed to the least squares angular size.

NOTE 2 The changed default specification operator is the default angular size, unless otherwise stated.

NOTE 3 The default specification for this drawing applies to angular sizes only.

Figure 12 — Example of change of default specification operator for angular size for the entire drawing

To facilitate the reading of the drawing, it is possible to show all other types of modifiers used on the drawing by listing them in brackets after the specific default specification indication. See Figure 13.

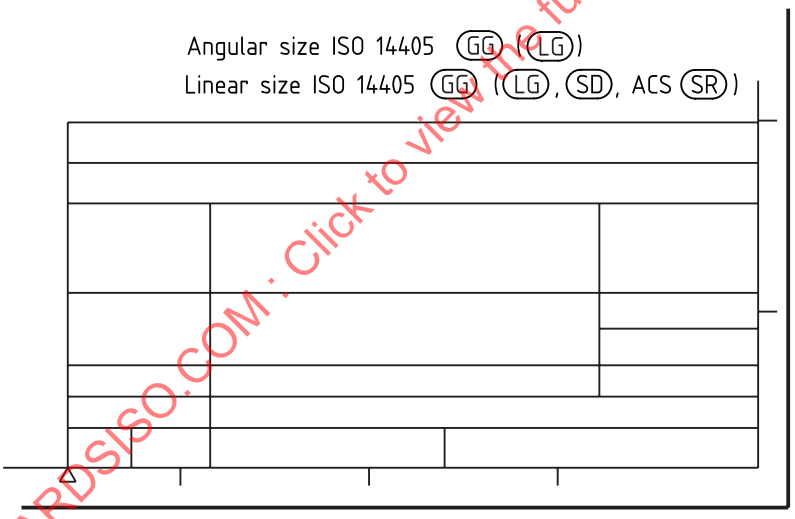


Figure 13 — Example of change of default specification operator for both linear and angular size for the entire drawing

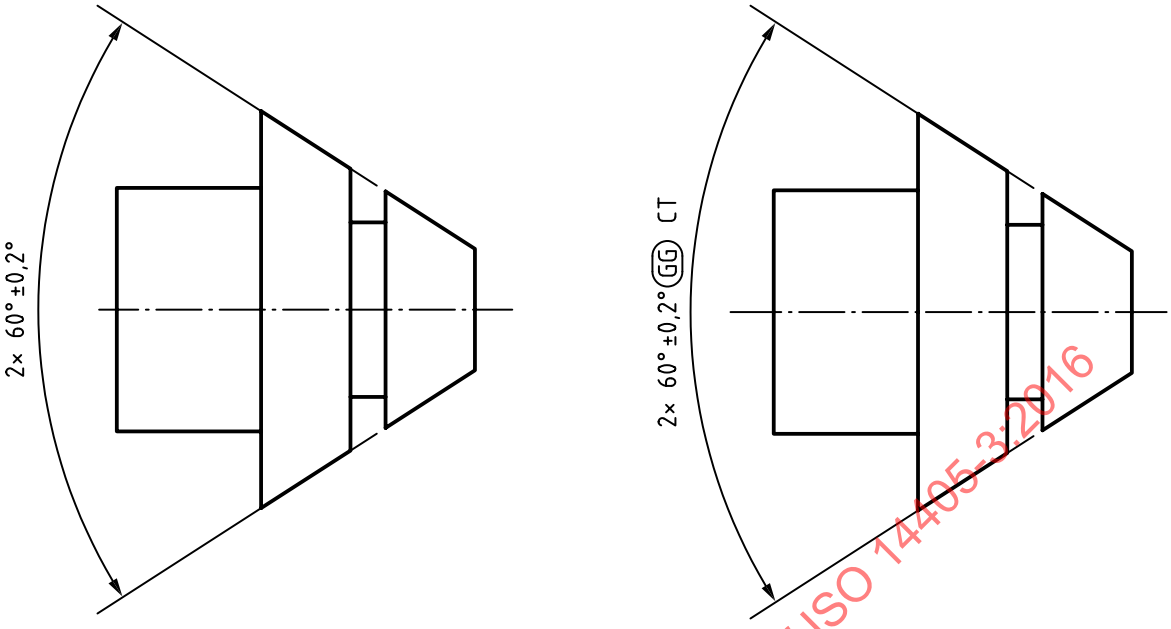
6 Drawing indication

6.1 Drawing indication for special specification operators for angular size

A tolerance indication for angular size applies to one single complete feature of angular size. It is possible to indicate

— the tolerance applies to any restricted part or a fixed restricted part of the feature of angular size, or

— the tolerance applies to more than one feature of angular size; see Figure 14 a) and Figure 14 b).



a) Same requirement for two separate features of angular size evaluated individually

b) Common requirement for the two features of angular size considered as one (CT modifier)

Figure 14 — Example of tolerance applied to more than one angular feature of size

When the ISO default specification operator for angular size does not apply, the tolerance indication shall include specification modifiers (see Table 1 and Table 2) indicating which special specification operator(s) apply.

The rules for sequence and indication of modifiers (see Table 1 and Table 2) for angular size shall respect those defined in ISO 14405-1:2016, Clause 6.

6.2 Indication of the toleranced feature on which the angular size characteristic is defined

When the toleranced feature is the complete feature, no additional indication is necessary (see Figure 15).

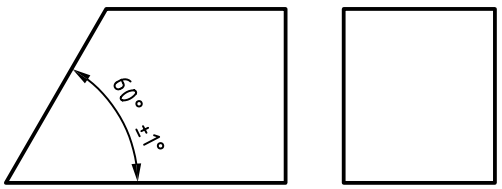


Figure 15 — Example of requirement for the complete angular feature of size

When the tolerance feature is a part of the complete feature, indications to define a cross-section or a portion according to ISO 14405-1:2016, 7.2 to 7.3 shall be applied.

When a requirement applies individually to more than one angular feature of size, then rules about the use of the modifier for the number of repeated features "*n*×" from ISO 14405-1:2016, 7.6 shall be applied.

When a requirement applies simultaneously to multiple angular features of size, considered as one, then the CT modifier shall be applied in accordance with ISO 14405-1:2016, 7.7.

Annex A
(normative)

Association criteria for two-line angular size (for a revolute or prismatic feature of size)

Two-line angular size

Two sequential association operations are used to define a two-line angular size. See Table A.1.

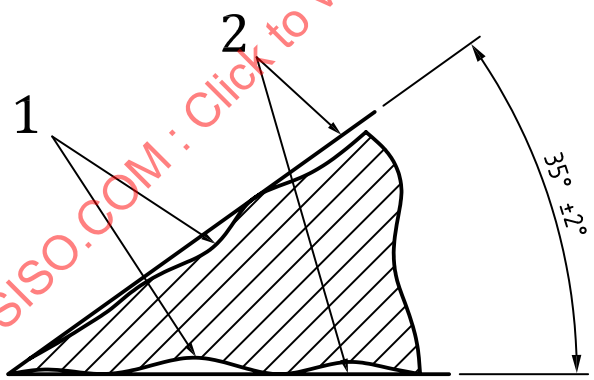
a) To associate the real angular features of size with a feature of the same nature.

b) To associate the extracted lines (coming from intersection of the real angular features of size and the intersection plane) with two straight lines. See Figure A.1 for an example with minimax criterion.

For the first association (a): the association criterion is the least squares association criterion (without material constraint, see Clause 3) for the two extracted surfaces of a prismatic feature of size (independently of each other) and for the extracted surface of a revolute feature of size.

NOTE The first association with a least squares criterion is to establish either a stable intersection line for the prismatic feature of size, see Figure 4, or a stable axis for the revolute feature of size.

For the second association (b): the second association criterion can be either a minimax association criterion (default case) or a least squares association criterion (without material constraint, see Clause 3). The two lines are associated independently of each other.



Key

1 extracted lines
2 associated lines

Figure A.1 — Two-line angular size: Second association with minimax criterion

Table A.1 — Symbols for two-line angular size

	First association mandatory	Second association specification dependent	
		Minimax = default case	Least squares
Two-line angular size	Least squares no symbol	LC	LG