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Geometrical Product Specifications (GPS) — Indication of dimensions and tolerances — Mechanical engineering drawings

Spécification géométrique des produits (GPS) — Indication des cotes et tolérances — Dessins pour la construction mécanique

[Revision of second edition (ISO 406:1987)]

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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 129-2 was prepared by Technical Committee ISO/TC 213, *Dimensional and geometrical product specifications and verification*.

ISO 129 consists of the following parts, under the general title *Geometrical product specifications (GPS) — Indication of dimensions and tolerances*:

— *Part 1: General principles*

— *Part 2: Mechanical engineering drawings*

Introduction

This International Standard is a geometrical product specification (GPS) standard and is to be regarded as a general GPS standard (see ISO/TR 14638). It influences link 1 in the size, distance, radius and angle chain of standards in the general GPS matrix.

Dimensions and related tolerances are defined on the nominal model only. The consequence is that dimensional tolerances applied to features of real workpieces will result in an unlimited specification uncertainty outside the designer's control.

It must be realised that this specification uncertainty can only be avoided for features of size toleranced according to ISO 14405. For all other dimensions, geometrical tolerancing shall be used in order to control the specification uncertainty.

For more detailed information of the relation of this standard to other standards and the GPS matrix model see Annex C.

Geometrical Product Specifications (GPS) — Indication of dimensions and tolerances — Mechanical engineering drawings

1 Scope

This part of ISO 129 establishes the principles of indication and shortcomings of the context of plus/minus tolerances (± tolerances) in the field of mechanical engineering. General tolerances for dimensions shall be interpreted as ± tolerances.

This part of ISO 129 covers indications and shortcomings related to linear as well as angular dimensions and identify the sub types of these dimensions.

This part of ISO 129 also identifies the limitations of the use of dimensions and related tolerances in the field of mechanical engineering to avoid specification uncertainties. For general principles of dimensioning see ISO 129-1.

The figures, as shown in this part of ISO 129, merely illustrates the text and are not intended to reflect actual usage. The figures are consequently simplified to indicate only the relevant principles.

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 129-1:2001, *Technical drawings – Indication of dimensions and tolerances – Part 1: General principles*

ISO 286-1[1)], *Geometrical Product Specification (GPS) – ISO code system for tolerances of linear sizes – Part 1: Basis of tolerances and fits*

ISO 1101:2004, *Geometrical Product Specifications (GPS) – Geometrical tolerancing – Tolerances of form, orientation, location and run-out*

ISO/R 1938:1971[2)], *ISO system of limits and fits – Part II: Inspection of plain workpieces*

ISO 13715:200, *Technical drawings – Edges of undefined shape – Vocabulary and indications*

ISO 14405[1)], *Geometrical product specifications (GPS) – Dimensional tolerancing- Linear sizes*

ISO 14569[1)], *Geometrical Product Specifications (GPS) – Fundamental principles and rules*

1) Under preparation

2) Under revision

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

ISO/TS 17450-2:2002, *Geometrical product specifications (GPS) – General concepts – Part 2: Basic tenets, specifications, operators and uncertainties*

3 Terms and definitions

For the purpose of this International Standard, the terms and definitions given in ISO 129-1, ISO 286-1, ISO 1101, ISO/R 1938, ISO 13715, ISO 14405, ISO 14638, ISO 14569, ISO 14660-1, ISO 14660-2, ISO/TS 17450-1, ISO/TS 17450-2 and the following definitions apply.

The term drawing is used in this standard 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 limits

3.2
dimension
distance or a size or a radius or a path dimension or the characteristic values of an edge

3.2.1
linear dimension
dimension in length units

3.2.1.1
path dimension
linear dimension along a defined path

NOTE The path dimension on an arc is called: Arc length.

3.2.1.2
radius dimension
linear dimension characterizing the curvature of a feature, which is a circle or cylinder or sphere or part of these types of geometry

NOTE The feature (circle or cylinder or sphere) can be an integral or derived feature.

3.2.2
angular dimension
dimension in angle units

3.3
size
value of a local size, a global linear size, a calculated size, or a rank order size

NOTE The size can only be defined on features of size.

[See 3.2 of ISO 14405]

3.3.1
linear size
value in length units characterizing a feature of size

3.3.2
angular size
value in angle units characterizing a feature of size

3.4
distance
value of the dimension between two features, not 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

3.4.1.1
linear step dimension
linear distance between two nominal parallel integral features facing the same direction

3.4.1.2
angular step dimension
angular distance between two integral features nominal inclined to each other and facing the same direction

3.4.2
angular distance
distance in angle units

3.5
feature
geometrical feature
point, line or surface

[See 2.1 of ISO 14660-1:1999]

3.5.1
integral feature
surface or line on a surface

NOTE An integral feature is intrinsically defined.

[See 2.1.1 of ISO 14660-1:1999]

3.5.1.1
feature of size
geometrical shape defined by a linear or angular dimension which is a size

NOTE 1 The features of size can be a cylinder, a sphere, two parallel opposite surfaces, a cone or a wedge.

NOTE 2 In International Standards such as ISO 286-1 and ISO/R 1938, the meanings of the terms "plain workpiece"and "single features" are close to that of "feature of size".

[See 2.2 of ISO 14660-1:1999]

3.5.2
derived feature
centre point, median line or median surface from one or more integral features

EXAMPLES

1 The centre of a sphere is derived feature obtained from the sphere, which is an integral feature.

2 The median line of a cylinder is a derived feature obtained from the cylindrical surface, which is an integral feature.

[See 2.1.2 of ISO 14660-1:1999]

3.6
specification uncertainty
uncertainty inherent in an actual specification operator when applied to a real feature/feature

NOTE 1 Specification uncertainty is of the same nature as measurement uncertainty and may – if relevant – be part of an uncertainty budget.

NOTE 2 The specification uncertainty quantifies the ambiguity in the specification operator.

NOTE 3 For the purposes of this part of ISO/TS 17450, specification uncertainty is considered as part of the compliance uncertainty.

NOTE 4 Specification uncertainty is a property related to the actual specification operator.

NOTE 5 The magnitude of the specification uncertainty is also dependent on the expected or actual variation of the geometrical characteristics (deviations of form and angularity) of workpieces.

EXAMPLE

The specification uncertainty of step dimension 30 ± 0,1, which does not specify which association shall be used, is obtained from the range of values that can be obtained with different association criteria.

[See 3.4.3 of ISO 17450-2:2002]

3.7
correlation uncertainty
uncertainty arising from the difference between the actual specification operator and the functional operator that defines the intended function of the workpiece, expressed in the terms and units of the actual specification operator

NOTE 1 Correlation uncertainty is, if possible, expressed in numbers and units comparable to the specification given.

NOTE 2 Correlation uncertainty is usually not related to a single GPS specification. Usually it takes a number of single GPS specifications to simulate a function (e.g. size, form and surface texture for the same feature of the workpiece).

EXAMPLE

Where the functional operator for a shaft is the shaft's ability to run in a hole with a seal for 2 000 h without leaking, and the specification operator is Φ30 h7 for the size of the shaft and *R*a 1,5 using a 2,5 mm filter for the surface texture of the shaft, then the correlation uncertainty is derived from this specification's ability to ensure that

— a shaft complying with the specification will run for 2 000 h without leaking, and

— a shaft that does not comply with the specification will not run for 2 000 hours without leaking.

[See 3.4.4 of ISO 17450-2:2002]

3.8
specification operator
ordered set of specification operation(s)

NOTE 1 The specification operator is the result of the full interpretation of the combination of the GPS specification(s) indicated in the technical product documentation according to ISO GPS standards.

NOTE 2 A specification operator can be incomplete and could, in such case, introduce specification uncertainty.

NOTE 3 A specification operator is intended to define, for example, a specific possible "diameter" in a cylinder (two-point diameter, minimum circumscribed circle diameter, maximum inscribed circle diameter, least squares circle diameter, etc.), and not the generic concept "diameter".

NOTE 4 The difference between the specification operator and the functional operator causes correlation uncertainty.

EXAMPLE

If the specification for a shaft were Φ 30 h7 (see ISO 286-1 and ISO 14405), then the specification operators for the upper and lower limits would be

- partition from the skin model of the non-ideal cylindrical surface,
- association of an ideal feature of type cylinder with the least squares criteria of association,
- construction of straight lines perpendicular to and penetrating the axis of the associated cylinder,
- extraction of two points for each straight line, and
- evaluation of the distance between each set of two points, the largest distance being compared to the upper limit and the smallest distance to the lower limit.

[See 3.3.3 of ISO 17450-2:2002]

3.9
default definition (of an extracted feature)
detailed supplementary definition, selected by convention, of the extracted feature concerned, which is applicable only by using the basic ISO tolerance indication on the drawing or in other technical documents

NOTE 1 The basic ISO tolerance indications are those given in, for example, ISO 286-1, ISO 1101 and ISO 1302.

NOTE 2 The default definition (of an extracted feature) can be changed to a special definition by adding an extension to the basic ISO tolerance indication. Such extensions are under development.

[See 3.1 of ISO 14660-2:1999]

4 Principles and rules for indication of dimensions and related tolerances

4.1 General

The general rules and principles for indicating dimensions and tolerances given in ISO 129-1 is the basis for dimensioning on mechanical engineering drawings. In some cases special rules apply.

Dimensions and related tolerances are defined on the nominal model only. The consequence is that dimensional tolerances applied to features of real workpieces will result in an unlimited specification uncertainty outside the designer's control.

It must be realised that this specification uncertainty can only be avoided for features of size toleranced according to ISO 14405. For all other dimensions, geometrical tolerancing shall be used in order to control the specification uncertainty.

One dimension can by nature relate only two features. If the dimensions with ± tolerancing are used to relate more than two features it will result in a tolerance stack-up, e.g. as in a chain dimensioning.

NOTE If geometrical tolerances and a datum system as an alternative to dimensions with ± tolerances the tolerance stack-up will be avoided.

The ambiguity of specifications stated in drawings as dimensions and related tolerances is dependent on the relative magnitude between the dimension tolerance and form deviations on the features and/or angular deviations between the features related by the dimension. But other reasons may also influence the ambiguity or specification uncertainty. For more details about ambiguities in dimensioning and alternative unambiguous ways to express the intended requirement see Annex B.

Indications of dimensions on a mechanical engineering drawing shall generally be understood as individual and independent requirements without any relations to other requirements for the same feature(s) – Independency principle (see ISO 14659).

Dimension is a common designation for a number of different subtypes of geometrical characteristics of a work piece (see Table 1).

Table 1 — The hierarchy of dimensions

Dimension		**Feature characterization, type and number of**			**Detailed characteristic**	**Details in**
Level 0	**Level 1**	**Level 2**	**Level 3**		**Level 4**	
Dimension	Linear dimension [length units]	One feature	Integral – Only features of size		Linear size	6.2 and ISO 14405
			Integral or derived		Radius dimension	6.5
				Path	Path dimension	6.4
					Arc length	6.4
		Two features	Integral – integral	Facing same direction	Linear distance or step height	6.3.2
				Facing opposite direction	Thickness	6.3.2
					Linear distance	6.3.2
			Integral – derived		Linear distance	6.3.3
			Derived – derived		Linear distance	6.3.4
		Edge (Transition region between two integral features)	Integral	Chamfer shape	Chamfer height and angle	8.2
				Rounding shape	Edge radius	8.3
				Undefined shape	Dimensions of edge of undefined shape	8.4 and ISO 13715
	Angular dimension [Angle units]	One feature	Integral – Only features of size		Angle size	7.2
		Two features	Integral – integral		Angular distance	7.3.2
			Integral – derived		Angular distance	7.3.3
			Integral – derived		Angular distance	7.3.4

The subtypes of dimension form a hierarchy:

1st level The main types of dimension are linear dimensions and angular dimensions with length units and angle units respectively;

2nd level Features involved for linear dimensions and angular dimensions;

3rd level Details about the features, integral or derived and their relations;

4th level Detailed dimension characteristic and terms used.

It is necessary to observe the 4th level of the dimension hierarchy to see the possible specification uncertainties and the reason for these.

4.2 Writing rules for dimensions and associated tolerances

A dimension indication on a drawing, the dimension indicator, consists of a number of elements. Not all elements are present in a specific dimension indicator. The elements are:

— Number of features, the dimension indicator is valid for - e.g. 2×

— Symbol for type of dimension, e.g. Φ R □ SΦ SR ⌒ t = (defined in ISO 129-1), followed of the nominal value of the dimension – e.g. 38 and 45° (for units see 5.), e.g. Φ 55

— Information about the tolerance - e.g. limit deviations, dimension limit values, unilateral dimension limit value or a tolerance code according to ISO 286-1;

— Specification modifiers (not used in this standard, see ISO 14405 for examples of use of specification modifiers).

The format for the dimension indicator is (for details and dimensions of the dimension indicator see Annex A):

— The dimension indicator is based on the ISO 3098 font and the width (d) of the narrow line used on the drawing;

— A space separates the elements of the dimension indicator – e.g. 2× Φ55 ± 0,2

— No spaces inside the elements

— If two limits for the tolerance are used (e.g. limit deviations, dimension limit values) the vertical distance between the baselines of the text shall allow the use of specification modifiers and the decimal places of the upper and lower shall be at the same horizontal position (for details see Annex A), e.g.:

$$2\times\ \Phi 55\ {}^{+0,2}_{-0,2}$$

For more details see Annex A.

5 Units used in drawings for dimensions

The default units for dimensions are:

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

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