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

Spécification géométrique des produits (GPS) — Tolérancement géométrique — Tolérancement de forme, orientation, position et battement

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ISO copyright office
Ch. de Blandonnet 8 • CP 401
CH-1214 Vernier, Geneva, Switzerland
Tel. +41 22 749 01 11
Fax +41 22 749 09 47
copyright@iso.org
www.iso.org

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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.

This document was prepared by Technical Committee ISO/TC 213, *Dimensional and geometrical product specifications and verifications*.

This fourth edition cancels and replaces the third edition (ISO 1101:2012), which has been technically revised.

It also incorporates the Technical Corrigendum ISO 1101:2012/Cor.1:2013.

The main changes are as follows.

— Tools have been added to specify the filtering of the toleranced feature and a line type has been designated for its illustration.

— Tools have been added to tolerance associated features.

— Tools have been added to specify form characteristics by specifying the reference feature association and the specified parameter.

— Tools have been added to specify the constraints to the tolerance zone.

— The rules for specifications using “all around” or “all over” modifiers have been clarified.

— The direction of the tolerance zone in the case of roundness tolerances for revolute surfaces that are neither cylindrical nor spherical, e.g. cones shall now always be indicated to avoid an exception to the general rule that specifications for integral features apply perpendicular to the surface.

— The “from-to” symbol has been retired and replaced by the “between” symbol.

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 links A, B and C of the chain of standards on form, orientation, location and run out.

The ISO GPS Masterplan 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. The default decision rules given in ISO 14253-1 apply to specifications made in accordance with this document, unless otherwise stated.

For more detailed information on the relation of this document to the GPS matrix model, see Annex G.

This document represents the initial basis and describes the required fundamentals for geometrical tolerancing. Nevertheless, it is advisable to consult the separate standards referenced in Clause 2 and in Tables 3 and 4 for more detailed information.

For the presentation of lettering (proportions and dimensions), see ISO 3098-2.

All figures in this document for the 2D drawing indications have been drawn in first-angle projection with dimensions and tolerances in millimetres. It should be understood that third-angle projection and other units of measurement could have been used equally well without prejudice to the principles established. For all figures giving specification examples in 3D, the dimensions and tolerances are the same as for the similar figures shown in 2D.

The figures in this document represent either 2D drawing views or 3D axonometric views on 2D drawings and are intended to illustrate how a specification can be fully indicated with visible annotation. For possibilities of illustrating a specification where elements of the specification may be available through a query function or other interrogation of information on the 3D CAD model and rules for attaching specifications to 3D CAD models, see ISO 16792.

The figures in this document illustrate the text and are not intended to reflect an actual application. Consequently, the figures are not fully dimensioned and specified, showing only the relevant general principles. Neither are the figures intended to imply a particular display requirement in terms of whether hidden detail, tangent lines or other annotations are shown or not shown. Many figures have lines or details removed for clarity, or added or extended to assist with the illustration of the text. See Table 1 for the line types used in definition figures.

In order for a GPS specification to be unambiguous, the partition defining the boundary of the toleranced feature, as well as the filtering, has to be well defined. Currently, the detailed rules for partitioning and the default for filtering are not defined in GPS standards.

For a definitive presentation (proportions and dimensions) of the symbolization for geometrical tolerancing, see ISO 7083 and Annex F.

Annex A has been provided for information only. It presents previous drawing indications that have been omitted here and are no longer used.

For the purposes of this document, the terms “axis” and “median plane” are used for derived features of perfect form, and the terms “median line” and “median surface” for derived features of imperfect form. Furthermore, the following line types have been used in the explanatory illustrations, i.e. those representing non-technical drawings for which the rules of ISO 128 (all parts) apply.

Table 1

Feature level	Feature type	Details	Line type	
			Visible	Behind plane/surface
Nominal feature	integral feature	point line/axis surface/plane	wide continuous	narrow dashed
	derived feature	point line/axis surface/plane	narrow long dashed dotted	narrow dashed dotted
Real feature	integral feature	surface	wide freehand continuous	narrow freehand dashed
Extracted feature	integral feature	point line surface	wide short dashed	narrow short dashed
	derived feature	point line surface	wide dotted	narrow dotted
Filtered feature	integral feature	line surface	continuous narrow	continuous narrow
Associated feature	integral feature	point straight line plane	wide doubled-dashed double-dotted	narrow double-dashed double-dotted
	derived feature	point straight line (axis) plane	narrow long dashed double-dotted	wide dashed double-dotted
	datum	point line/axis surface/plane	wide long dashed double-short dashed	narrow long dashed double-short dashed
Tolerance zone limits, tolerance planes		line surface	continuous narrow	narrow dashed
Section, illustration plane, drawing plane, aid plane		line surface	narrow long dashed short dashed	narrow dashed short dashed
Extension, dimension, leader and reference lines		line	continuous narrow	narrow dashed

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

IMPORTANT — The illustrations included in this document are intended to illustrate the text and/or to provide examples of the related technical drawing specification; these illustrations are not fully dimensioned and toleranced, showing only the relevant general principles. In particular, many illustrations do not contain filter specifications. As a consequence, the illustrations are not a representation of a complete workpiece, and are not of a quality that is required for use in industry (in terms of full conformity with the standards prepared by ISO/TC 10 and ISO/TC 213), and as such are not suitable for projection for teaching purposes.

1 Scope

This document defines the symbol language for geometrical specification of workpieces and the rules for its interpretation.

It provides the foundation for geometrical specification.

The illustrations in this document are intended to illustrate how a specification can be fully indicated with visible annotation (including e.g. TEDs).

NOTE 1 Other International Standards referenced in Clause 2 and in Tables 3 and 4 provide more detailed information on geometrical tolerancing.

NOTE 2 This document gives rules for explicit and direct indications of geometrical specifications. Alternatively, the same specifications can be indicated indirectly in accordance with ISO 16792 by attaching them to a 3D CAD model. In this case, it is possible that some elements of the specification are available through a query function or other interrogation of information on the model instead of being indicated using visible annotation.

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 128-24:1999, *Technical drawings — General principles of presentation — Part 24: Lines on mechanical engineering drawings*

ISO 1660, *Technical drawings — Dimensioning and tolerancing of profiles*

ISO 2692:2014, *Geometrical product specifications (GPS) — Geometrical tolerancing — Maximum material requirement (MMR), least material requirement (LMR) and reciprocity requirement (RPR)*

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

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

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

ISO 10579:2010, *Geometrical product specifications (GPS) — Dimensioning and tolerancing — Non-rigid parts*

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

ISO 16610 (all parts), *Geometrical product specifications (GPS) — Filtration*

ISO 17450-1:2011, *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*

ISO 22432, *Geometrical product specifications (GPS) — Features utilized in specification and verification*

ISO 25378:2011, *Geometrical product specifications (GPS) — Characteristics and conditions — definitions*

3 Terms and definitions

For the purpose of this document, the terms and definitions given in ISO 8015, the ISO 16610 series, ISO 17450-1, ISO 17450-2, ISO 17450-3, ISO 22432, ISO 25378 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at https://www.iso.org/obp/

3.1
tolerance zone
space limited by and including one or two ideal lines or surfaces, and characterized by one or more linear dimensions, called a tolerance

Note 1 to entry: See also 4.4.

3.2
intersection plane
plane, established from an extracted feature of the workpiece, identifying a line on an extracted surface (integral or median) or a point on an extracted line

Note 1 to entry: The use of intersection planes makes it possible to define toleranced features independent of the view.

Note 2 to entry: For areal surface texture, the intersection plane can be used to define the orientation of the evaluation area, see ISO 25178-1.

3.3
orientation plane
plane, established from an extracted feature of the workpiece, identifying the orientation of the tolerance zone

Note 1 to entry: The use of an orientation plane makes it possible to define the direction of the planes or cylinder that limit the tolerance zone independent of the TEDs (for location) or of the datum (for orientation). The orientation plane is only used for this purpose when the toleranced feature is a median feature (centre point, median straight line) and the tolerance zone is defined by two parallel straight lines or two parallel planes or, for a centre point, a cylinder.

Note 2 to entry: The use of an orientation plane also makes it possible to define the orientation of a rectangular restricted area.

3.4
direction feature
ideal feature, established from an extracted feature of the workpiece, identifying the direction of local deviations

Note 1 to entry: The direction feature can be a plane, a cylinder or a cone.

Note 2 to entry: For a line in a surface, the use of a direction feature makes it possible to change the direction of the width of the tolerance zone.

Note 3 to entry: The direction feature is used when the tolerance value applies in a specified direction instead of normal to the specified geometry.

Note 4 to entry: The direction feature is constructed from the datum indicated in the second compartment of the direction feature indicator. The geometry of the direction feature depends on the geometry of the toleranced feature.

3.5
compound continuous feature
single feature composed of more than one single feature joined together without gaps

Note 1 to entry: A compound continuous feature can be closed or not.

Note 2 to entry: A non-closed compound continuous feature can be defined using the "between" symbol (see 9.1.4) and, if applicable, the UF modifier.

Note 3 to entry: A closed compound continuous feature can be defined using the "all around" symbol (see 9.1.2) and the UF modifier. In this case, it is a set of single features whose intersection with any plane parallel to a collection plane is a line or a point.

Note 4 to entry: A closed compound continuous feature can be defined using the "all over" symbol (see 9.1.2) and the UF modifier.

3.6
collection plane
plane, established from a feature on the workpiece, defining a closed compound continuous feature

Note 1 to entry: The collection plane is always used when the "all around" symbol is applied.

3.7
theoretically exact dimension
TED
linear or angular dimension used in GPS operations to define theoretically exact geometry, extents, locations and orientations of features

Note 1 to entry: For the purpose of this document, the term "theoretically exact dimension" has been abbreviated as TED.

Note 2 to entry: A TED can be used to define the following:

— the nominal shape and dimensions of features;

— the definition of theoretically exact features (TEF);

— the location and dimensions of portions of features, including restricted toleranced features;

— the length of projected toleranced features;

— the relative location and orientation of two or more tolerance zones;

— the relative location and orientation of datum targets, including moveable datum targets;

— the location and orientation of tolerance zones relative to datums and datum systems;

— the direction of the width of tolerance zones.

Note 3 to entry: A TED can be explicit or implicit. When indicated, an explicit TED is indicated by a rectangular frame including a value and sometimes an associated symbol, e.g. ø or R. On 3D models, explicit TEDs may be available by queries.

Note 4 to entry: An implicit TED is not indicated. An implicit TED is one of the following: 0 mm, 0°, 90°, 180°, 270° and the angular distance between equally spaced features on a complete circle.

Note 5 to entry: TEDs are not affected by individual or general specifications.

3.8
theoretically exact feature
TEF
nominal feature with ideal shape, size, orientation and location, as applicable

Note 1 to entry: A theoretically exact feature (TEF) can have any shape and can be defined by explicitly indicated theoretically exact dimensions (TEDs) or implicitly defined in CAD data.

Note 2 to entry: The theoretically exact location and orientation, if applicable, is relative to the indicated datum system for the specification of the corresponding actual feature.

Note 3 to entry: See also ISO 25378.

EXAMPLE 1 The spherical surface shown in Figure 110 is a theoretically exact feature, with a defined spherical radius and a defined location and orientation relative to datum A.

EXAMPLE 2 A virtual condition, e.g. a maximum material virtual condition (MMVC) according to ISO 2692 is a theoretically exact feature.

3.9
united feature
compound integral feature which may or may not be continuous, considered as a single feature

Note 1 to entry: A united feature can have a derived feature.

Note 2 to entry: The definition of a united feature is intentionally very broad to avoid excluding any useful applications. However, it is not intended that a united feature can be used to define something that is by nature several separate features. For example, building a united feature from two parallel, non-coaxial cylindrical features, or two parallel, non-coaxial rectangular tubes (each built from two perpendicular pairs of parallel planes) is not an intended use.

EXAMPLE 1 A cylindrical feature defined from a set of arc features, such as the outside diameter of a spline, is an intended use of a united feature, see Figure 48.

EXAMPLE 2 Two complete coaxial cylinders, which do not have the same nominal diameter, cannot be considered as a united feature.

4 Basic concepts

4.1 Geometrical tolerances shall be specified in accordance with functional requirements. Manufacturing and inspection requirements can also influence geometrical tolerancing.

NOTE Indicating geometrical tolerances does not necessarily imply the use of any particular method of production, measurement or gauging.

4.2 A geometrical tolerance applied to a feature defines the tolerance zone around the reference feature within which the toleranced feature shall be contained.

NOTE 1 In some cases, i.e. when using the characteristic parameter modifiers introduced in this document, see Figure 13, geometrical specifications can define characteristics instead of zones.

NOTE 2 All dimensions given in the figures in this document are in millimetres.

4.3 A feature is a specific portion of the workpiece, such as a point, a line or a surface; these features can be integral features (e.g. the external surface of a cylinder) or derived features (e.g. a median line or median surface). See ISO 17450-1.

4.4 Depending on the characteristic to be specified and the manner in which it is specified, the tolerance zone is one of the following:

— the space within a circle;

— the space between two concentric circles;

— the space between two parallel circles on a conical surface;

— the space between two parallel circles of the same diameter;

— the space between two equidistant complex lines or two parallel straight lines;

— the space between two non-equidistant complex lines or two non-parallel straight lines;

— the space within a cylinder;

— the space between two coaxial cylinders;

— the space within a cone;

— the space within a single complex surface;

— the space between two equidistant complex surfaces or two parallel planes;

— the space within a sphere;

— the space between two non-equidistant complex surfaces or two non-parallel planes.

NOTE The tolerance zone may be defined in the CAD model.

4.5 Unless a more restrictive indication is required, for example by an explanatory note, the toleranced feature may be of any form, orientation and/or location within this tolerance zone.

4.6 The specification applies to the whole extent of the considered feature unless otherwise specified. See Clauses 11 and 12.

Currently, the detailed rules for partitioning (defining the boundary of the toleranced feature) are not elaborated in GPS standards. This leads to an ambiguity of specification.

4.7 Geometrical specifications which are assigned to features related to a datum(s) do not limit the form deviations of the datum feature(s) itself.

4.8 For functional reasons, one or more characteristics can be specified to define the geometrical deviations of a feature. Certain types of specifications, which limit the geometrical deviations of a toleranced feature, can also limit other types of deviations for the same feature.

— A location specification controls location deviation, orientation deviation and form deviation of the toleranced feature.

— An orientation specification controls orientation and form deviations of the toleranced feature but cannot control its location.

— A form specification controls only form deviations of the toleranced feature.

5 Symbols

The symbols used in symbol section of the tolerance indicator are defined in Table 2.

The symbols used in zone, feature and characteristic section of the tolerance indicator are defined in Table 3. Annex C defines the meaning of the filtration symbols and Annex D defines the meaning of association symbol and parameter (of characteristic) symbols.

Some symbols defined in other standards and used in ISO 1101 are presented in Table 4 for information.

For filter symbols, see Table C.1; for nesting indices, see Table C.2; for association symbols, see Table D.1; and for parameter symbols, see Table D.2.

NOTE For symbol proportions, see ISO 7083 and Annex F.

Table 2 — Symbols for geometrical characteristics

Specification	Characteristics	Symbol	Datum needed	Subclause
Form	Straightness	—	no	17.2
	Flatness	▱	no	17.3
	Roundness	○	no	17.4
	Cylindricity	⌭	no	17.5
	Line profile	⌒[a]	no	17.6
	Surface profile	⌓[a]	no	17.8
Orientation	Parallelism	//	yes	17.10
	Perpendicularity	⊥	yes	17.11
	Angularity	∠	yes	17.12
	Line profile	⌒[a]	yes	
	Surface profile	⌓[a]	yes	
Location	Position	⌖	no	[b]
			yes	17.13
	Concentricity (for centre points)	◎	yes	17.14
	Coaxiality (for median lines)	◎	yes	17.14
	Symmetry	⌯	yes	17.15
	Line profile	⌒[a]	yes	17.7
	Surface profile	⌓[a]	yes	17.9
Run-out	Circular run-out	↗	yes	17.16
	Total run-out	⌰	yes	17.17

NOTE 1 The line profile specification symbol was called “profile any line” in former versions of this document.

NOTE 2 The surface profile specification symbol was called “profile any surface” in former versions of this document.

[a] See also ISO 1660.

[b] See also ISO 5458.

Table 3 — Additional symbols defined in this document

Description	Symbol	Clause
Combination specification elements		
Combined zone	CZ[a c]	8.2.2.1.2
Separate zones	SZ[a]	8.2.2.1.2, ISO 2692 and ISO 5458
Unequal zone specification elements		
Specified tolerance zone offset	UZ[a]	8.2.2.1.3
Constraint specification elements		
Unspecified linear tolerance zone offset (offset zone)	OZ	8.2.2.1.4.1
Unspecified angular tolerance zone offset (variable angle)	VA	8.2.2.1.4.2
Associated toleranced feature specification elements		
Minimax (Chebyshev) feature	Ⓒ	8.2.2.2.2
Least squares (Gaussian) feature	Ⓖ	8.2.2.2.2
Minimum circumscribed feature	Ⓝ	8.2.2.2.2
Tangent feature	Ⓣ	8.2.2.2.2
Maximum inscribed feature	Ⓧ	8.2.2.2.2
Derived toleranced feature specification elements		
Derived feature	Ⓐ	Clause 6 and 8.2.2.2.3
Projected tolerance zone	Ⓟ	Clause 12 and 8.2.2.2.3
Reference feature association specification elements		
Minimax (Chebyshev) feature without constraint	C	8.2.2.3.1
Minimax (Chebyshev) feature with external material constraint	CE	8.2.2.3.1
Minimax (Chebyshev) feature with internal material constraint	CI	8.2.2.3.1
Least squares (Gaussian) feature without constraint	G	8.2.2.3.1
Least squares (Gaussian) feature with external material constraint	GE	8.2.2.3.1
Least squares (Gaussian) feature with internal material constraint	GI	8.2.2.3.1
Minimum circumscribed feature	N	8.2.2.3.1
Maximum inscribed feature	X	8.2.2.3.1
Parameter specification elements		
Total range of deviations	T	8.2.2.3.2
Peak height	P	8.2.2.3.2
Valley depth	V	8.2.2.3.2
Standard deviation	Q	8.2.2.3.2

For drawing default symbols, see Table 6.

[a] See also ISO 1660, ISO 2692 and ISO 5458.

[b] The letters, values and characteristic symbols in these symbols are examples.

[c] The CZ symbol was called “common zone” in the former version of this document.