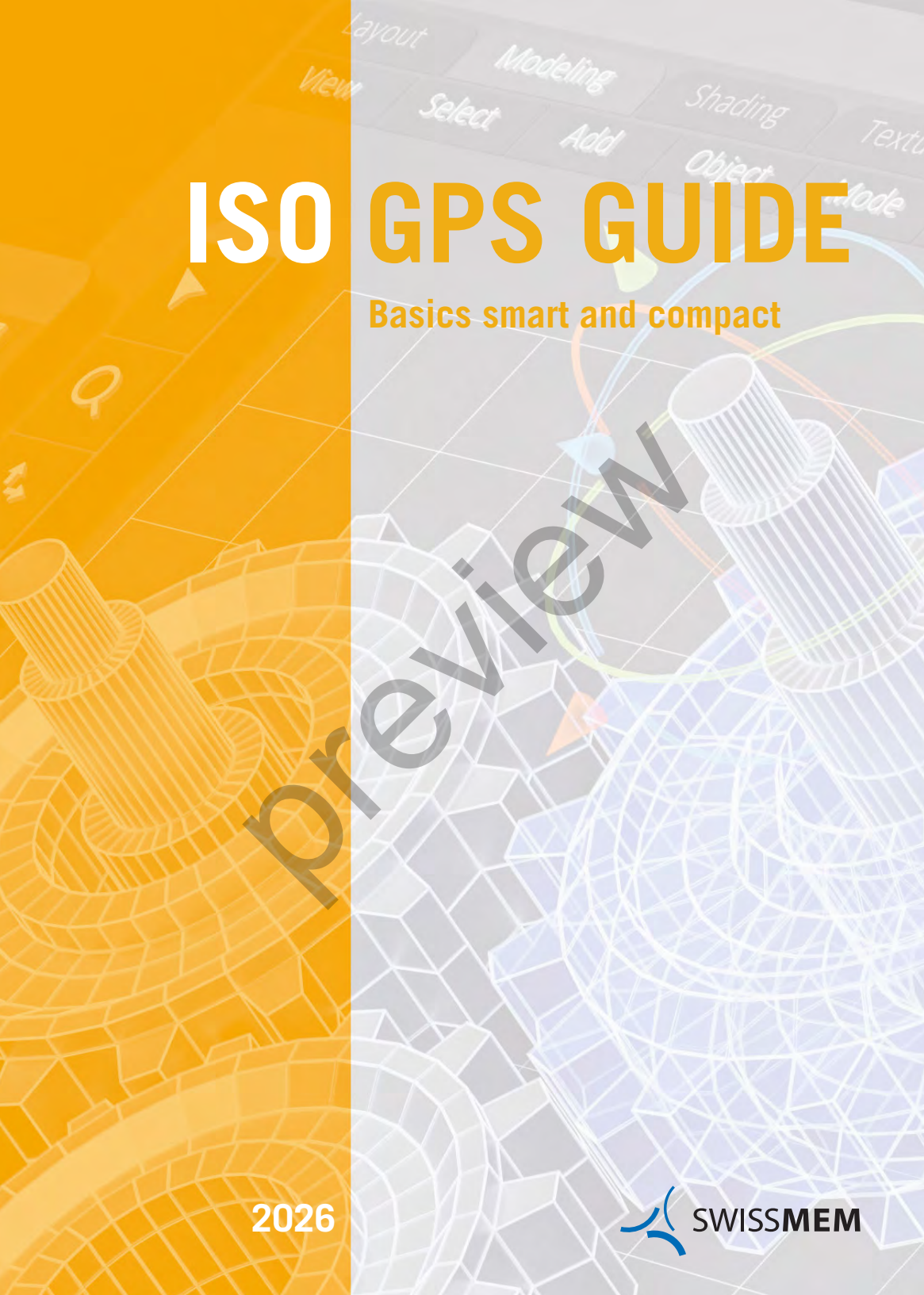

ISO GPS GUIDE

Basics smart and compact

preview

2026

SWISSMEM

Imprint

Publisher:	EDITION SWISSMEM
Titel:	ISO GPS GUIDE Basics smart and compact
Version:	2nd edition 2026
ISBN:	978-3-03866-687-5
Project manager:	Joachim Pérez, Swissmem Vocational Training, 8400 Winterthur, Switzerland
Author:	Willi Tschudi, 8355 Aadorf, Switzerland
Layout and graphic concept:	Daniel Baur, Swissmem Vocational Training, 8400 Winterthur, Switzerland
Subject editor:	Prof. Dr.-Ing. Volker Läpple, Steinbeis-Beratungszentrum Konstruktion, Werkstoffe und Normung, 73614 Schorndorf, Germany www.toleranzen-beratung.de
Printing:	Printed in Switzerland
Source:	Swiss Association for Standardisation (SNV)
Feedback tool:	for suggestions for improvement, corrections or comments https://www.swissmem-berufsbildung.ch/feedback-tool
Purchasing source:	Swissmem Berufsbildung Brühlbergstrasse 4 8400 Winterthur, Switzerland Phone +41 52 260 55 55 Fax +41 52 260 55 59 vertrieb.berufsbildung@swissmem.ch www.swissmem-berufsbildung.ch

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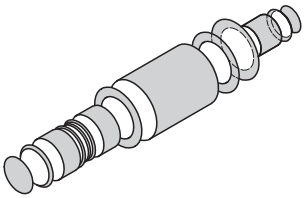
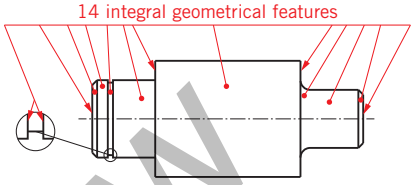
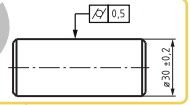
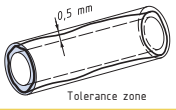
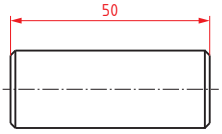
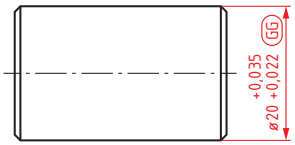
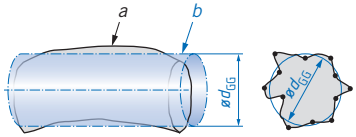
Fundamentals – Concepts, principles and rules

Principles	Contents	Examples
Feature principle	Each workpiece consists of a finite number of features (integral or central). Each GPS specification for a feature or for a relationship between features applies by default to the entire feature and only to a single feature or a single relationship between features.	Grey = integral geometrical features  14 integral geometrical features 
Independency principle	All GPS requirements, such as size, shape, orientation and location, must be fulfilled independently of each other, unless a dependency is established by a standard or by a individual specification (e.g. specification of an group of elements according to ISO 5458 or specification of the envelope requirement according to ISO 14405-1).	**Specification**  **Condition after production (skin model)**  **Verification** Measuring method or measuring equipment depending on the specified tolerance (measurement uncertainty) Cylindricity independent of size  Size independent of the cylindricity 
Decimal principle	Decimal places that are not specified are to be interpreted as zeros.	50 ≙ 50,000 … 

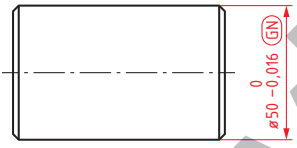
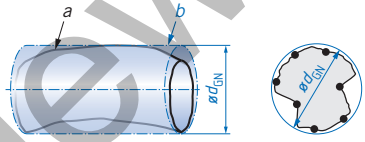
preview

Linear sizes

Size characteristics and modifiers for linear sizes

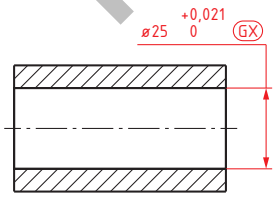
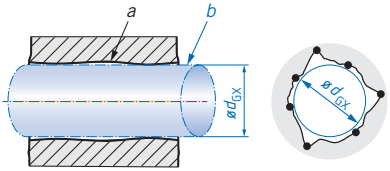
Indication	Specification (examples)	Interpretation
Least-square size Ⓖ Ⓖ	Cylinder 	 20.022 mm ˆ ød_{GG} ˆ 20.035 mm *a* = Extracted integral surface *b* = Associated ideal cylinder Objective function: Total least-squares method (L_2 or Gaussian) Association constraints: none.

Possible application for total least-squares size: Good reproducibility (“stability”) of measurement results, as outliers generally have little influence on the measurement result. Therefore, among other things, suitable for monitoring the production process.

Minimum circumscribed size Ⓖ Ⓝ	Cylinder 	 49.984 mm ˇ ød_{GN} ˇ 50.0 mm *a* = Extracted integral surface *b* = Smallest circumscribed cylinder (envelope cylinder)

– Possibility of applying the minimum circumscribed size: To ensure a fit function (clearance, transition or interference fit).
– The minimum circumscribed size can be applied to external and internal linear features of size.

Note
The dimensional characteristic does not limit local deviations. Only the linear dimension of the associated feature must be within the specification limits.

Maximum inscribed size Ⓖ Ⓧ	Cylinder 	 25 mm ⋅ ød_{GX} ⋅ 25.021 mm *a* = Extracted integral surface *b* = Maximum inscribed cylinder (pen cylinder)

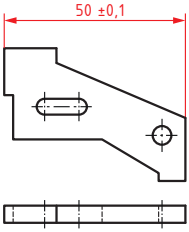
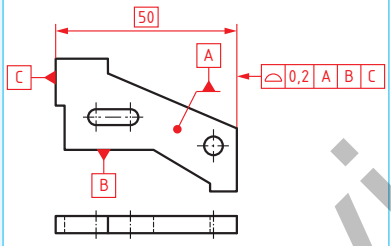
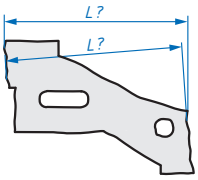
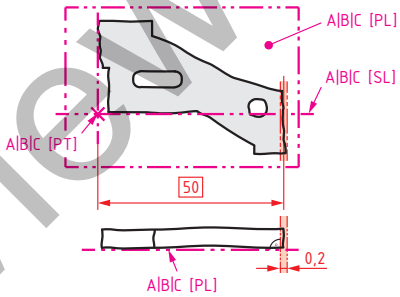
– Possible application of the maximum inscribed size: To ensure a fit function (clearance, transition or interference fits).
– The maximum inscribed size can be applied to external and internal linear features of size.

Note
The dimensional characteristic does not limit local deviations. Only the linear dimension of the associated feature must be within the specification limits.

preview

Dimensions other than linear or angular sizes

Non-sizes

Indication	Specification (examples)	Interpretation
Linear distance between two integral features	Ambiguous  Unambiguous with geometric tolerance 	 The specification (“± tolerancing”) cannot be interpreted as it is ambiguous.  = Tolerance zone AIBIC [PL] = Situation feature plane of datum system AIBIC AIBIC [SL] = Situation feature straight line of datum system AIBIC AIBIC [PT] = Situation feature point of datum system AIBIC For clarity, the associated surfaces are not shown.

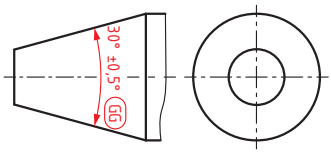
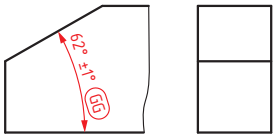
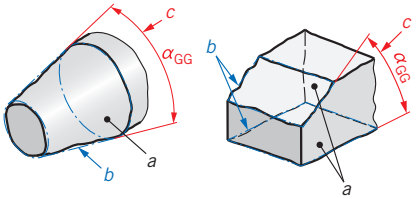
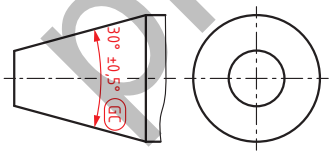
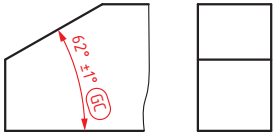
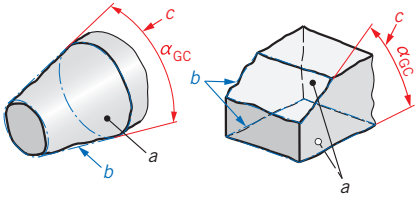
The toleranced, extracted surface must be within the tolerance zone (linear, width 0.2 mm). The tolerance zone is constrained in terms of orientation and location in relation to the situation features of the A|B|C datum system.

Notes

preview

Angular sizes

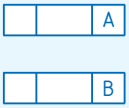
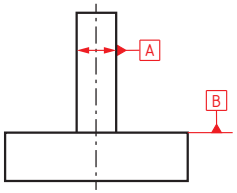
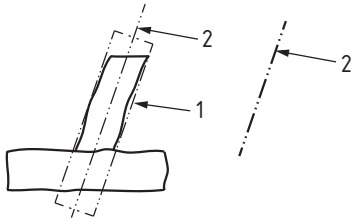
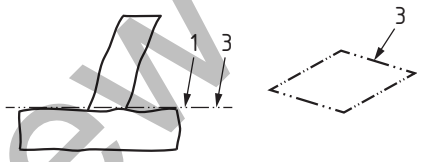
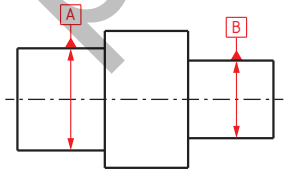
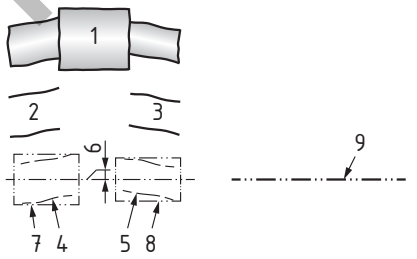
Sizes characteristics and modifiers for angular sizes

Indication	Specification (examples)	Interpretation
Direct global angular size with association criterion of the total least-squares GG	Cone or frustrum  Wedge or truncated wedge 	 The direct global angular size with association criterion of the total least-squares (α_{GG}) must be between 29.5° and 30.5° (cone) or between 61° and 63° in each cross section of the surface (wedge). *a* = Extracted integral surface *b* = Associated ideal cone Objective function: Total least-squares method (L_2 or Gaussian) without material constraint. Cone: The cone angle is variable (not explicitly mentioned in ISO 14405-3) Wedge: The two planes are associated independently of each other. *c* = Specified angular dimension characteristic: Direct global angular size with association criterion of the total least-squares
Direct global angular size with minimax association criterion GC	Cone or frustrum  Wedge or truncated wedge 	 The direct global angular size with minimax association criterion (α_{GC}) must be between 29.5° and 30.5° (cone) or between 61° and 63° (wedge). *a* = Extracted integral surface *b* = Associated ideal cone or ideal planes Objective function: Minimax ($L\infty$). Cone: The cone angle is variable. Wedge: The two planes are associated independently of each other. *c* = Specified angular dimension characteristic: Direct global angular size with minimax association criterion

preview

Datums and datum systems

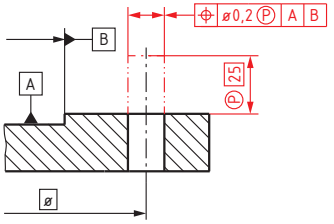
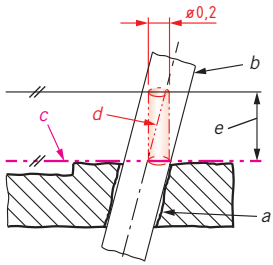
Single datums and common datums

Indication	Specification (examples)	Interpretation
Single datum 		 1 = Associated feature 2 = Reference element A is the axis of the associated cylinder  1 = Associated feature 3 = Reference element B is the associated plane.
Common datum 		 1 = Real workpiece 2 = Datum feature of the collection surface for the common datum 3 = Datum feature of the collection surface for the common datum 4 = Filtered feature of datum feature N° 2 5 = Filtered feature of datum feature N° 3 6 = Orientation constraint and location constraint between the associated features of the collection feature (coaxiality) 7 = Associated feature of datum feature N° 2 respecting constraint 6 8 = Associated feature of datum feature N° 3 respecting constraint 6 9 = Common datum (in this case, the axis of the collection surface – the two coaxial associated cylinders)

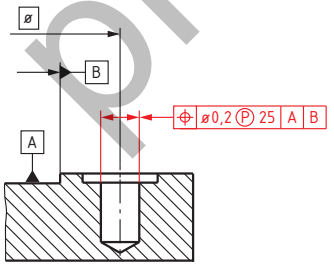
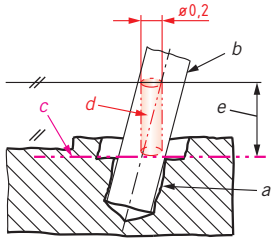
preview

Geometrical tolerancing

Derived toleranced feature specification elements

Indication	Specification (examples)	Interpretation
Projected tolerance zone Ⓟ		 = Tolerance zone *a* = Extracted integral surface *b* = Extended feature *c* = Datum plane *d* = Projected toleranced feature *e* = Length of the projected toleranced feature

Indication of a geometric specification with a projected tolerance modifier, with direct indication of the extension length using TED. The geometric specification is measured above the datum surface (here 25 mm).

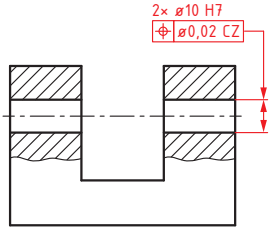
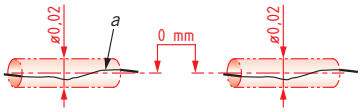
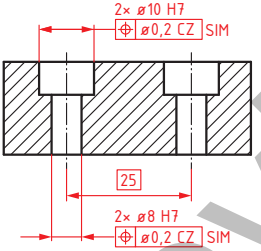
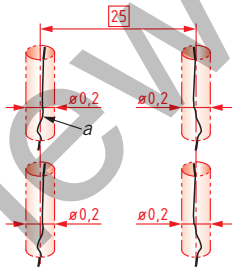
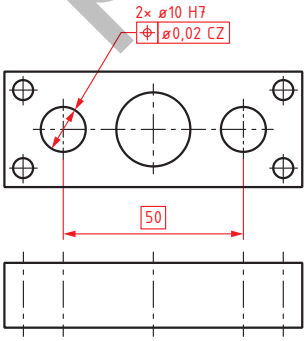
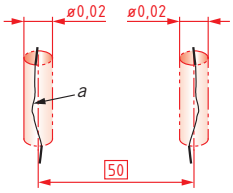
Indication	Specification (examples)	Interpretation
Projected tolerance zone Ⓟ		 = Tolerance zone *a* = Extracted integral surface *b* = Extended feature *c* = Datum plane *d* = Projected toleranced feature *e* = Length of the projected toleranced feature

– Indication of a geometric specification with a projected tolerance modifier relative to a datum plane.
– The datum plane is the first plane that intersects the feature in question. The geometric specification is measured above the datum plane (here, 25 mm). By default, the origin of the projected feature is located at the datum plane. The end corresponds to the displacement of the length of the projected feature from the origin in the direction out of the material.

preview

Positional and pattern tolerancing

Element group specification

Indication	Specification (examples)	Interpretation
Position (several median lines) 		 = Tolerance zones *a* = Extracted median lines Between the situation features (straight lines) of the tolerance zones, there are orientation constraints (0°, or parallelism) and location (0 mm, or coaxiality) defined by the specified continuous line of symmetry.
	 The SIM modifier (simultaneous requirement) converts a group of more than one geometrical specification into a combined specification (element group specification).	 = Tolerance zones *a* = Extracted median lines Between the situation features (straight lines) of the tolerance zones, there are internal orientation constraints (0°, or parallelism) and location (0 mm, or coaxiality) as well as a distance of 25 mm from each other.
		 = Tolerance zones *a* = Extracted median lines Implicit orientation constraint of 0°, or parallelism, and explicit orientation constraints (50 mm).

– By specifying the modifier “CZ”, the tolerance zones form a tolerance zone group and are individual element group specifications.
– Without datum/datum system.

preview

Surface texture: Profile

Symbol for the surface texture

Symbol	Indication	Specification (examples)	Interpretation
Rz	**Minimal indication, e.g. with an Rz-parameter**	Rz 10 ø10 ±0,1 ⌖ ø0,2 A B	a b c Rz 10 *a* = Graphical symbol (material must be removed) *b* = R-parameter: Rz (maximum height) *c* = Numerical limit: 10 µm

For parameters with a defined default (e.g. Rz, Ra, see ISO 21920-3), it is sufficient to specify the minimal indication consisting of the graphical symbol, the symbol for the parameter and the numerical limit (e.g. Rz 10), if all defaults apply.

Rz (Rz)	**Specification of several features with the same requirements**	Rz 25 Rz 10 Rz 25 Rz 40 (Rz) oder Rz 40 (Rz 25 Rz 10)	Surface with maximum height of: — = 40 µm — = 25 µm — = 10 µm

Collective indications for identical surface requirements must be placed close to the title block of the drawing.

Ra old: Ra	**Specification "All around"**	Ra 3,2 Ra 3,2 Ra 3,2 Ra 3,2 Ra 6,3 (Ra)	according to ISO 1302 Ra 3,2 Ra 6,3 (Ra)

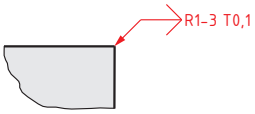
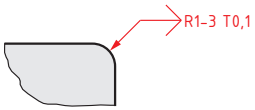
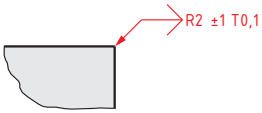
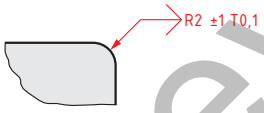
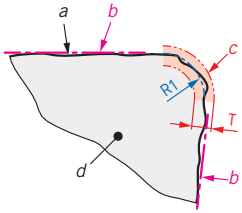
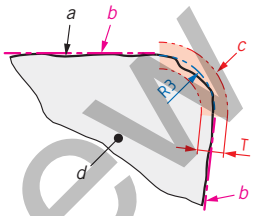
To avoid ambiguity, the graphical symbol for "All around" is no longer defined in ISO 21920-1.

Notes

preview

Specification of transitions

Symbol for transition specifications with indicators

Indication	Specification (examples)	Interpretation
Profile specification with variable radius and tolerance zone 	Simplified (not modelled):  Detailed (modelled):  or:  	Minimum radius:  Maximum radius:  *a* = Real workpiece/skin model *b* = Adjacent reference sections (L_2 norm, outside the material) *c* = Tolerance zone *d* = Material side T = Tolerance value (0.1 mm) for the transition tolerance

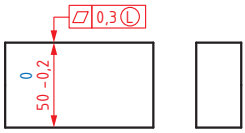
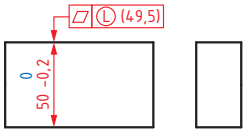
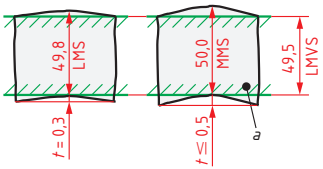
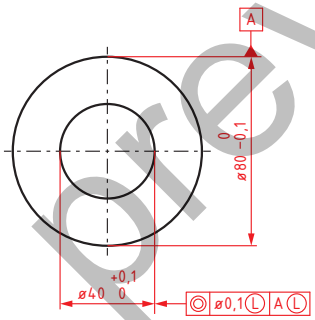
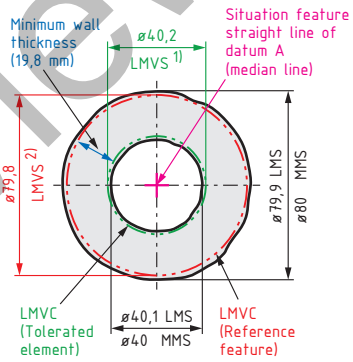
The radius of the nominal profile can be between 1 mm and 3 mm in any cross section with a tolerance zone width of 0.1 mm.

Notes

preview

Maximum material requirement

Modifiers for the material requirements

Indication	Specification (examples)	Interpretation
Minimum material requirement (LMR) Ⓛ	Without direct specification of the LMVS:  With direct specification of the LMVS: 	 *a* = Least material virtual condition LMVC LMVS = Least material virtual size LMVS = LMS – *t* MMS = Maximum material size LMS = Least material size
	Minimum wall thickness: 	 LMVC = Least material virtual condition LMVS = Least material virtual size MMS = Maximum material size LMS = Least material size *t* = Geometric tolerance 1) To internal part (hole) applies: LMVS = LMS + *t* (LMVS = 40.1 + 0.1 = 40.2 mm) 2) To external part (shaft) applies: LMVS = LMS – *t* (LMVS = 79.9 – 0.1 = 79.8 mm)

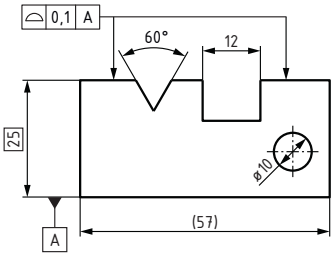
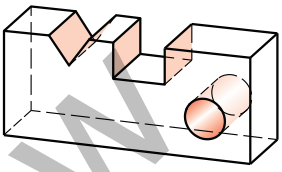
– Minimum material requirement allows a specified geometric tolerance to be exceeded.
– Toleranced feature:
  - The maximum deviation of the coaxiality can be 0.2 mm (if hole ø40.0 (MMS)).
  - The dimensions ø40.1 (LMS) and ø40 (MMS) must be fulfilled.
  - LMVC, which has the dimension ø40.2 (LMVS), must not be exceeded.

– Datum feature:
  - LMVC of the datum feature (shaft) must not exceed the diameter ø79.8 (LMVS).

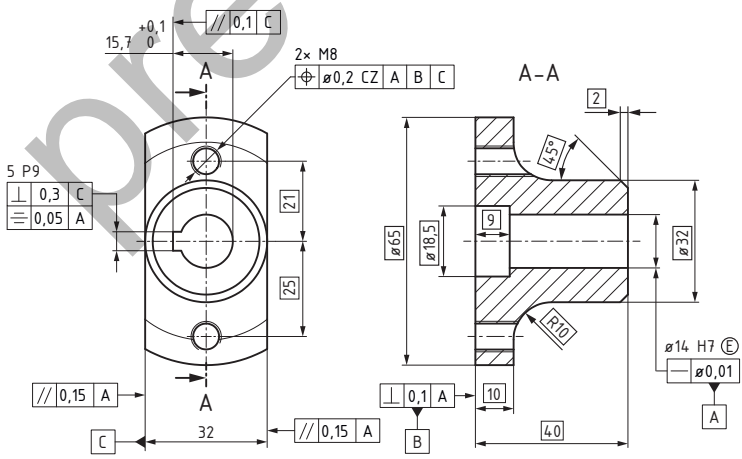
preview

General geometric and size specifications

General dimensional tolerances

Indication	Specification (examples)	Interpretation
ISO 22081 (Dimensional specification)	**General size specifications** The general size specifications apply to each size characteristic that is identified in accordance with one of the following rules: – by a CAD attribute defining the nominal value of the feature of size. – by a size specification that defines the nominal value of the linear size or angular size, which has no individual tolerance, is not a TED and is not an auxiliary dimension.	
General tolerance for size specifications	 General tolerances ISO 22081 Linear size: ±0,2 (E) Angular size: ±0,5° Digital product definition data ISO 16792 Classification code 3 with model 1234.xyz	 General dimensional tolerance only applies to the red surfaces.

The dimensional general tolerance only applies to linear size and angular size specifications (ISO 14405-1 and -3) but not to "Other than non-sizes or angular sizes (ISO 14405-2)".

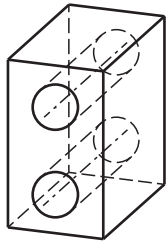
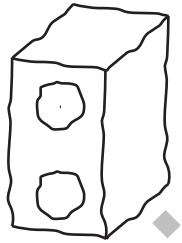
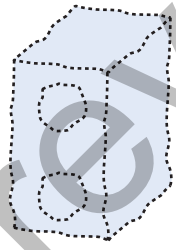
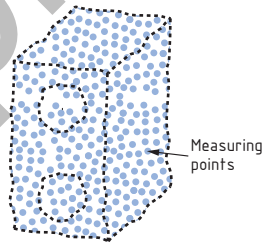
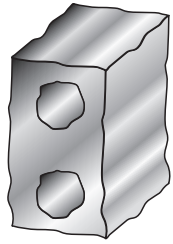
ISO 22081 (Complete specification)	 General tolerances ISO 22081 ⌓ 0,2 A B C Linear size: Tolerance class «m», see also ISO 2768-1:1989

Example of a geometrical and dimensional general tolerance specification with reference to ISO 2768-1 for linear size.

preview

Specification and verification

Surface models according to ISO 22432

Surface model	Illustration	Explanation
Nominal surface model (nominal model)		Surface model with ideal geometry, defined by the technical product specification. Corresponds to the nominal model of the paper drawing or the CAD model (TED values only).
Non-ideal surface model (skin model)		Surface model with non-ideal geometry (virtual model). Deviation of the ideal shape, with dimensional and geometric deviations due to production influences and the product specifications. The designer can use this model to optimise the permissible limiting values of the tolerances that still ensure the function.
Discrete surface model		Surface model, obtained by extraction from the non-ideal surface model (skin model). The discrete surface model is used to express the specification operator and the verification operator, considering a finite number of points
Sampled surface model		Surface model obtained by physically extraction the model of the real workpiece. The measuring points are sampled by measuring devices. In addition to the required points, the verification can imply an interpolation.
Real surface of a workpiece		Real manufactured workpiece.

preview