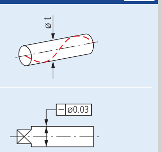
Form and position tolerances
DIN ISO 1101

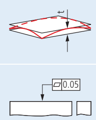
Form tolerances

Straightness —



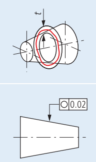
The axis of the cylindrical part of the bolt must be within a diameter of t = 0.03 mm cylinder.

Flatness ⏥



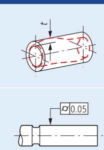
The tolerated surface must be between two parallel planes with a gap of t = 0.05 mm.

Roundness ○



The acquired circumferential line of any cross section must be between two concentric circles with a gap of t = 0.02 mm.

Cylindricity ⌭

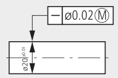


The acquired cylinder shell surface must be between two coaxial cylinders that have a radial distance of t = 0.05 mm.

Drawing notations

Ⓔ Symbol for envelope requirement
Ⓜ Symbol for maximum material requirement
Ⓟ Symbol for projected tolerance zone
Ⓛ Symbol for minimum material requirement

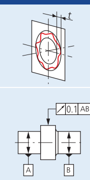
Example:



Maximum material condition (simple case): the maximum material requirement (MMR) permits utilization of unused dimension tolerances through the tolerated form or position tolerance. For example, cylinder diameter dimension tolerance 20 ±0.01 and the axis straightness tolerance t = 0.02. If the actual diameter = 19.99 mm, the straightness of the axis can deviate up to 0.04 mm.

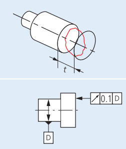
Runout tolerances

Radial runout ↗



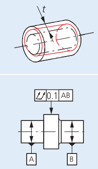
The acquired circumferential line of all cross sections perpendicular to the reference axis AB must be within two concentric circles lying in the same cross section whose radial distance is t = 0.1 mm.

Axial runout ↗



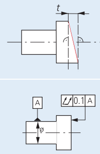
Each acquired profile line, in each radial distance, must be between two parallel planes perpendicular to reference axis D with a distance of t = 0.1 mm.

Total radial runout ⌰



The acquired surface must be within two cylinders lying coaxially to reference axis AB whose radial distance is t = 0.1 mm.

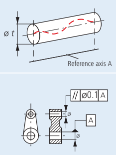
Total axial runout ⌰



The acquired surface must be between two parallel planes perpendicular to reference axis D with a distance of t = 0.1 mm.

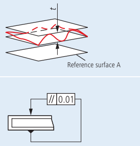
Directional tolerances

Parallelism, axes //



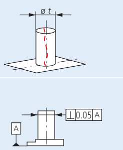
The acquired axis must be within a cylinder lying parallel to reference axis A with a diameter of Ø t = 0.1 mm.

Parallelism, surface //



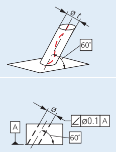
The acquired surface must be between two planes parallel to reference surface A with a gap of t = 0.01 mm.

Perpendicularity ⊥



The acquired axis must be within a cylinder lying perpendicular to reference axis A with a diameter of t = 0.05 mm.

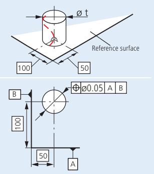
Slope (angularity) ∠



The acquired axis of the borehole must be within a cylinder with a diameter of t = 0.1 mm, which is sloped to reference plane A at the theoretically accurate angle of 60°.

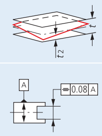
Location tolerances

Position ⌖



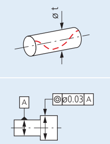
The axis of the borehole must be within a cylinder with a diameter of t = 0.05 mm whose axis is positioned perpendicularly to the reference plane at the geometrically accurate location (with framed dimensions).

Symmetry ⌯



The acquired mid-point of the groove must be between two parallel planes that have a gap of t = 0.08 mm and are symmetrical to the reference mid-plane A.

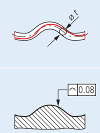
Coaxiality, Concentricity ◎



The acquired actual axis of the tolerated cylinder must be in a cylinder with a diameter of t = 0.03 mm lying coaxially to reference axis A.

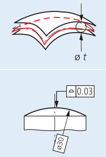
Profile tolerances

Profile of any line ⌒



The acquired profile must be between two minimum circumscribed lines whose distance is limited by circles with a diameter of t = 0.08 mm. The mid-points are located on the geometrically ideal line.

Profile of any surface ⌓



The acquired surface must be between two minimum circumscribed surfaces whose distance is limited by spheres with a diameter of t = 0.03 mm. The mid-points of these spheres are located on the geometrically ideal line.

Form and position toleration – ISO 1101 brief information

1. General

Form tolerances limit the deviation of a single element from its geometrically ideal form.

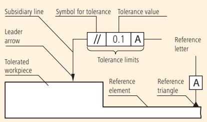
Directional, location and runout tolerances limit the deviations of the mutual position of two or more elements. One or more elements can be specified as reference elements. A reference element should be sufficiently form accurate for its intended use. Therefore, it can be necessary to specify form tolerances for the reference elements.

Unless otherwise specified, the tolerance for the overall expansion of the tolerated element applies. If a limited area is indicated, e.g. 0.02/50 it means that a tolerance of 0.02 mm applies for a length of 50 mm at any location along the tolerated element. When tolerances are specified, the following procedure is recommended:

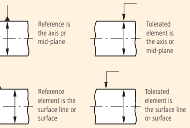
1. Are the general tolerances for form and position deviations (ISO 2768-2) sufficient depending on the production procedure? If no:
2. Specify the feature element
3. Specify the reference (if required)
4. Specify the type of tolerance
5. Form tolerance for reference required?
6. Form tolerance of the tolerated element required?

2. Symbole

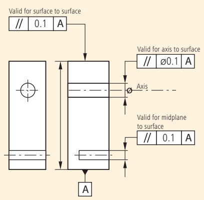
2.1 Identification of the feature element and the reference.



The following possibilities of drawing notations have been defined depending on the drawing requirement for references, reference elements and tolerated elements:



Example of parallelism:



A — A single reference is identified with a capital letter.

A-B — A joint reference created by two references is identified by two reference letters combined by a horizontal line.

A | B | C — If the order of two or more references is important, these reference letters must be placed in different boxes where the order from left to right identifies the hierarchy and must be adhered to during the measurement. (See ISO 5459 "Technical drawings; geometrical tolerancing; datums and datum-systems for geometrical tolerances")

// | 0.01/100 | B — If the tolerance value applies to a limited length at any location of the tolerated element, the value of this length is given after the tolerance value and separated from it through a slash.

// | Ø 0.01 | B — If the Ø symbol precedes the tolerance value, it means that the tolerance zone is a cylinder. Without the Ø symbol, the tolerance only applies in the direction of the leader arrow.

50 — Theoretical dimensions are tolerance-less dimensions that are required for specifying the geometrically ideal (theoretically exact) position and form or the dimensioned element. They are identified through a squared frame.

General tolerances for form and position in accordance with ISO 2768-2

ISO 2768-2 is used to simplify drawings, defines general tolerances in three tolerance classes for form and position.

The selection of a specific tolerance class will take into consideration the respective accuracy common in the workshop.

If narrower tolerances are required for form and position or larger tolerances are more economical, these tolerances must be entered directly in accordance with ISO 1101.

General tolerances for form and position should be applied if the tolerance principle applies in accordance with ISO 8015 or it is entered in the drawing. This tolerance principle states that size, form and position tolerances are not interrelated (principle of independence).

General tolerances for form and position apply for form elements in which the form and position tolerances are not entered individually. They can be applied for all properties of form elements with the exception of the cylinder form, profile of a line or surface, inclination, concentricity, position and total runout.

Tolerance Class	General tolerances for straightness and flatness in mm					
	Nominal size range in mm					
	up to 10	more than 10 to 30	more than 30 to 100	more than 100 to 300	more than 300 to 1000	more than 1000 to 3000
H	0.02	0.05	0.1	0.2	0.3	0.4
K	0.05	0.1	0.2	0.4	0.6	0.8
L	0.1	0.2	0.4	0.8	1.2	1.6

Tolerance Class	General tolerances for perpendicularity			
	Nominal size range in mm			
	up to 100	more than 100 to 300	more than 300 to 1000	more than 1000 to 3000
H	0.2	0.3	0.4	0.5
K	0.4	0.6	0.8	1.0
L	0.6	1.0	1.5	2.0

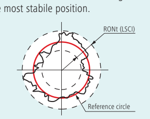
Tolerance Class	General tolerances for symmetry			
	Nominal size range in mm			
	up to 100	more thean 100 to 300	more than 300 to 1000	more than 1000 to 3000
H	0.5			
K	0.6		0.8	1.0
L	0.6	1.0	1.5	2.0

Regardless of the size of the nominal size ranges, the following values are valid for the radial runout and axial runout tolerances: H (0.1 mm), K (0.2 mm) and L (0.5 mm).

Reference circle EN ISO 12181-1, 2

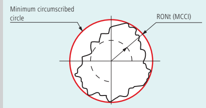
Least squares circle (LSCI)

Compensating circle calculated through the roundness profile. Circle in which the sum of squares of the local roundness deviations is at a minimum. Compared to other circles, the center of this circle has the advantage of having the most stabile position.



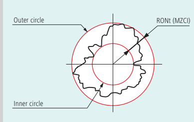
Minimum circumscribed circle (MCCI)

Calculated circle with the smallest possible diameter, which encompasses the roundness profile externally.



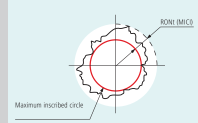
Minimal radial distance (MZCI)

Two calculated concentric circles that encompass the roundness profile with the least possible radial distance.



Maximum inscribed circle (MICI)

Calculated, largest encompassed circle of the roundness profile.



Created in cooperation with Prof. Dr. habil. Eberhard Heldt, Chemnitz

Carl Zeiss
Industrielle Messtechnik GmbH
73446 Oberkochen
Germany
Phone: +49 (0) 7364 20-6336
Fax: +49 (0) 7364 20-3870
Email: imt@zeiss.de
Internet: www.zeiss.de/imt

Carl Zeiss
Industrial Metrology, LLC
6250 Sycamore Lane North
Maple Grove, MN 55369/USA
Phone: +1 763 744-2400
Fax: +1 763 533-0219
Email: metrology@zeiss.com
Internet: www.zeiss.com/metrology

ZEISS
We make it visible.

EN_60_050_0028I Printed in Germany VII/2011 © Carl Zeiss