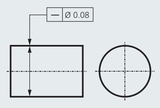
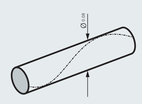
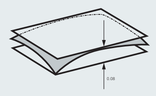
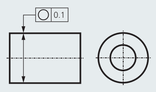
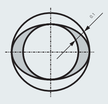
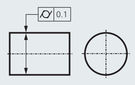
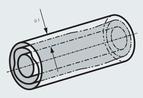
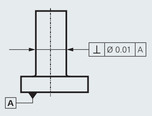
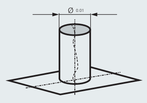
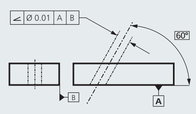
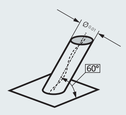
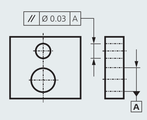
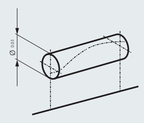
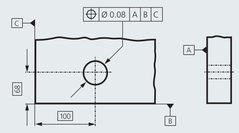
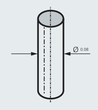
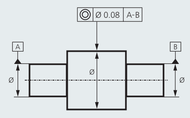
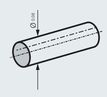
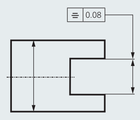
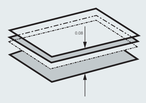
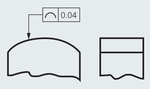
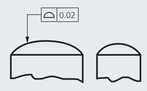
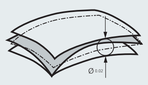
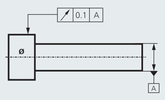
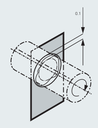
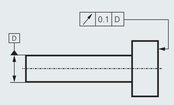
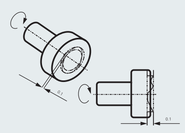
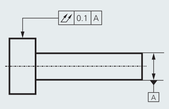
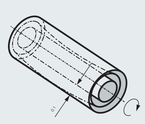
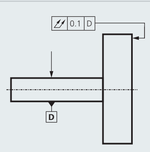
Geometric Dimensioning and Tolerancing

Seeing beyond

Terms and drawing specifications

Symbol and Tolerated Properties		Drawing Specification and Explanation			
		Drawing Specification	Tolerance Zone		Explanation
Form Tolerances					
	Straightness				The extracted median line (extracted axis) of the cylinder connected to the feature control frame shall be contained within a cylindrical tolerance zone with a diameter of 0.08.
	Flatness				The extracted surface shall be contained between two parallel planes 0.08 apart.
	Roundness				The extracted circumferential line of each cross-section of the cylinder lateral surface shall be contained between two concentric circles in the same plane at a distance of 0.1.
	Cylindricity				The extracted cylinder lateral surface shall be contained between two coaxial cylinders with a radial distance of 0.1.
Position and Orientation Tolerances					
Orientation Tolerances	Perpendicularity of a line (axis) to a surface				The extracted median line (extracted axis) shall be contained within a cylinder of diameter 0.01, perpendicular to the datum plane A.
	Angularity of a line (axis) to a datum surface				The extracted median line (extracted axis) shall be contained within a cylinder of diameter 0.01, which is inclined at a theoretically exact angle of 60° to the datum plane A.
	Parallelism of a line (axis) to a datum line				The extracted median line (extracted axis) shall be contained within a cylinder of diameter 0.03, which is parallel to the datum straight line A.
Location Tolerances	Position of a line				The extracted median line (extracted axis) shall be contained within a cylindrical tolerance zone with a diameter of 0.08, whose axis is perpendicular to datum plane A, at a distance of 68 to datum plane B and at a distance of 100 to datum plane C (theoretically exact location of the bore axis).
	Coaxiality of an axis				The extracted median line (extracted axis) of the cylinder connected to the feature control frame shall be contained within a cylinder of diameter 0.08 that is coaxial to the common datum axis A-B.
	Symmetry of a median plane				The extracted median surface shall be contained between two parallel planes 0.08 apart, which are symmetrical to the datum median plane.
Profile Tolerances	Profile form of any line				In each section, parallel to the projection plane, the extracted profile line shall be contained between two equidistant lines enveloping circles with a diameter of 0.04, the centers of which are situated on a line having the ideal geometrical form.
	Profile form of any surface				The extracted surface shall be contained between two equidistant surfaces enveloping spheres with a diameter of 0.02, the centers of which are situated on a surface having the ideal geometrical form.
Run-Out Tolerances	Circular run-out (radial)				The extracted circumferential line, which is perpendicular to the datum straight line A in each cross-section, shall be contained between two concentric circles with a radial distance of 0.1 in the same plane.
	Circular run-out (axial)				In each cylindrical section, whose axis coincides with the datum axis D, the extracted line shall be contained between two circles of distance 0.1 arranged perpendicular to datum axis D.
	Total run-out (radial)				The extracted surface shall be contained between two coaxial cylinders with a radial distance of 0.1, whose axes coincide with the datum straight line A.
	Total run-out (axial)				The extracted surface shall be contained between two parallel planes 0.1 apart, perpendicular to the datum straight line D.

Extract from DIN ISO 1101, dimensions in mm

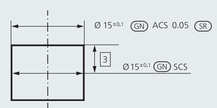
Geometrical Product Specifications

Seeing beyond

Terms and drawing specifications

Sizes and Modifiers

Sizes are dimensions of enclosed geometric elements, e.g. diameters of cylinders and circles or distances between parallel surfaces. Here the type of metrological evaluation can be determined by specifying modifiers.



LP **Local Point:** Evaluation of the measuring points as two-point size (relative to the Gaussian circle center)

GX **Global Maximum:** Evaluation of the measuring points as maximum inscribed circle/maximum inscribed cylinder (MICI/MICY).

GN **Global Minimum:** Evaluation of the measuring points as minimum circumscribed circle/minimum circumscribed cylinder (MCCI /MCCY).

GC **Global Chebychev:** Evaluation of the measuring points in accordance with the Chebyshev minimum method (MZCI/MZCY).

GG **Global Gauss:** Evaluation of the measuring points as Gaussian best-fit (LPCI/LPCY).

To supplement the modifiers, so-called rank-order sizes can be entered:

SX **Statistical Maximum:** The largest of the measured values

SN **Statistical Minimum:** The smallest of the measured values

SA **Statistical Average:** The average of the measured values

SM **Statistical Median:** The median of the measured values

SR **Statistical Range:** The range of the measured values

SD **Statistical Mid-Range:** The average of SX and SN

Additional information provide directions for the measurement and analysis:

ACS **Any Cross Section:** Inspection in any (possible) circular section

SCS **Specific Cross Section:** Inspection only in the cross section (usually specified by means of a theoretical dimension)

ALS **Any Longitudinal Section:** Inspection in any (possible) longitudinal section

CZ **Common Zone:** Joint inspection of the features in a common tolerance zone

TED **Theoretically Exact Dimension:** Theoretical dimension without tolerance for specifying the ideal location, e.g. [25] or [60°]

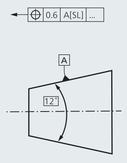
Datum and Tolerance Direction Restrictions

Datum elements can also be restricted as regards their characteristics and effective direction:

>< Datum element only acts as direction element. The location coordinates are not taken into account.

[PL] **Plane:** Datum element acts as plane only. Other parameters of the datum element (e.g. zero-point coordinates) are not taken into account.

[SL] **Straight Line:** Datum element acts as straight line only. Other parameters of the datum element (e.g. zero-point coordinates) are not taken into account.



[PT] **Point:** Datum element acts as point only. Other parameters of the datum element (e.g. orientation specifications) are not taken into account.

Orientation Plane Indicator: The tolerance is to be checked in orientation B only. In the example on the right, the parallelism is to be checked parallel to datum B only.

Section Plane Indicator: The tolerance is to be checked in section plane B only. For example, the straightness is to be checked perpendicular to B only.

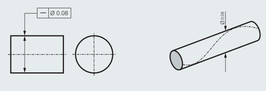
A↔B **Tolerance Zone Limit:** The tolerance must only be checked in the area between A and B.

t/... **Tolerance Zone Limit:** The tolerance must be limited to value 0.5 (in the example on the right) in each segment with length 100.

A→B **Variable Tolerance Zone:** The tolerance width linearly changes from 0.3 mm (at A) to 0.5 mm (at B).

Circumferential Zone: The tolerance applies for all line and surface elements surrounding the entire workpiece in the viewing plane.

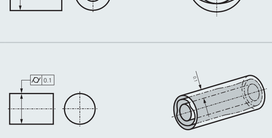
Geometric Dimensioning and Tolerancing



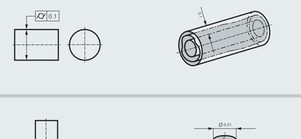
– The extracted median line (extracted axis) of the cylinder connected to the feature control frame shall be contained within a cylindrical tolerance zone with a diameter of 0.08.

▱ The extracted surface shall be contained between two parallel planes 0.08 apart.

○ The extracted circumferential line of each cross-section of the cylinder lateral surface shall be contained between two concentric circles in the same plane at a distance of 0.1.

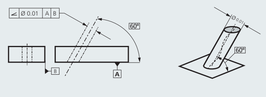


⌭ The extracted cylinder lateral surface shall be contained between two coaxial cylinders with a radial distance of 0.1.

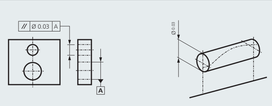


⊥ The extracted median line (extracted axis) shall be contained within a cylinder of diameter 0.01, perpendicular to the datum plane A.

∠ The extracted median line (extracted axis) shall be contained within a cylinder of diameter 0.01, which is inclined at a theoretically exact angle of 60° to the datum plane A.



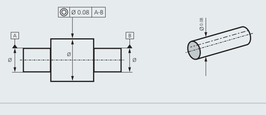
// The extracted median line (extracted axis) shall be contained within a cylinder of diameter 0.03, which is parallel to the datum straight line A.



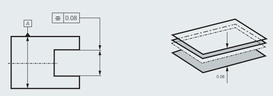
⌖ The extracted median line (extracted axis) shall be within a cylindrical tolerance zone with a diameter of 0.08, whose axis is perpendicular to datum plane A, at a distance of 68 to datum plane B and a distance of 100 to datum plane C (theoretical exact location of the bore axis).

◎ The extracted median line (extracted axis) of the cylinder connected to the feature control frame shall be contained within a cylinder of diameter 0.08 that is coaxial to the common datum straight lines A-B.

⌯ The extracted median surface shall be contained between two parallel planes 0.08 apart, which are symmetrical to the datum median plane.



⌒ In each section parallel to the projection plane for which the specification has been entered, the extracted profile line shall be contained between two equidistant lines enveloping circles with a diameter of 0.04, the centers of which are situated on a line having the ideal geometrical form.

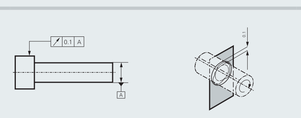


⌓ The extracted surface shall be contained between two equidistant surfaces enveloping spheres with a diameter of 0.02, the centers of which are situated on a surface having the ideal geometrical form.

↗ The extracted circumferential line, which is perpendicular to the datum straight line A in each cross-section, shall be contained between two concentric circles with a radial distance of 0.1 in the same plane.

↗ In each cylindrical section, whose axis coincides with the datum axis D, the extracted line shall be contained between two circles of distance 0.1 arranged perpendicular to datum axis D.

↗ The extracted surface shall be contained between two coaxial cylinders with a radial distance of 0.1, whose axes coincide with the datum straight line A.



↗ The extracted surface shall be contained between two parallel planes 0.1 apart, perpendicular to the datum straight line D.

Important ISO Standards for GPS

DIN EN ISO 1101	GPS – Tolerances of form, orientation, location and run-out
DIN EN ISO 5458	GPS – Pattern and combined geometrical specification
DIN EN ISO 5459	GPS – Datums and datum systems
DIN EN ISO 8015	GPS – Geometrical tolerancing – Maximum material requirement (MMR), least material requirement (LMR) and reciprocity requirement (RPR)
DIN EN ISO 2692	GPS – Geometrical tolerancing – Maximum material requirement (MMR), least material requirement (LMR) and reciprocity requirement (RPR)
DIN EN ISO 10579	GPS – Dimensioning and tolerancing - non-rigid parts
DIN EN ISO 12180	GPS – Cylindricity
DIN EN ISO 12181	GPS – Roundness
DIN EN ISO 12780	GPS – Straightness
DIN EN ISO 12781	GPS – Flatness
DIN EN ISO 14405 -1	GPS – Dimensional tolerancing – Part 1: Linear sizes
DIN EN ISO 14405 -2	GPS – Dimensional tolerancing – Part 2: Dimensions other than linear or angular sizes
DIN EN ISO 14405 -3	GPS – Dimensional tolerancing – Part 3: Angular sizes

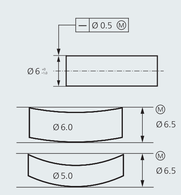
AD If another standard or factory standard becomes applicable for a technical drawing in addition to the GPS standards (or even in place thereof), this can be specified in the feature control frame with the addition "AD Name of own standard."

Additional Drawing Specifications

In the feature control frame, additional letters, usually in circles, can in many cases be entered in addition to the tolerance value (and in part also in the reference fields).

M **Maximum Material Requirement:** When the element contains the maximum amount of material, the tolerance specified in the feature control frame applies. Thus the function is fulfilled even in the worst-case combination (largest possible shaft mating with smallest possible bore). The maximum material requirement corresponds to a virtual gauge.

The size of the gauge for a shaft is computed as follows:
Ø6 + Upper Tolerance Limit + Form/Location Tolerance = Gauge Diameter.
For a bore, the following applies:
Ø6 – Lower Tolerance Limit – Form/Location Tolerance = Gauge Diameter



L **Least Material Requirement:** The least material requirement is applied when remaining material thicknesses are checked. When the element contains the minimum amount of material, the tolerance specified in the feature control frame applies. The minimum material requirement corresponds to a virtual gauge in the material.

The size of the gauge for a shaft is computed as follows:
Ø6 – Lower Tolerance Limit – Form/Location Tolerance = Gauge Diameter.
For a bore, the following applies:
Ø6 + Upper Tolerance Limit + Form/Location Tolerance = Gauge Diameter

R **Reciprocity Requirement:** The reciprocity requirement permits an increase in the size tolerance possible if the geometric deviation of the workpiece allows it.
Can only be used in combination with Ⓜ or Ⓛ.

E **Envelope Condition:** According to DIN EN ISO 8015, dimension tolerances and form and location tolerances must always be viewed as being independent from each other. The independence principle applies by default. The geometric element is checked using a two-point size inspection.

Entering Ⓔ at the size tolerance results in an exception from the default being required. The geometric element has to be checked with a minimum circumscribed element and a two-point size. This corresponds to Taylor's gauging principle.

A **Axis as Toleranced Element:** To clarify that it is not the surface, but instead the axis or middle plane (middle straight), Ⓐ can be entered into the drawing (required in 3D drawings).

F **Free State:** The (elastic or plastic, non-rigid) workpiece has to be tested in an unrestrained state (shaped only by gravity).

UZ **Unequally Disposed Tolerance Zone (for Profile Tolerances):** Here the tolerance zone is offset outward from the material center by value 0,15 (in the example on the right, the zone is completely outside of the material).

P **Projected Tolerance Zone:** The tolerance zone is offset by value 25 and lies completely outside the workpiece, e.g. to check relevant positions for later assembly.

Tolerance Specifications for Associations and Filters

In the feature control frame, specifications can also be made regarding the association (calculated fit) of the elements and for filtering, e.g.
[/ 0.1 Ⓜ A] or [○ 0.1 S50-150] or [○ 0.1 F3]. The following applies:

X **Maximum Inscribed Element:** The toleranced and measured element must be evaluated as a maximum inscribed circle/maximum inscribed cylinder (MICI /MICY).

N **Minimum Circumscribed Circle:** The toleranced and measured element must be evaluated as a minimum circumscribed circle/minimum circumscribed cylinder (MCCI /MCCY).

G **Gaussian Element:** The toleranced and measured element must be evaluated as a Gaussian best fit (LPCI/LPCY).

C **Minimum Element:** The toleranced and measured element must be evaluated in accordance with the Chebyshev minimum method (MZCI /MZCY).

T **Tangential Element:** The toleranced and measured element must be evaluated as tangential element (in accordance with the Chebyshev minimum method) (OTPL).

G **Gaussian Filtering:** The standard Gaussian filter must be used as digital filter. The specification "G50" means a low-pass filter with 50 waves per rotation. "G50-150" would be a bandpass filter.

S **Spline Filtering:** The spline filter must be used as digital filter. The specification "S50" indicates a low-pass filter, "S50-150" indicates a bandpass filter with 50–150 waves per rotation.

F **Fourier Analysis:** The evaluation is performed by means of a Fourier analysis. Here "F3" restricts the analysis to the 3rd harmonic oscillation (shape of constant width).

Auszug aus DIN ISO 1101, Maße in mm