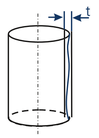
# Precise form measurement

## Geometrical tolerancing in practice

HOMMEL ETAMIC

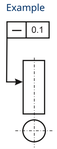
## Form tolerances according to ISO 1101

### Straightness



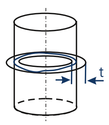

The tolerance zone is limited by two parallel lines at a distance ***t*** apart. Every envelope line of the toleranced cylinder must be between these two parallel lines.

Example



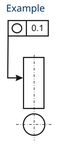

Every envelope line of the toleranced cylinder surface must be between two parallel lines at a distance apart of 0.1.

### Roundness



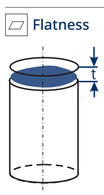

The tolerance zone is limited by two concentric circles at a distance ***t*** apart. The circumference line of the toleranced cylinder must be within a circle ring of the zone width ***t***, in every radial section plane.

Example




The circumference line of the toleranced cylinder must be within a circle ring of the zone width 0.1 in every radial section plane.

### Flatness

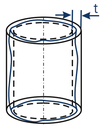



The tolerance zone is limited by two parallel planes at a distance ***t*** apart, the dimensions of which correspond to those of the toleranced area. The real workpiece area must be between the two parallel planes at distance ***t*** apart.

Example

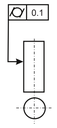

The real workpiece area must be between two parallel planes at a distance apart of 0.2.

### Cylindricity




The tolerance zone for the cylinder envelope area limits the deviation of the roundness, the straightness of the envelope line and the parallelism of the envelope line to the cylinder axis. It is formed by two coaxial cylinders with the radial distance ***t***.

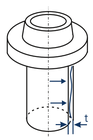
Example




The toleranced cylindrical area must be between two coaxial cylinders with a radial distance of 0.1.

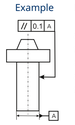
## Position tolerances according to ISO 1101

### Parallelism



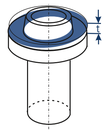

The tolerance zone within which the envelope lines of the toleranced cylinder must lie is limited by two parallel lines at a distance ***t*** apart which run parallel to the datum plane.

Example



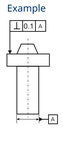

Every single envelope line of the toleranced area must be between two parallel lines that are at a distance of 0.1 apart, and are parallel to the center axis.

### Perpendicularity



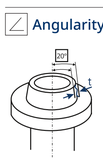

The tolerance zone is limited by two parallel planes at a distance ***t*** apart, which are perpendicular to the datum axis. The toleranced plane face must be between these two planes.

Example



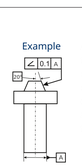

All points/circle lines of the toleranced area must be between two parallel planes that are at a distance of 0.1 apart, and are perpendicular to the datum plane.

### Angularity



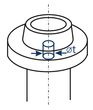

The tolerance zone is limited by two parallel planes at a distance ***t*** apart at the nominal angle to the datum axis.

Example



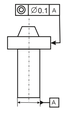

All points of the toleranced area must be between two parallel planes that are at a distance apart of 0.1, and are angled at 20° to the datum axis.

### Coaxiality




The tolerance zone is limited by a cylinder of diameter ***t***, the axis of which matches the datum axis. The actual axis of the toleranced element must be within the tolerance zone.

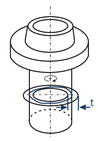
Example




The axis of the toleranced cylinder must be within a cylinder that has a diameter of 0.1 and is coaxial to the datum axis A.

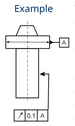
## Run-out tolerances according to ISO 1101

### Radial run-out



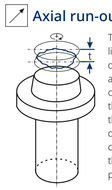

In every radial section plane perpendicular to the surface, the tolerance zone is limited by two concentric circles at a distance ***t*** apart, the common center point of which is on the datum axis. The radial run-out tolerance applies generally for a full revolution of the toleranced element around the datum axis.

Example



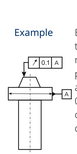

The circumference line of every radial section plane of the toleranced cylindrical area must be between two concentric circles at a distance apart of 0.1 with their common center point on the datum axis A.

### Axial run-out



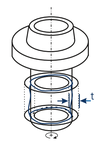

The tolerance zone is limited in every radial distance of two circles at a distance ***t*** apart. The circles are in a cylinder, the axis of which matches the datum axis. The diameter of the cylinder can adopt any value of the diameter of the plane face.

Example



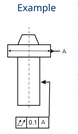

Every circle line of the toleranced area must be between two parallel circle planes at a distance apart of 0.1 with their common center point on the datum axis A.

### Total radial run-out



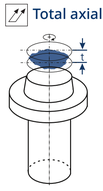

The tolerance zone is limited by two coaxial cylinders at a distance ***t*** apart, the axes of which match the datum axis. After several rotations around the datum axis and axial shift of the transducer all points of the toleranced element must be within the tolerance zone.

Example



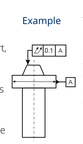

The toleranced cylindrical area must be between two coaxial cylinders with a radial distance apart of 0.1 with their common axis on the datum axis.

### Total axial run-out




The tolerance zone is limited by two parallel planes at a distance ***t*** apart, which are perpendicular to the datum (rotational) axis. After several rotations around the datum axis and radial shift of the transducer, all points of the surface of the tolerance plane face must be within the tolerance zone.

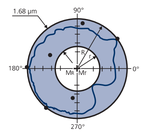
Example




The toleranced area must be between two parallel circle planes at a distance apart of 0.1 with their common center point on the datum axis A.

## Evaluation method

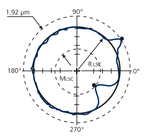
Effect and function of different evaluation methods on the roundness evaluation.




**MZCI**
**Minimum Zone Circle**

Concentric inner and outer perimeter circles with a minimum radial distance, and which enclose the roundness profile.

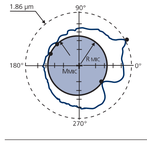
Individual profile peaks influence the center point **considerably.** This method gives the least possible form error.




**LSCI**
**Least Square Circle**

Circle through the roundness profile with minimum sum of profile deviation squares.

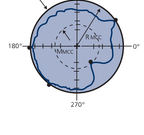
Individual profile peaks influence the center point **only a little.** This method is very suitable for stable datum formation.




**MICI**
**Maximum Inscribed Circle**

Maximum circle inscribed in the roundness profile for inside areas.

The method is used for form measurement of the inside diameter.



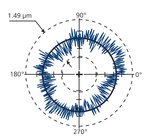

**MCCI**
**Minimum Circumscribed Circle**

Minimum circle circumscribing the roundness profile for outside areas.

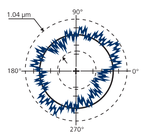
The method is used for form measurement of the outside diameter.

## Filter stages

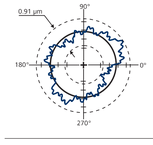
Filter effect of different cut-off numbers on the roundness result. Gauss filter 50 %.



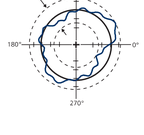

**No filter**
1.49 µm
RONt (MZCI) = 1.49 µm




**Filter 150 W/R**
1.04 µm
RONt (MZCI) = 1.04 µm




**Filter 50 W/R**
0.91 µm
RONt (MZCI) = 0.91 µm




**Filter 15 W/R**
0.71 µm
RONt (MZCI) = 0.71 µm

## General tolerances according to ISO 2768 part 2

### Tolerance class H

| Nominal dimensional range | ...10 | > 10 ...30 | > 30 ...100 | > 100 ...300 | > 300 ...1000 | > 1000 ...3000 |
|---|---|---|---|---|---|---|
| ⏤ ▱ | 0.02 | 0.05 | 0.1 | 0.2 | 0.3 | 0.4 |
| ⊥ | 0.2 | | | 0.3 | 0.4 | 0.5 |
| ⌯ | 0.5 | | | | | |
| ∠ | 0.1 | | | | | |

### Tolerance class K

| Nominal dimensional range | ...10 | > 10 ...30 | > 30 ...100 | > 100 ...300 | > 300 ...1000 | > 1000 ...3000 |
|---|---|---|---|---|---|---|
| ⏤ ▱ | 0.05 | 0.1 | 0.2 | 0.4 | 0.6 | 0.8 |
| ⊥ | 0.4 | | | 0.6 | 0.8 | 1.0 |
| ⌯ | 0.6 | | | | 0.8 | 1.0 |
| ∠ | 0.2 | | | | | |

### Tolerance class L

| Nominal dimensional range | ...10 | > 10 ...30 | > 30 ...100 | > 100 ...300 | > 300 ...1000 | > 1000 ...3000 |
|---|---|---|---|---|---|---|
| ⏤ ▱ | 0.1 | 0.2 | 0.4 | 0.8 | 1.2 | 1.6 |
| ⊥ | 0.6 | | | 1.0 | 1.5 | 2.0 |
| ⌯ | 0.6 | | | 1.0 | 1.5 | 2.0 |
| ∠ | 0.5 | | | | | |

For workpieces produced by cutting

All dimensions in mm

○ Tolerance value corresponds to the diameter tolerance or maximum general tolerance for the radial run-out.

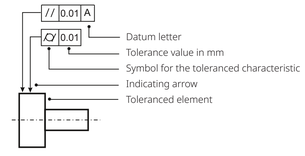
// Tolerance value corresponds to the maximum value in comparison of the dimension tolerance of the distance dimension with the general tolerance for the straightness or the flatness of the form elements being inspected.

## Standards of practical relevance

| | |
|---|---|
| ISO 1101 | Geometrical Product Specifications (GPS) – Geometrical tolerancing – Tolerances of form, orientation, location and run-out |
| ISO 12180-1 | Geometrical Product Specifications (GPS), Cylindricity – Part 1 Vocabulary and parameters of cylindricity |
| ISO 12181-1 | Geometrical Product Specifications (GPS), Roundness – Part 1 Vocabulary and parameters of roundness |
| ISO 12780-1 | Geometrical Product Specifications (GPS), Straightness – Part 1 Vocabulary and parameters of straightness |
| ISO 12781-1 | Geometrical Product Specifications (GPS), Flatness – Part 1 Vocabulary and parameters of flatness |
| VDI/VDE 2631 Sheet 1 | Form measurement – Basic principals of the determination of form and positional deviations |
| VDI/VDE 2631 Sheet 2 | Form measurement – Determination of the sensitivity of the signal transmittal chain |
| VDI/VDE 2631 Sheet 3 | Form measurement – Filter characteristics and selection |

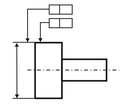
## Drawing entries

### Tolerance frame

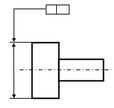



### Toleranced elements

Indicating arrow to contour line or subsidiary line (offset from dimension line): if the tolerance refers to the line or area.



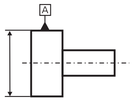
Indicating arrow as an extension of the dimension line: if the tolerance applies for the axis or median plane or a point of the element.



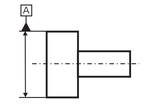
### Datums

Datum triangle with datum letters

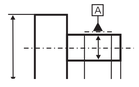
on the contour line of the element or on the subsidiary line: if the displayed datum is a line or area.



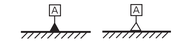

as an extension of the dimension line: if the datum is the axis, the median plane or an appropriately dimensioned point.




Restriction of the datum to an area of the element as a dot-dash line with dimensioning.




A filled in or empty datum triangle has the same meaning.



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