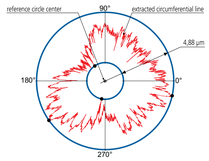
ASSESSING ROUNDFORM GEOMETRICAL DEVIATIONS

Defining roundness

Deviation from perfect roundness is defined by the difference in radii of two coplanar and concentric reference circles whose sizes and center position are constructed by one of four methods (described below) after the circumferential line has been extracted. The diagrams show how the deviation value obtained is affected by the method used.

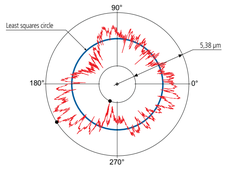
Minimum Zone Circle (MZC)

The size and position of two concentric circles that touch and together enclose the extracted circumferential line are adjusted until their radial difference is a minimum.



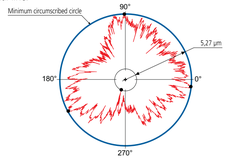
Least Squares Circle (LSC)

The size and position of a circle from which the sum of the squares of the radial deviations of the extracted circumferential line are a minimum is constructed. Two concentric circles coaxial with this circle are then constructed that touch and together enclose the extracted circumferential line.



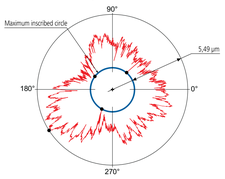
Minimum Circumscribed Circle (MCC)

A circumscribing circle of the minimum size to touch and enclose the extracted circumferential line is constructed. A second circle concentric with the first is then constructed to touch and, together with the first circle, enclose the extracted circumferential line.

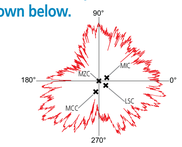


Maximum Inscribed Circle (MIC)

An inscribing circle of the maximum size to touch the extracted circumferential line is constructed. A second circle concentric with the first is then constructed to touch and, together with the first circle, enclose the extracted circumferential line.



The position of the center of the concentric circles defines the center of the extracted circumferential line and therefore the location of the circular feature measured. Each of the methods described above results in different center positions for the reference circles, as shown below.



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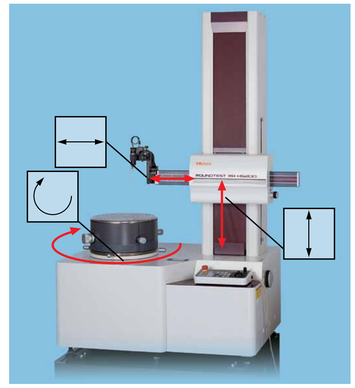
Characteristic Symbol*	Definition	Geometrical Tolerancing*	Test Method	Result	Permissible Machine Movements
○	**Roundness** Roundness deviation is the difference in radii between two concentric circles constructed to touch and enclose the extracted circumferential line. A feature is toleranced by limiting the deviation to a value t.	○ t			↻ ✗ ✗
—	**Straightness** Straightness deviation is the distance between two parallel lines constructed to touch and enclose the extracted straight line with minimum separation. A feature is toleranced by limiting the deviation to a value t.	— t			✗ ↕ ✗
▱	**Flatness** Flatness deviation is the distance between two parallel planes constructed to touch and enclose the extracted plane surface with minimum separation. A feature is toleranced by limiting the deviation to a value t.	⏥ t			↻ ✗ ✗
⌭	**Cylindricity** Cylindricity deviation is the difference in radii between two coaxial cylinders constructed to touch and enclose the extracted cylindrical surface with minimum separation. A feature is toleranced by limiting the deviation to a value t.	⌭ t			↻ ↕ ✗
◎	**Coaxiality** Coaxiality deviation is the maximum radial distance between the extracted cylindrical surface axis and the datum axis over the length of the evaluation range. A feature is toleranced by limiting the deviation to a value t/2.	⌀ ⌀t A A			↻ ↕ ↔
◎	**Concentricity** Concentricity deviation is the maximum radial distance between the extracted circumferential line center and the datum element center in a circular cross section. A feature is toleranced by limiting the deviation to a value t/2.	⌀ ⌀t A A			↻ ↕ ↔
//	**Parallelism (Plane to Plane)** Plane-to-Plane Parallelism deviation is the maximum difference in distance between the extracted plane surface and the datum plane. A feature is toleranced by limiting the deviation to a value t.	// t A A			↻ ↕ ↔
⊥	**Perpendicularity (Plane to Axis)** Plane-to-Axis Perpendicularity deviation is the maximum difference in distance between the extracted plane surface and a plane perpendicular to the datum axis. A feature is toleranced by limiting the deviation to a value t.	A ⌀ ⊥ t A			↻ ↕ ↔
⊥	**Perpendicularity (Axis to Plane)** Axis-to-Plane Perpendicularity deviation is the maximum difference in distance between the extracted axial line and an axis perpendicular to the datum plane. A feature is toleranced by limiting the deviation to a value t.	⌀ ⊥ ⌀t A A			↻ ↕ ↔
↗	**Run-out (Radial)** Radial Run-out deviation is the maximum difference in radii of an extracted circumferential line centered on the datum axis. A feature is toleranced by limiting the deviation to a value t.	⌀ ↗ t A A			↻ ↕ ↔
↗	**Run-out (Axial)** Axial Run-out deviation is the maximum difference in distance in the axial direction between an extracted circular line and a plane perpendicular to the axis. A feature is toleranced by limiting the deviation to a value t.	⌀ A ↗ t A			↻ ↕ ↔
⌰	**Total Run-out (Radial)** Radial Total Run-out deviation is the difference in radii between two concentric cylinders coaxial with the datum axis constructed to touch and enclose the extracted cylindrical surface with minimum separation. A feature is toleranced by limiting the deviation to a value t.	⌀ ⌰ t A A	a b		a ↻ ↕ ✗ b ↻ ↕ ↔
⌰	**Total Run-out (Axial)** Total Axial Run-out deviation is the maximum difference in distance in the axial direction between an extracted flat surface and a plane perpendicular to the axis. A feature is toleranced by limiting the deviation to a value t.	⌀ A ⌰ t A	a b		a ↻ ↕ ↔ b ✗ ↔

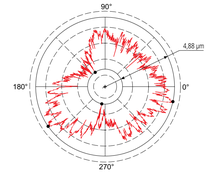
* Following ISO 1101:2012 — t = tolerance — Reference Element — Extracted Geometry



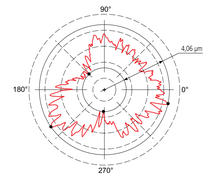
Filtering

Extracted lines can be low-pass filtered in various ways to reduce or eliminate unwanted detail, with a cut-off value set in terms of undulations per revolution (upr). The effect of different upr settings is shown in the diagrams below, for a phase-corrected 50% Gaussian filter, which illustrate how the measured roundness value decreases as lower upr settings progressively smooth out the extracted line.

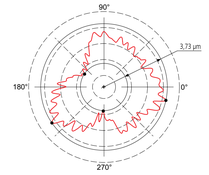
No filter



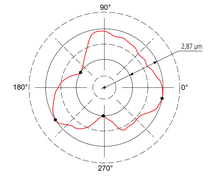
150 upr



50 upr



15 upr



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