ISO 10360

Acceptance and re-verification tests for
Coordinate Measuring Machines

a brief introduction

HEXAGON
METROLOGY

ISO 10360

Acceptance and re-verification Tests for Coordinate Measuring Machines (CMMs)

Consisting of:

ISO 10360-1 (2000):

Vocabulary [1]

ISO 10360-2 (2001):

CMMs used for measuring size

ISO 10360-3 (2000):

CMMs with the axis of a rotary table as the fourth axis

ISO 10360-4 (2000):

CMMs used in scanning measuring mode

ISO 10360-5 (2000):

CMMs using multiple-stylus probing system

ISO 10360-6 (1999):

Estimation of errors in computing Gaussian associated features [1]

[1] Not dealt with in this introduction

A brief introduction

Since 1994 the ISO 10360 »Acceptance and re-verification Tests for Coordinate Measuring Machines« is in force. This standard describes the procedures to verify the performance of Coordinate Measuring Machines (CMMs).

Before purchasing a CMM, it is important to get familiar with the basics of this standard. The following pages are intended as a guide through the ISO 10360. Some terms and definitions have been simplified for a more easy understanding.

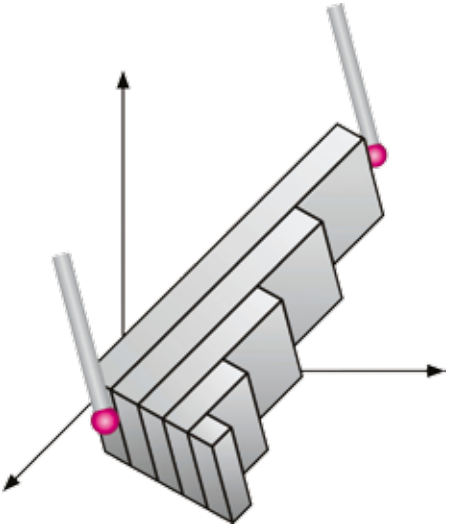
Although the ISO 10360 is an international accepted standard, there are still CMM makers who specify their CMMs according to other outdated national standards, such as VDI/VDE 2617 (German) or B89 (American).

Only if customers insist on specifications based on ISO 10360, they can compare the performance of CMMs made by different manufacturers.

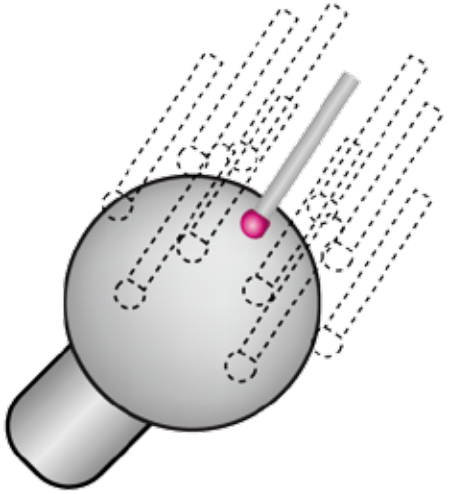
The original ISO standards can be obtained for example through publishing house Beuth at www.beuth.de.

ISO 10360-2 CMMs used for measuring size

Volumetric Length Measuring Error E



Volumetric Probing Error P
(Form Error of the CMM)



Test procedure

- A set of 5 length gauges is measured 3 times in 7 spatial positions.
- Total number of measurements: 5 x 3 x 7 = 105.
- 100% of results must be within the specification.

- A reference sphere is measured with 25 evenly distributed points.
- P = (Rmax - Rmin = Sphere form) => Form error of the CMM

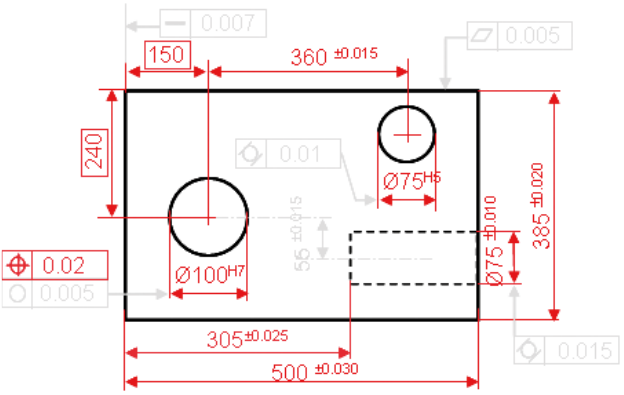
General remark:
The ISO 10360 also uses the terms MPE_E, MPE_P, MPE_{THP} etc.
MPE stand for „Maximum Permitted Error". In CMM metrology the specifications are colloquially referred to as just E, P, THP etc.

ISO 10360-2 Where do E and P apply?

Volumetric Length Measuring Error E

describes the CMM error when measuring

- **Distances**
- **Diameters**
- **Position Tolerance**

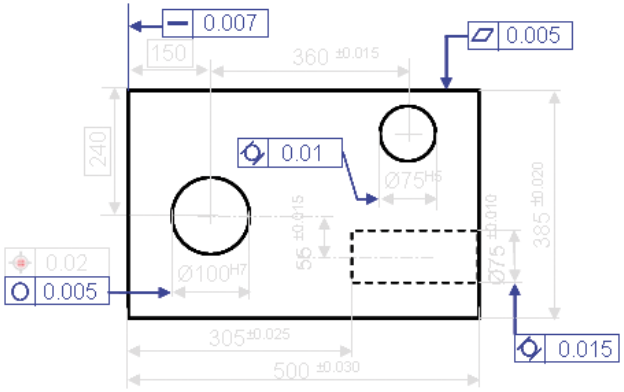


Volumetric Probing Error P

describes the CMM error at all form inspections

- **Free Form Tolerances**
- **Straightness**
- **Flatness**
- **Roundness**
- **Cylindricity**

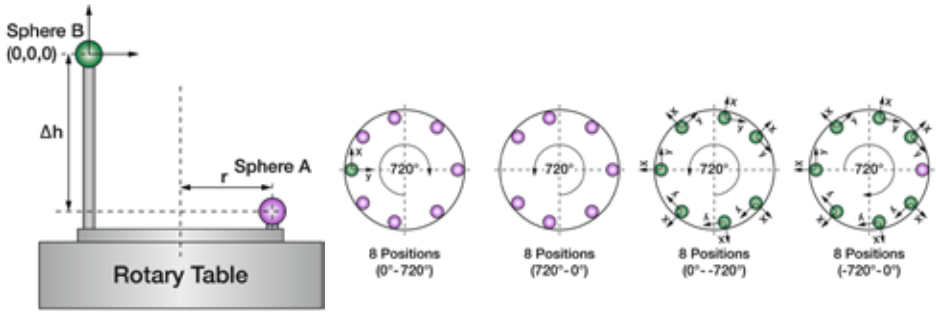
in single point modus.



ISO 10360-3 CMMs with the axis of a rotary table as the fourth axis

Rotary table Errors are:

Radial Error FR - Tangential Error FT - Axial Error FA

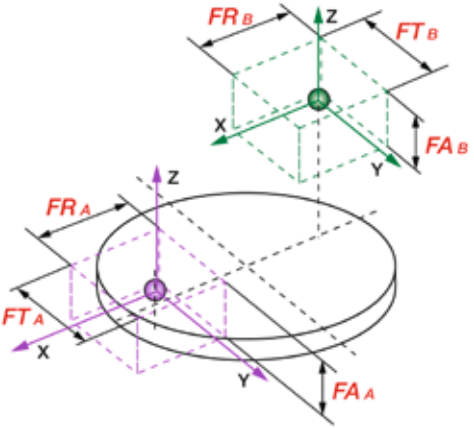


Test procedure

1. Fix spheres A and B on RT. (recom.: Δ h = 400, r = 200mm).[1]
2. Measure sphere B and set center-point to zero (0,0,0).
3. Measure sphere A in 14 positons:
   7 positions from 0° to 720°
   7 positions from 720° to 0.
4. Measure sphere B in 14 positions:
   7 from 0° to 720°
   7 from 720° to 0°
   At the last position (28) measure sphere A one more time
5. Calculate range of X, Y and Z for A and B.
6. **Rotary table error - Radial**
   FR = Max. range in X (A or B)

   Rotary table error - Tangential
   FT = Max. range in Y (A or B)

   Rotary table error - Axial
   FA = Max. range in Z (A or B)



[1] The errors of a rotary table generally increase with Δ h, radius r and table load.

ISO 10360-3 CMMs with the axis of a rotary table as fourth axis

Evaluation of a rotary table test according to ISO 10360-3

Position No.	Angle	Measured Coordinates for Test sphere A			Test sphere B		
		X_A	Y_A	Z_A	X_B	Y_B	Z_B
0	0	401.6647	0.0000	-398.276	0,0000	0,0000	0,0000
1	103	401.6632	0.0011	-398.2285	-	-	-
2	206	401.6631	-0.0016	-398.2270	-	-	-
3	309	401.6625	-0.0014	-398.22 92	-	-	-
4	412	401.6652	0.0012	-398.2285	-	-	-
5	515	401.6648	0.0009	-398.2290	-	-	-
6	618	401.6660	-0.0011	-398.2270	-	-	-
7	721	401.6646	-0.0018	-398.2263	-	-	-
8	618	401.6658	-0.0015	-398.2273	-	-	-
9	515	401.6635	0.0006	-398.2265	-	-	-
10	412	401.6623	0.0003	-398.2260	-	-	-
11	309	401.6649	-0.0011	-398.2264	-	-	-
12	206	401.6640	0.0009	-398.2278	-	-	-
13	103	401.6638	0.0004	-398.2285	-	-	-
14	0	401.6655	-0.0013	-398.2277	0.0012	-0.0011	0.0015
15	-103	-	-	-	-0.0005	0.0005	0.0007
16	-206	-	-	-	-0.0011	0.0009	-0.0003
17	-309	-	-	-	0.0014	0.0014	-0.0010
18	-412	-	-	-	0.0020	0.0000	0.0002
19	-515	-	-	-	0.0001	-0.0019	0.0012
20	-618	-	-	-	-0.0010	-0.0010	0.0012
21	-721	-	-	-	0.0017	0.0016	0.0009
22	-618	-	-	-	-0.0003	0.0003	0.0013
23	-515	-	-	-	-0.0009	-0.0003	-0.0008
24	-412	-	-	-	-0.0017	-0.0018	-0.0003
25	-309	-	-	-	0.0011	0.0004	0.0006
26	-206	-	-	-	0.0018	0.0015	0.0004
27	-103	-	-	-	0.0005	0.0004	0.0014
28	0	401.6628	0.0020	-398.2290	-0.0018	-0.0009	-0.0007
Rotary Table Error		**FR_A**	**FT_A**	**FA_A**	**FR_B**	**FT_B**	**FA_B**
		3.7µm	3.8µm	3.2µm	3.8	3.5	2.5

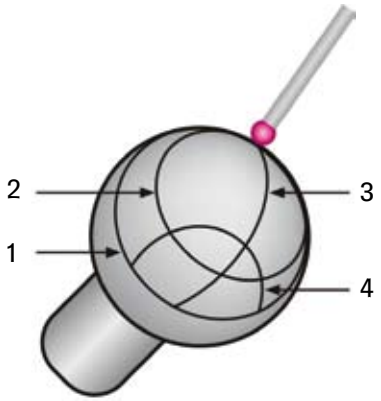
Test result:					
Rotary table error in radial direction		**FR =**	**3.8µm**		
Rotary table error in tangential direction		**FT =**	**3.8µm**		
Rotary table error in axial direction		**FA =**	**3.2µm**		

Marked with ▭ are the maximum deviations.

Remark: Rotary table errors are always specified for „Rotary table and CMM". The same rotary table used on different types of CMMs will have different specifications.

ISO 10360-4 CMMs used in scanning measuring mode

Scanning Probing Error THP



Where does THP apply?

THP defines the measuring error of the CMM for **Form Measurements**:

- Straightness
- Flatness
- Roundness
- Cylindricity
- Free Form Tolerances

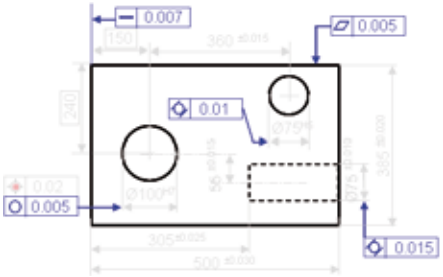
when the CMM is used in scanning mode.

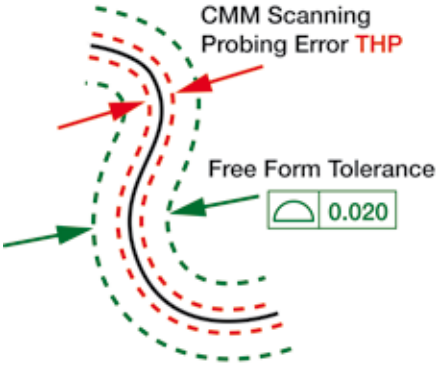
Note: THP means „scanning on a **P**redefined path, collecting a **H**igh density of points". The ISO 10360-4 describes also test procedures for TLP, THN and TLN. But they are usually not specified in CMM metrology.

Test procedure

- A reference sphere, ⌀ 25 mm, is scanned at 4 defined lines.
- THP is the range of all radii (spere form, i.e. Form Error of the CMM in scanning mode).

Important:
The scanning measuring error depends on the scanning speed. Therefore the CMM maker has to specifiy the THP-value with the corresponding total measuring time, for example **THP = 1.5 µm** at **t = 45 sec**.

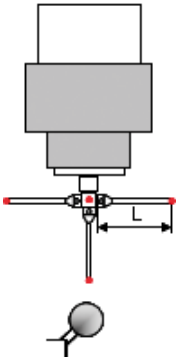




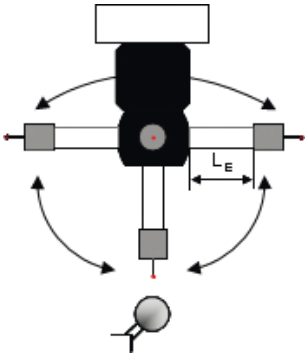
ISO 10360-5 CMMs using multiple-stylus probing system

Multiple Stylus Errors of Location, Size and Form

Fixed probing system



Articulating probing system



Test procedure

Qualify 5 orthogonal styli of length L.

Qualify 1 stylus (length 20 mm) with extension L_E in 5 orthogonal positions.

A high precision reference sphere is measured with each stylus resp. with each qualified position. Every sphere measurement takes 25 probings, total number of probings is 5 x 25 = 125.

Evaluations[1]:

Multiple Stylus Location Error
ML resp. AL = Max. Range of the 5 centre coordinates in X, Y or Z.

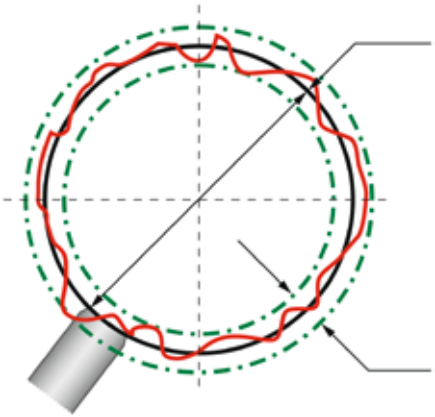
Multiple Stylus Size Error
MS resp. AS = Deviation from the calibrated diameter (all 125 points).

Multiple Stylus Form Error
MF resp. AF = Form error of the calculated sphere (all 125 points).

[1] „A" stands for „articulating probe system"
„M" stands for „fixed probe system"

ISO 10360-5 CMMs using multiple-stylus probing system

Multiple Stylus Errors of Location, Size and Form: Evaluations

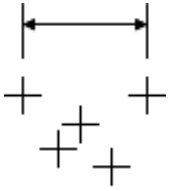


Multiple Stylus Size Error AS / MS [1]

over 125 points
- from 5 different styli (fixed head) or 5 different orientations (articulating head).

Multiple Stylus Form Error AF / MF [1]

over 125 points
from 5 different styli (fixed head) or 5 different orientations (articulating head).



Multiple Stylus Location Error AL / ML [1]

Biggest axial distance in X, Y or Z between the 5 measured center points.

[1] „A" stands for „articulating probe system"
„M" stands for „fixed probe system"

ISO 10360-5 Where do AL, AS and AF apply?

Multi Stylus Probing Errors
for CMMs with articulating probe system

AL (Location),

AS (Size) and

AF (Form)

have to be considered, if for a measurement of a feature the probe system has to be articulated.

Example:

CMM specs:

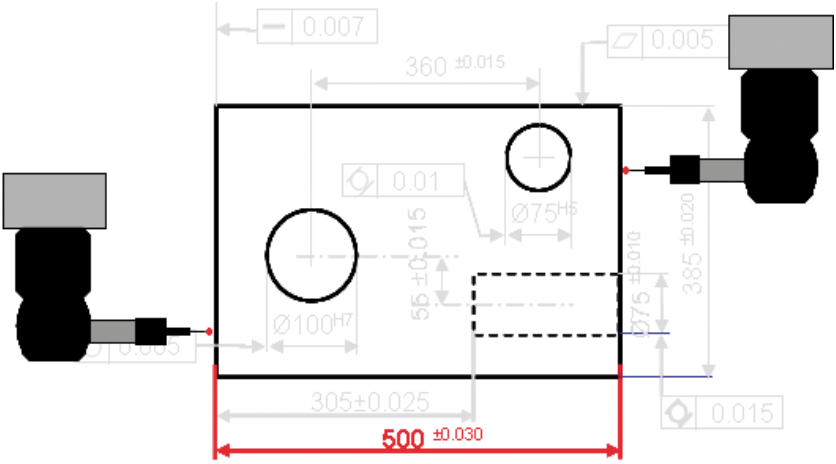
E = 2.4 + L / 300; P = 2.8µm
AL = 4.8µm; AS = 1.9µm
AF = 8.6µm

Measuring feature:

Distance 500 $^{\pm 0.030}$

Max. CMM measuring error for this feature:

= AL + E
= 4.8 + 2.4 + 500 / 300
= 4.8 + 2.4 + 1.7
=> 8.9µm



ISO 10360-5 Where do ML, MS and MF apply?

Multi Stylus Probing Errors for CMMs with a fixed probe system

ML (Location),

MS (Size) and

MF (Form)

have to be considered, if for a measurement of a feature more than 1 stylus is used.

Max. CMM measuring error for this feature:

= ML + E
= 1.9 + 0.9 + 500 / 600
= 1.9 + 0.9 + 0.8
=> 3.6µm

Example:

CMM specs:

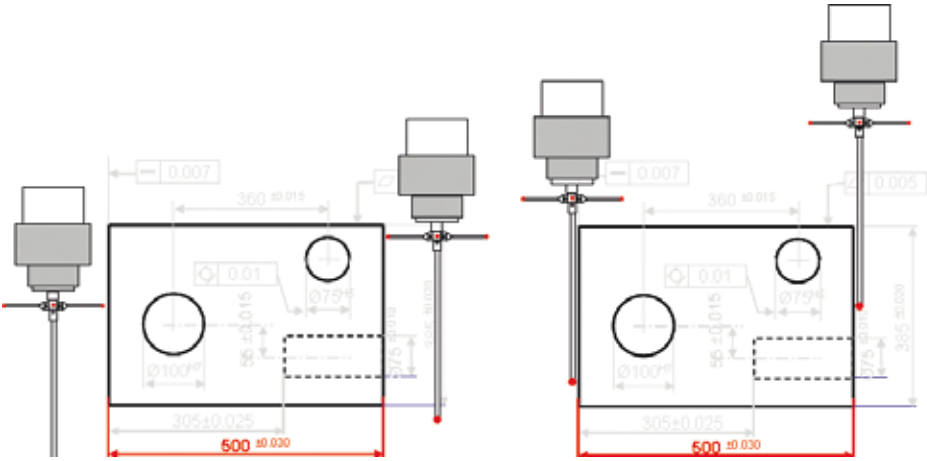
E = 0.9 + L / 600; P = 0.9µm
ML = 1.9µm; MS = 0.5µm
MF = 3.0µm

Measured feature:

Distance 500 $^{\pm 0.030}$

Max. CMM measuring error for this feature:

= E
= 0.9 + 500 / 600
= 0.9 + 0.8
=> 1.7µm



In this case the multiple styli error ML has to be considered.

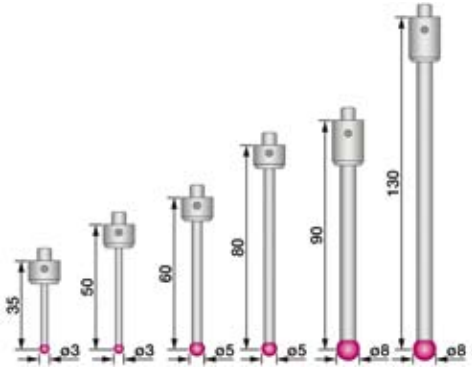
Attention should also be paid to the following restrictions

1. Styli

For which styli are the stated measuring errors valid?

For information on that please check the fine print in the data sheets. Regarding this important subject there are big differences between the various CMM makers. For example the specification for the length measuring error E is given by 3 different CMM makers for the following styli:

CMM maker A:



CMM maker B:

CMM maker C:

scale 1 : 3

Attention:
If the data sheet does not clearly specify, for which styli length and diameter the stated measuring errors are valid ➡check with the manufacturer.

2. Environment, throughput and part material

When evaluating the measuring errors of a CMM, it is also important to know:

- For which temperature range and temperature gradients are the stated specifications valid?
- For which machine dynamics (probing frequency, acceleration and moving speed) are the stated specifications valid?
- For which part material are the stated specifications valid?
  For steel (coefficient of expansion 11.5µm/m/K) or only for Invar/Zerodur (coefficient of expansion close to 0µm/m/K)

Ratio of CMM measuring error to tolerance

CMM Capability Charts

This chart is used to determine which CMM specification E is required in order to measure a distance or a diameter with a given tolerance.

Tolerance	Distance or diameter [mm]						
[mm]	50	100	200	400	600	1000	2000
± 0.003	0.3+L/1000						
± 0.005	0.5+L/900	0.4+L/1000	0.3+L/1000				
± 0.007	0.7+L/700	0.5+L/500	0.5+L/1000	0.3+L/1000			
± 0.010	0.9+L/400	0.8+L/500	0.6+L/500	0.5+L/800	0.4+L/1000		
± 0.015	1.3+L/300	1.2+L/350	0.9+L/350	0.7+L/500	0.6+L/800	0.4+L/900	
± 0.020	1.8+L/200	1.6+L/250	1.3+L/300	0.9+L/350	0.8+L/500	0.6+L/700	
± 0.030	2.8+L/200	2.6+L/250	2.2+L/250	1.7+L/300	1.5+L/400	1.0+L/500	
± 0.050	4.7+L/150	4.3+L/150	4.0+L/200	3.0+L/200	2.6+L/400	1.7+L/300	1.0+L/500
± 0.070	6.5+L/100	6.0+L/100	5.7+L/150	5.0+L/200	4.0+L/200	2.0+L/200	2.0+L/400
± 0.100	9.5+L/100	9.0+L/100	8.0+L/100	6.0+L/100	6.0+L/150	5.0+L/200	4.4+L/350

Example: A diameter of 400 mm has a tolerance of ± 0.010 mm.
For the inspection of this feature a CMM with a length measuring error of E = 0.5 + L / 800 [µm] or better is required.

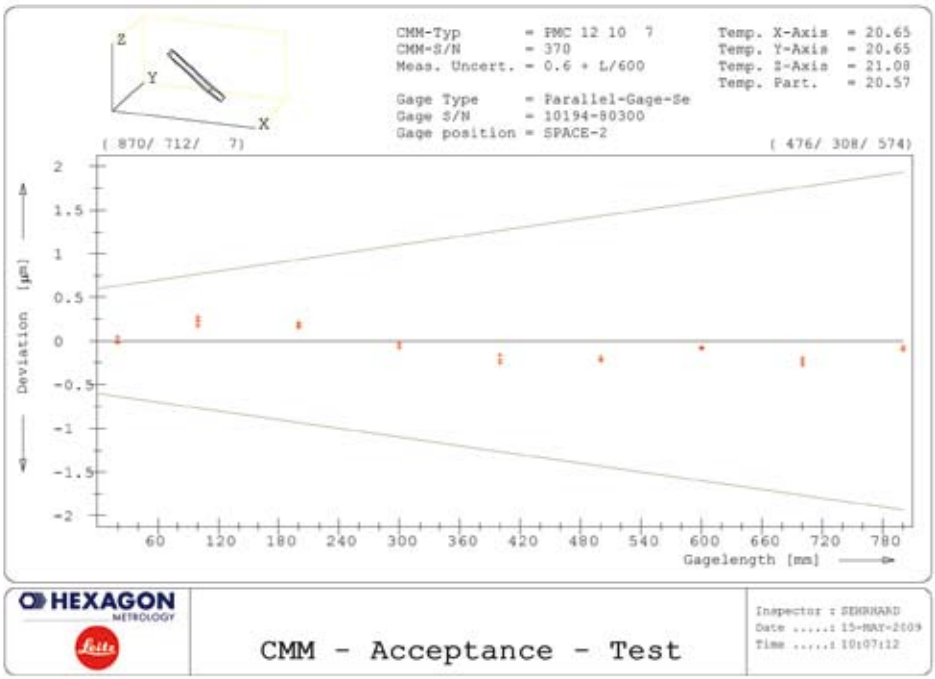
CMM Capability Analysis

By entering all critical features in the Excel chart below, the ratio of CMM error to tolerance for all features can be easily determined

CMM type Measuring error according to ISO 10360-2 E =					Leitz Reference 15.9.7 0.9 + L / 400 [µm]		
No.	feature	nom. value [mm]	upper tol. [mm]	lower tol. [mm]	CMM error [mm]	% of the tolerance	ratio
1	diameter	8	0.010	-0.010	± 0.0009	9 %	1 : 10.9
2	distance	985	0.015	-0.015	± 0.0034	22 %	1 : 4.5
3	distance	38	0.010	-0.010	± 0.0010	10 %	1 : 10.1
4	diameter	320	0.010	-0.010	± 0.0017	17 %	1 : 5.9
5	diameter	336	0.020	-0.020	± 0.0017	9 %	1 : 11.5
6	diameter	86	0.000	-0.024	± 0.0011	9 %	1 : 10.8
7	distance	168	0.025	0.000	± 0.0013	11 %	1 : 9.5
8	distance	70	0.012	-0.012	± 0.0011	9 %	1 : 11.2

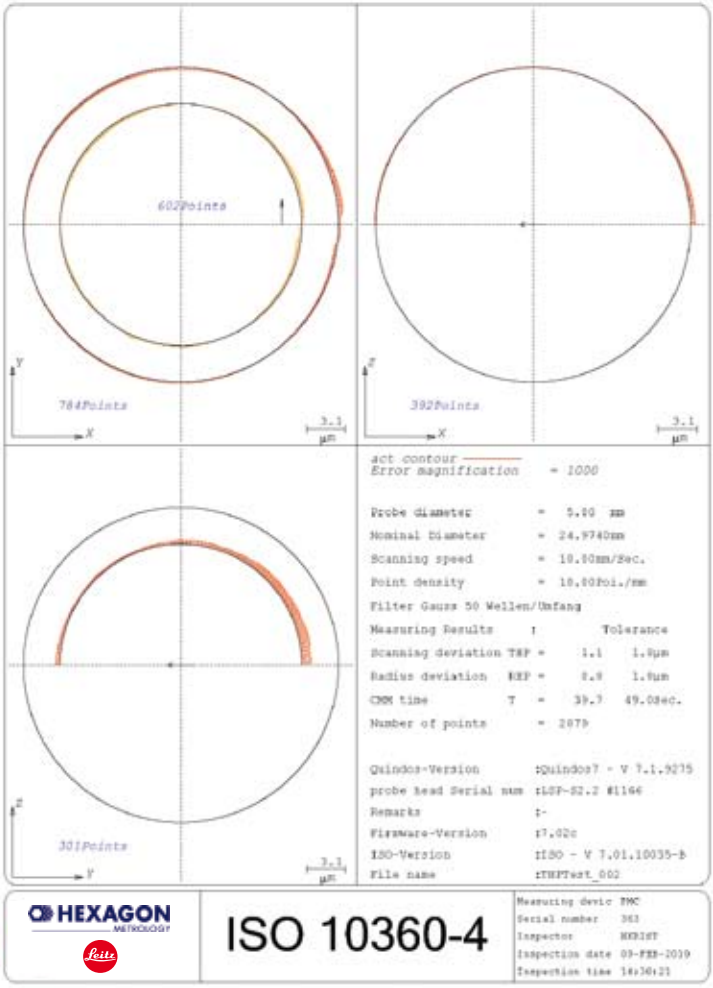
Example: Test report according to ISO 10360-2

Volumetric length measuring error E



Example: Test report according to ISO 10360-4

Volumetric scanning probing error THP



Leitz

The Leitz brand as part of Hexagon Metrology stands for high accuracy coodinate measuring machines, gear inspection centers and probes. Leitz measurement systems master quality assurance tasks equally well both in metrology labs as well as on the shop floor. The development and production are located in Wetzlar, Germany. For more than 30 years Leitz has been offering its customers the best innovative measurement technology available. The primary goal remains offering modern solutions for demanding measurement tasks.

Hexagon Metrology

Hexagon Metrology is a part of the Hexagon group and brings leading brands from the field of industrial metrology under one roof.

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