ZEISS ACADEMY
METROLOGY

COOKBOOK

Measuring strategies for
tactile Coordinate Metrology

Reading Sample

ZEISS

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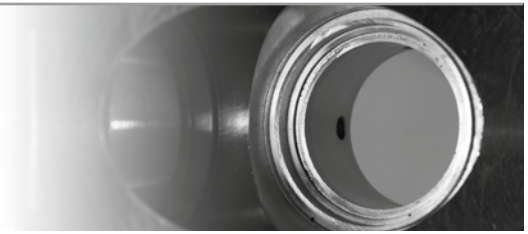

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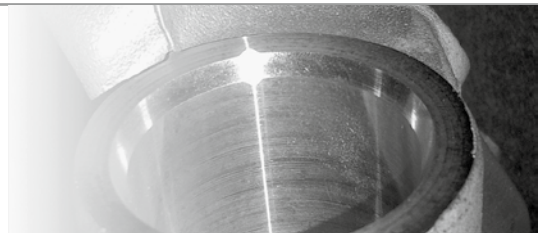

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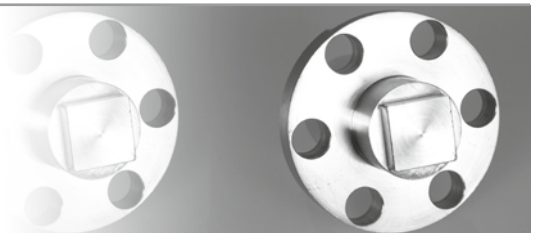

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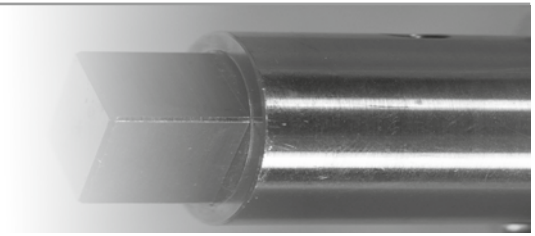

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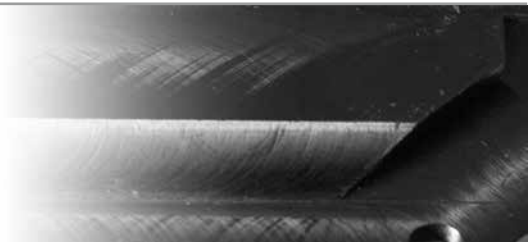

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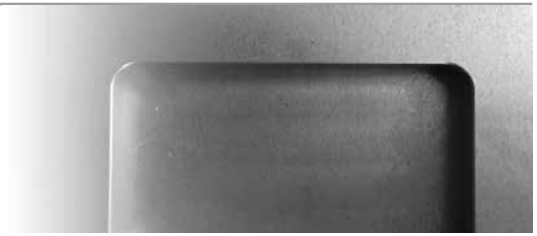

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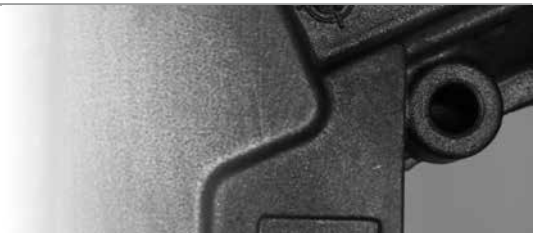

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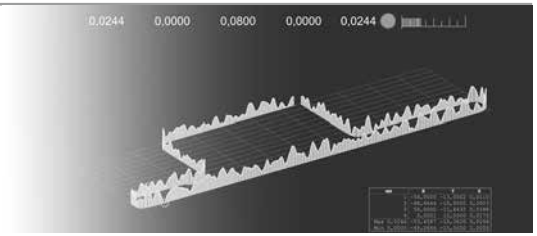

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Introduction

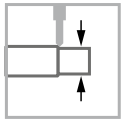
Understanding Measuring Strategies Cookbook

This cookbook tries to cover some of the most common measuring tasks (as evaluated in a study by Carl Zeiss Global Application Knowledge Group). These "default recipes" are a place to start when there is no additional information provided for measurement. These are only default suggestions, however when you know more about process and function/assembly of a part, these suggestions should be modified for your application. Remember all changes and modifications should always be documented for each measurement.

When When using one of the following recipes (measurement strategies), it can be referenced as PMI (by designer) or measuring programs (by metrologist) by using a standard naming convention referencing the strategy used. For example, if you have to measure the functional position of a cut threaded hole like in this cookbook (42, recipe "R111L-F"), you can identify it in your CNC program by naming the characteristic "THole_22_R111L-F". This naming convention indicates that the R111L-F cookbook strategy was used to measure the feature; by using a common naming and measurement convention, measurements will be more comparable.

For many strategies there are differences in sampling and evaluation according to the purpose of the measurement:

Functional Check
A functional check is a quality process in which a part is checked against the designed functional requirements. This check is for assembly purposes, prototyping, guage replacement, incoming/outgoing inspection etc. The results will cover fitting/mating situations, functional datums etc., in order to accurately report the deviations of the workpiece.



Process Control
A process control check will be run if the part under consideration is still within the manufacturing loop. That is to say that the part is still in the process of being made. This enables the operator to control production parameters, process flow, or calculate c_g, c_{gk} or GR&R values. The process control check requires a robust, stable, outlier-independent, and repeatable result. A typical use of a process check may be to show possible manufacturing deviations such as, worn tools, clamping errors, location errors etc. These results report information about the relative deviations of the work piece during serial production.

Overview

Measuring Strategies Basics

Kind	Feature number	Inspection Task	Purpose
R: Evaluation strategy (characteristic)	Bore hole (metal): 100	L: Location	-F: Functional check
	Blind hole: 106	LC: Coaxiality	-P: Process control
Z: Sampling strategy (feature)	Threaded hole formed: 110	LL: Position	-FS: Functional check with single points
	Cut thread: 111	LR: Parallelism	
A: Alignment	Taper / cone hole: 115	LR: Perpendicularity	-PS: Process control with single points
	Casted hole: 120	LS: Symmetry	
D: Output format Result report	Bore pattern: 150	R: Runout	
	Shaft metal: (same system like bores) . . . 200	TR: Total runout	
	…	…	
	Sphere: 300	A: Angle	
	Plane (machined metal): 400	D: Diameter	
	Groove (machined metal): 404	H: Height …	
	Freeform surface (machined metal): . . . 410	G: Geometric form	
	Casted plane: 420	GS : Straightness	
	…	GA: Straightness axis	

Example 1: R110LL-F Functional inspection of the position of a formed thread:			
R	110	LL	-F
Example 2: Z110L-F Measuring a formed thread for a functional location inspection:			
Z	110	L	-F

All recipes consist of one or more "ingredients" for feature probing (like measuring a cut threaded hole for functional check Z111L-F) and evaluation procedures (like calculating the position of this threaded hole by LSCY).

All recipes have been proven by ZEISS as being a "good default", but depending on your special functional needs and special production processes they might be not the appropriate measuring strategies.
So it is of much importance to control always the measuring results on plausibility and conformity yourself.

A short introductory video to this cookbook can be seen at https://www.youtube.com/watch?v=C_LdgBhgHD0

Bores (Metal)

Probing strategies Z100

A Determine the feature

The feature is a circle or a cylinder.

- Feature type depends on the ratio of bore depth to bore diameter
- Number of paths (circles) to be measured depends on measuring task (see table below)
- If only one circle is measured: immersion depth is 2 mm
- If more circles are measured: first and last circle paths are to be 3 mm away from top and bottom of hole

Bore depth	Z100L-F Bore for location	Z100L-P Bore for 2D position	Z100G-F Geometric form
<1 x diameter	1 circle	1 circle	1 circle, measured perpendicular to bore axis
1-3 x diameter	Cylinder with 3 circle paths	1 circle	Cylinder using 3 circle paths, measured perpendicular to the bore axis
>3 x diameter	Cylinder with 5 circle paths	1 circle	Cylinder using 5 circle paths, measured perpendicular to the bore axis

Bore depth	Z100D-F Diameter (functional)	Z100D-P Diameter (process control)
<1 x diameter	1 circle (fitting: cylinder with 2 circle paths)	1 circle
1-3 x diameter	Cylinder with 3 circle paths	Cylinder with 2 circle paths
>3 x diameter	Cylinder with 5 circle paths	Cylinder with 2 circle paths

B Measure the selected feature

Probing mode is scanning.
Angle range 380° or 400° (small diameter).
Scan counterclockwise.

Scanning settings (if not VAST Navigator. For VAST Navigator set "optimal"):

Ø Bore	Speed in mm/s Z100G-F	Speed in mm/s Z100L-F Z100D-F	Speed in mm/s Z100L-P Z100D-P	Probing points per circle, angle range	Tactile sensor: Ø stylus tip
< 8 mm < 0.3 in	a: max. 3 p: max. 2	a: max. 5 p: max. 2	a: max. 10 p: max. 5	min. 145 for 400°	max. 3 mm
8 to 25 mm 0.3 to 1 in	a: max. 5 p: max. 3	a: max. 10 p: max. 5	a: max. 15 p: max. 5	min. 425 for 380°	max. 3 mm
26 to 80 mm 1.1 to 3 in	a: max. 5 p: max. 3	a: max. 10 p: max. 5	a: max. 30 p: max. 10	min. 1270 for 380°	max. 3 mm
81 to 250 mm 3.1 to 10 in	a: max. 10 p: max. 5	a: max. 15 p: max. 10	a: max. 40 p: max. 20	min. 4250 for 380°	5 mm
> 250 mm > 10 in	a: max. 15 p: max. 10	a: max. 25 p: max. 15	a: max. 50 p: max. 25	min. 12700 for 380°	> 5 mm

a: active sensor; p: passive sensor
Scanning speed and other settings may vary due to sensor type and form deviation.
Always check results on plausibility!

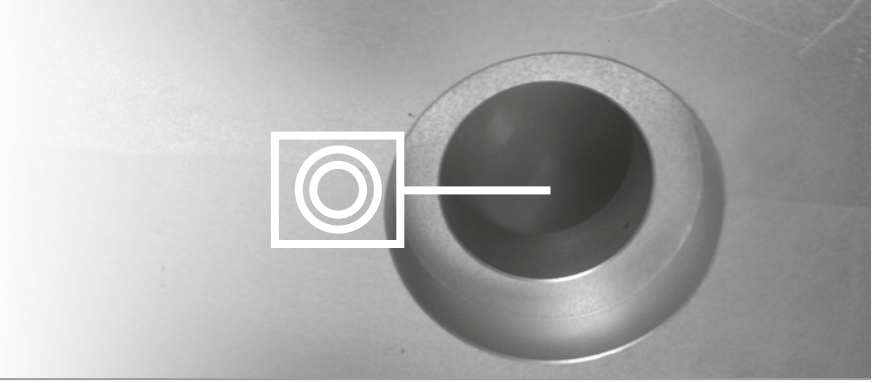
C Define the standard settings

Pre-setting for association criterion: LSCI/LSCY Least Squares Circle or Cylinder

- Oulier parameter sigma: ± 3s
- Prefilter: 10-5000 UPR, 5 adjacent points
- Filter settings in table below

Ø Bore	Cutoff wave number
< 8 mm	15 UPR Gauss filter
8 to 25 mm	50 UPR Gauss filter
26 to 80 mm	150 UPR Gauss filter
81 to 250 mm	500 UPR Gauss filter
> 250 mm	1500 UPR Gauss filter

Coaxiality / concentricity of a stepped bore



Get coaxiality deviation of a bore hole to another bore. Therefore according to ISO 1101 normally location tolerances like this one are measured as single circles and evaluated separately. In this recipe we modify evaluation to have only one result without considering form deviations.

1 Preparation

Create a measurement using a qualified probe. Setup the base alignment and clearance planes.

2 Measure the selected features

Decide what kind of features depending on ratio "bore depth" to "bore diameter".

Bore depth > 1 x diameter	Features	Ingredient / Strategy
Datum bore: yes Toleranced bore: yes	Datum feature: Cylinder Toleranced feature: Cylinder Additional datum: none	Z100L-F (page 16) Z100L-F (page 16) ./.
Datum bore: yes Toleranced bore: no	Datum feature: Cylinder Toleranced feature: Circle Additional datum: none	Z100L-F (page 16) Z100L-F (page 16) ./.
Datum bore: no Toleranced bore: yes	Datum feature: Circle Toleranced feature: Cylinder Additional datum: face	Z100L-F (page 16) Z100L-F (page 16) Z400L-F (page 88)
Datum bore: no Toleranced bore: no	Datum feature: Circle Toleranced feature: Circle Additional datum: face	Z100L-F (page 16) Z100L-F (page 16) Z400L-F (page 88)

3 Create and define characteristic

Decide what kind of characteristics depending on ratio "bore depth" to "bore diameter".

Bore depth > 1 x diameter	Characteristic
Datum bore: yes / Toleranced bore: yes or no	Coaxiality
Datum bore: no / Toleranced bore: yes or no	Concentricity

Create coaxiality or concentricity characteristic (depending on table) with the id extension "R100LC-F" and with primary datum as defined (and secondary datum plane).

4 Define the evaluation settings

Reference length = length of cylinder axis
Required evaluation methods for toleranced shaft and datum features are:

Feature	Association
Toleranced bore	LSCI Least Squares Circle / LSCY Least Squares Cylinder
cylinder/circle as datum	MICI / MICY Maximum Inscribed Circle / Cylinder
Projection plane	LSPL Least Squares Plane (Gauss)

5 Output of the characteristics

Output coaxiality or concentricity deviation "R100LC-F" to protocol.

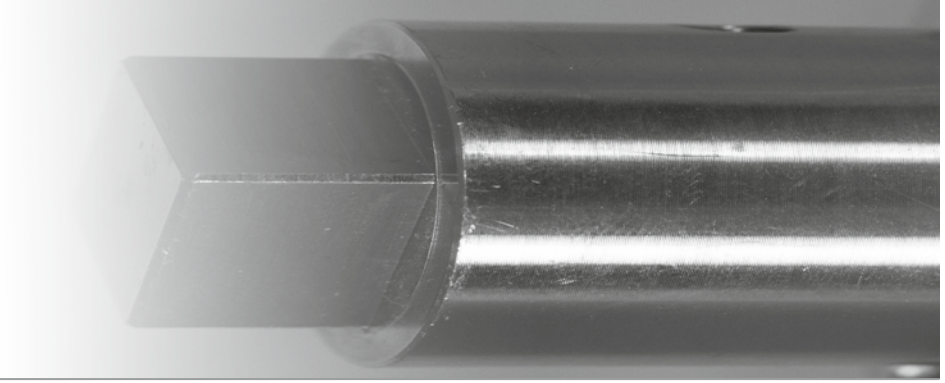
The following template(s) may be suitable for reporting the characteristic(s):

Output format	Presentation / Report template
Standard report	D050-F (page 124)

Coax_R100LC	0.1744	0.0000	0.2000	0.0000	0.1744
Coax_R100LC.Z	0.0050	0.0000	0.1000	-0.1000	0.0050
Coax_R100LC.X	0.0871	0.0000	0.1000	-0.1000	0.0871

Shafts (Metal)

Probing strategies Z200



A Determine the feature

The feature is a circle or a cylinder.

- Feature type depends on the ratio of shaft length to the shaft diameter
- Number of paths (circles) to be measured like in table below depends on measuring task
- If only one circle is measured: Immersion depth is 2 mm
- If more circles are measured: first and last circle paths are to be 3 mm away from top and bottom of shaft

Shaft lenght	Z200L-F Shaft for location	Z200L-P Shaft f. 2D position	Z200G-F Geometric form
<1 x diameter	1 circle	1 circle	1 circle, measured perpendicular to shaft axis
1-3 x diameter	Cylinder with 3 circle paths	1 circle	Cylinder using 3 circle paths, measured perpendicular to the shaft axis
>3 x diameter	Cylinder with 5 circle paths	1 circle	Cylinder using 5 circle paths, measured perpendicular to the shaft axis

Shaft length	Z200D-F Diameter (functional)	Z200D-P Diameter (process control)
<1 x diameter	1 circle (fitting: cylinder with 2 circle paths)	1 circle
1-3 x diameter	Cylinder with 3 circle paths	Cylinder with 2 circle paths
>3 x diameter	Cylinder with 5 circle paths	Cylinder with 2 circle paths

B Measure the selected feature

Probing mode is scanning. Angle range 380° or 400° (small diameter).

Scan counterclockwise. Scanning settings (if not VAST Navigator. For VAST Navigator set "optimal"):

Ø Shaft	Speed in mm/s Z200G-F	Speed in mm/s Z200L-F Z200D-F	Speed in mm/s Z200L-P Z200D-P	Probing points per circle, angle range	Tactile sensor: Ø Stylus tip
< 8 mm < 0.3 in	a: max. 2 p: max. 1	a: max. 3 p: max. 2	a: max. 5 p: max. 3	min. 145 for 400°	max. 3 mm
8 to 25 mm 0.3 to 1 in	a: max. 3 p: max. 2	a: max. 5 p: max. 3	a: max. 10 p: max. 5	min. 425 for 380°	max. 3 mm
26 to 80 mm 1.1 to 3 in	a: max. 3 p: max. 2	a: max. 10 p: max. 3	a: max. 15 p: max. 5	min. 1270 for 380°	max. 3 mm
81 to 250 mm 3.1 to 10 in	a: max. 5 p: max. 3	a: max. 15 p: max. 5	a: max. 25 p: max. 10	min. 4250 for 380°	5 mm
> 250 mm > 10 in	a: max. 10 p: max. 5	a: max. 17 p: max. 7	a: max. 30 p: max. 10	min. 12700 for 380°	> 5 mm

a: active sensor; p: passive sensor

Scanning speed and other settings may vary due to sensor type and form deviation.
Always check results on plausibility!

C Define the standard settings

Pre-setting for association criterion: LSCI/LSCY Least Squares Circle or Cylinder

- Oulier parameter sigma: ± 3s
- Prefilter: 10-5000 UPR, 5 adjacent points mode is scanning
- Filter settings in table below:

Ø Shaft	Cutoff wave number
< 8 mm	15 UPR Gauss filter
8 to 25 mm	50 UPR Gauss filter
26 to 80 mm	150 UPR Gauss filter
81 to 250 mm	500 UPR Gauss filter
> 250 mm	1500 UPR Gauss filter

Shaft (Metal)

Coaxiality / concentricity of two shaft segments – ISO

Get coaxiality deviation of a shaft segment to a next shaft segment. Therefore according to ISO 1101 normally location tolerances like this one are measured as single circles and evaluated separately. In this recipe we modify evaluation to have only one result without considering form deviations.

1 Preparation

Create a measurement using a qualified probe. Setup the base alignment and clearance planes.

2 Measure the selected features

Decide what kind of features depending on ratio "shaft segment length" to "shaft segment diameter".

Shaft length > 1 x diameter	Characteristic and Feature	Ingredient / Strategy
Shaft segment for datum: yes Toleranced shaft segment: yes	Datum feature: Cylinder Toleranced feature: Cylinder Additional datum: none	Z200L-F (page 56) Z200L-F (page 56) ./.
Shaft segment for datum: yes Toleranced shaft segment: no	Datum feature: Cylinder Toleranced feature: Circle Additional datum: none	Z200L-F (page 56) Z200L-F (page 56) ./.
Shaft segment for datum: no Toleranced shaft segment: yes	Datum feature: Circle Toleranced feature: Circle Additional datum: face	Z200L-F (page 56) Z200L-F (page 56) Z400L-P (page 88)
Shaft segment for datum: no Toleranced shaft segment: no	Datum feature: Circle Toleranced feature: Circle Additional datum: face	Z200L-F (page 56) Z200L-F (page 56) Z400L-P (page 88)

3 Create and define characteristic

Decide what kind of characteristic depending on ratio "shaft segement length" to "shaft segment diameter":

Shaft segment length >1 x diameter	Characteristic
Datum shaft segement: yes / toleranced shaft segement: yes or no	Coaxiality
Datum shaft segement: no / toleranced shaft segement: yes or no	Concentricity

Create coaxiality or concentricity characteristic (depending on table) with the id extension "R200LC-F" with primary datum as defined (and secondary datum plane as specified).

4 Define the evaluation settings

Reference length = length of segment axis
Required evaluation methods for toleranced shaft segment and datum features are:

Feature	Association
Toleranced shaft segement	LSCI Least Squares Circle / LSCY Least Squares Cylinder
Cylinder/circle as datum	MCCI / MCCY Minimum Circumscribed Circle / Cylinder
Projection plane	LSPL Least Squares Plane (Gauss)

5 Output of the characteristics

Output coaxiality or concentricity deviation "R200LC-F" to protocol.

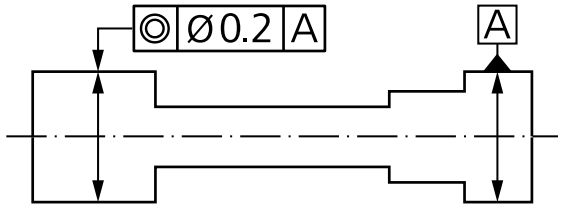
The following template(s) may be suitable for reporting the characteristic(s):

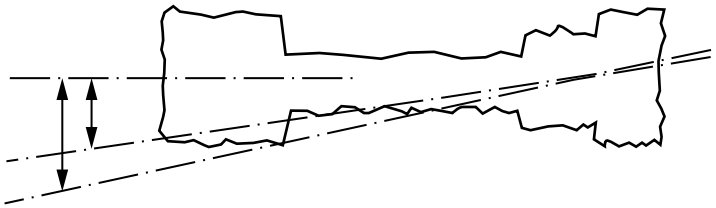
Output format	Presentation / Report template
Standard report	D050-F (page 124)

Shaft (Metal)

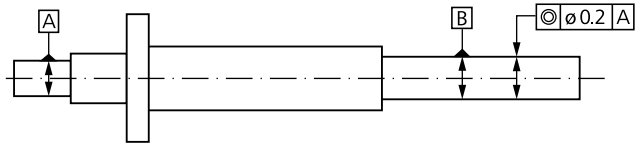
Coaxiality of two bearings

Having only a small datum far away makes coaxiality (ISO 1101) evaluation a big issue:

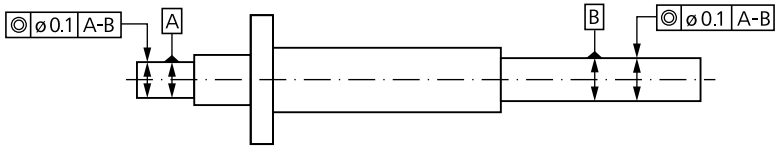




Therefore the idea is to change interpretation of:



to:



This can only be done after consultation with the designer / inspection planner / customer!

1 Preparation

Create a measurement using a qualified probe. Setup the base alignment and clearance planes.

2 Measure the selected features

Prepare the measurement plan with:

Feature	Ingredient / Strategy
Cylinder A	Z200L-P (page 56) – always measure a cylinder, not a circle
Cylinder B	Z200L-P (page 56) – always measure a cylinder, not a circle

3 Create and define characteristic

Create two characteristics "coaxiality" with the id extension "R200LCB-F" (A and B together as stepped cylinder), one time A as toleranced feature, one time B as toleranced feature.

4 Define the evaluation settings

Required evaluation methods for position and datum features are:

Feature	Association for both circles
Cylinder	LSCY Least Squares Cylinder (Gauss)

5 Output of the characteristics

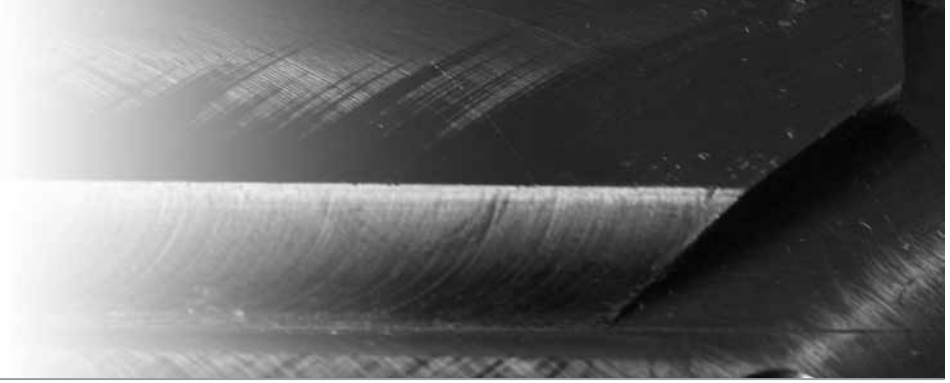
Output two coaxiality deviations "R200LCB-F" to protocol.

The following template(s) may be suitable for reporting the characteristic(s):

Output format	Presentation / Report template				
Standard report	D050-F (page 124)				
A_B_R200LCB	0.1079	0.0000	0.2000	0.0000	0.1079
B_A_R200LCB	0.0464	0.0000	0.2000	0.0000	0.0464

Planes (Metal)

Probing strategies Z400L



A Determine the feature

The feature is a plane.

B Measure the selected feature

Probing mode is scanning
Scan always 10% away from edges, perpendicular to waves/score marks (direction of machining).
Scanning settings (if not VAST Navigator. For VAST Navigator set "optimal"):

Plane size (length)	Z400L-F and -P plane for location
< 25 mm < 1 in	Stylus tip diameter: 3 mm Scanning speed active sensor: max. 5 mm/s Scanning speed passive sensor: max. 3 mm/s Step width: 0.1 mm
26 to 80 mm 1.1 to 3 in	Stylus tip diameter: 3 mm Scanning speed active sensor: max. 10 mm/s Scanning speed passive sensor: max. 5 mm/s Step width: 0.1 mm
81 to 250 mm 3.1 to 10 in	Stylus tip diameter: 3 mm Scanning speed active sensor: max. 20 mm/s Scanning speed passive sensor: max. 10 mm/s Step width: 0.31 mm
> 250 mm > 30 in	Stylus tip diameter: 5 mm or more Scanning speed active sensor: max. 40 mm/s Scanning speed passive sensor: max. 20 mm/s Step width: 1 mm

Scanning speed and other settings may vary due to sensor type and form deviation.
Always check results on plausibility!

Scanning at least 4 lines (polyline with 4 lines), 10% away from edges.

Exception: If the plane is too narrow for scanning 4 lines, scan 2 lines. If even this is too much, then only 1 line. This single line can NOT be used as a primary datum in any way.

C Define the standard settings

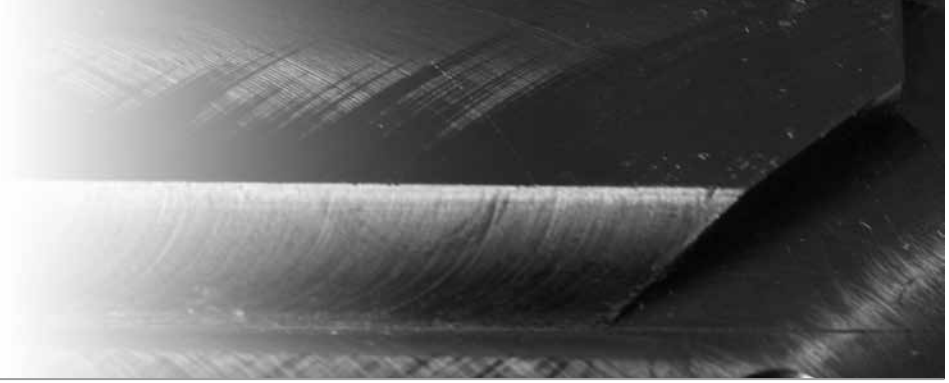
Pre-setting for association criterion: LSPL Gauss plane

- Oulier parameter sigma: ± 3s
- Prefilter: 0-10 mm, 5 adjacent points mode is scanning
- Filter settings in table below

Plane size (length)	Cutoff wave length
< 25 mm	λc = 0.8 mm Gauss filter
> 25 to 80 mm	λc = 0.8 mm Gauss filter
>80 to 250 mm	λc = 2.5 mm Gauss filter
> 250 mm	λc = 8.0 mm Gauss filter

Plane (Metal) Ingredients

Probing strategies Z400G / Z400GC



A Determine the feature

The feature is a plane.

B Measure the selected feature

Probing mode is scanning
Scan always 10% away from edges, perpendicular to waves/score marks (direction of machining).
Scanning settings (if not VAST Navigator. For VAST Navigator set "optimal"):

Roughness	Z400G-F and Z400GC-F
Ra ≤ 0,025 µm or Rz ≤ 0,1 µm	Stylus tip diameter: 1 mm **Scanning speed active sensor**: max. 5 mm/s **Scanning speed passive sensor**: max. 3 mm/s Step width: 0.031 mm
Ra > 0,025 µm to 0,4 µm or Rz > 0,1 µm to 1,6 µm	Stylus tip diameter: 3 mm **Scanning speed active sensor**: max. 10 mm/s **Scanning speed passive sensor**: max. 5 mm/s Step width: 0.1 mm
Ra > 0,4 µm to 3,2 µm or Rz > 1,6 µm to 12,5 µm	Stylus tip diameter: 3 mm **Scanning speed active sensor**: max. 20 mm/s **Scanning speed passive sensor**: max. 10 mm/s Step width: 0.31 mm
Ra > 3,2 µm or Rz > 12,5 µm	Stylus tip diameter: 5 mm or more **Scanning speed active sensor**: max. 40 mm/s **Scanning speed passive sensor**: max. 20 mm/s Step width: 1 mm
Scanning speed and other settings may vary due to sensor type and form deviation. Always check results on plausibility!	

For Z400G-F:
Scanning at least 4 lines (polyline with 4 lines), 10% away from edges.

For Z400GC-F:
Scanning at least 3 circular lines with big, middle and small diameter (10% away from edge / middle point).

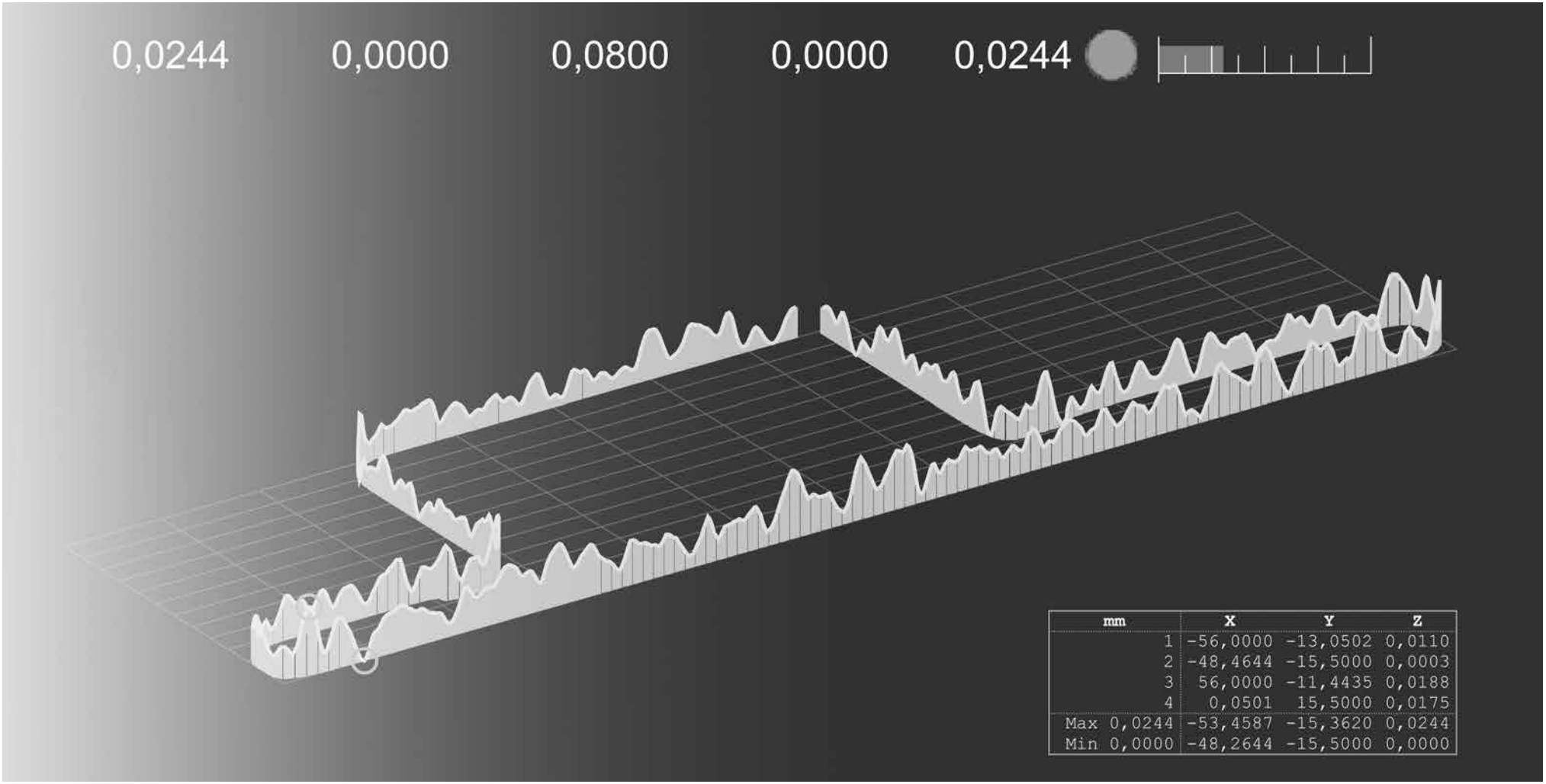
C Define the standard settings

Pre-setting for association criterion: LSPL Gauss plane

- Oulier parameter sigma: ± 3s
- Prefilter: 0-10 mm, 5 adjacent points mode is scanning
- Filter settings in table below

Roughness	Z400G-F and Z400GC-F plane for geometric form
Ra ≤ 0,025 µm or Rz ≤ 0,1 µm	λc = 0.25 mm Gauss filter
Ra > 0,025 µm to 0,4 µm or Rz > 0,1 µm to 1,6 µm	λc = 0.8 mm Gauss filter
Ra > 0,4 µm to 3,2 µm or Rz > 1,6 µm to 12,5 µm	λc = 2.5 mm Gauss filter
Ra > 3,2 µm or Rz > 12,5 µm	λc = 8.0 mm Gauss filter

Result Reports



mm	X	Y	Z
1	-56,0000	-13,0502	0,0110
2	-48,4644	-15,5000	0,0003
3	56,0000	-11,4435	0,0188
4	0,0501	15,5000	0,0175
Max 0,0244	-53,4587	-15,3620	0,0244
Min 0,0000	-48,2644	-15,5000	0,0000

Result Report

Standard Report

The standard report generates an overview list that shows the tolerance utilization of all characteristics. The results in the standard report can be displayed in groups with headlines. Additionally, the tolerance violations are highlighted in color.

A Preparation

In CALYPSO select and activate the menu "Multiple Printout" or in CALIGO select "Reporting" and "PiWeb" at CNC start or select report output in other measuring software.

B Define the report settings

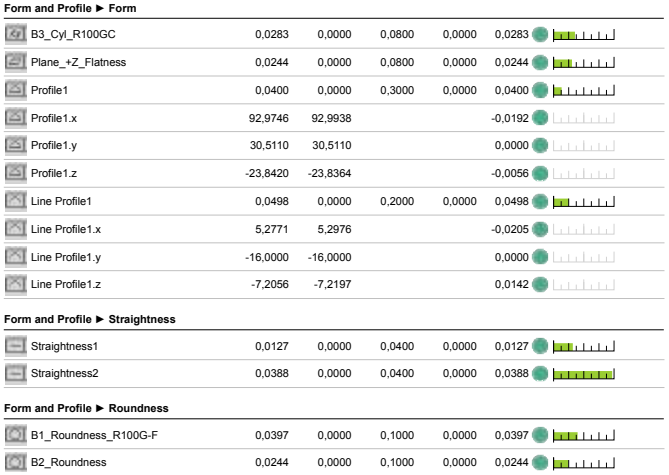
In CALYPSO select printout "Standard PiWeb Reporting" or in CALIGO activate "PiWeb/Export" at choosen report.

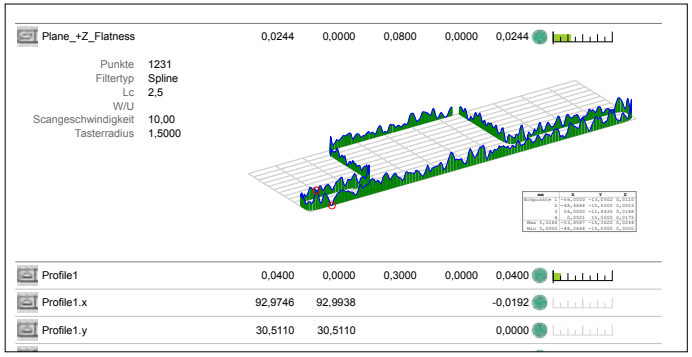
C Select the output format

Assign the output format template for the result report. The output format is described here:

Report / Presentation	Output format
Characteristics as a list	ZEISS template: StandardProtocol
Characteristics with plots	ZEISS template: StandardProtocol with „Detailed" view enabled

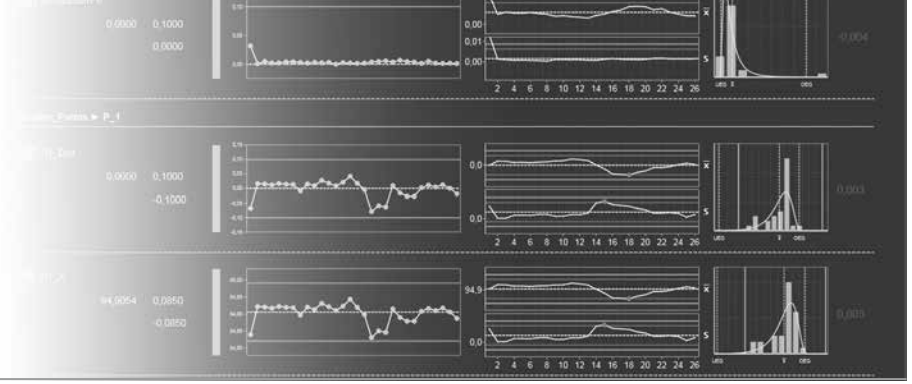
- Right clicking on the plot inside enables the magnification to be adjusted.
- Clicking on the graphics opens the form plot „D050G".
- It is recommended that you store the report electronically or create a hard-copy after CNC run is finished.
- The measuring values are stored in the result file.





Result Report

Table Report



The table report generates a view of the characteristics with at most 12 previous measurements in a table. By showing a detailed list of characteristic measurements it is possible to analyze the quality of production process. The deviations away from nominal are color coded.

Note: If you have the base level of PiWeb Reporting that comes with CALYPSO, you will only be able tzo access the previous 10 measurements.

A Preparation

In CALYPSO select and activate the menu "Multiple Printout" or in CALIGO select "Reporting" and "PiWeb" at CNC start or select report output in other measuring software.

B Define the report settings

In CALYPSO select printout "Standard PiWeb Reporting" or in CALIGO activate "PiWeb/Export" at choosen report.

C Select the output format

Assign the output format template for the result report. The output format is described here:

Report / Presentation	Output format
Characteristics with measurement history	ZEISS template: TableProtocol (CALYPSO)

- It is recommended that you store the report electronically or create a hardcopy after CNC run is finished.
- The measuring values are stored in the result file.

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Carl Zeiss Straße 22
73447 Oberkochen, Germany
Internet: http://www.zeiss.de/imt
E-Mail: imt@zeiss.de

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