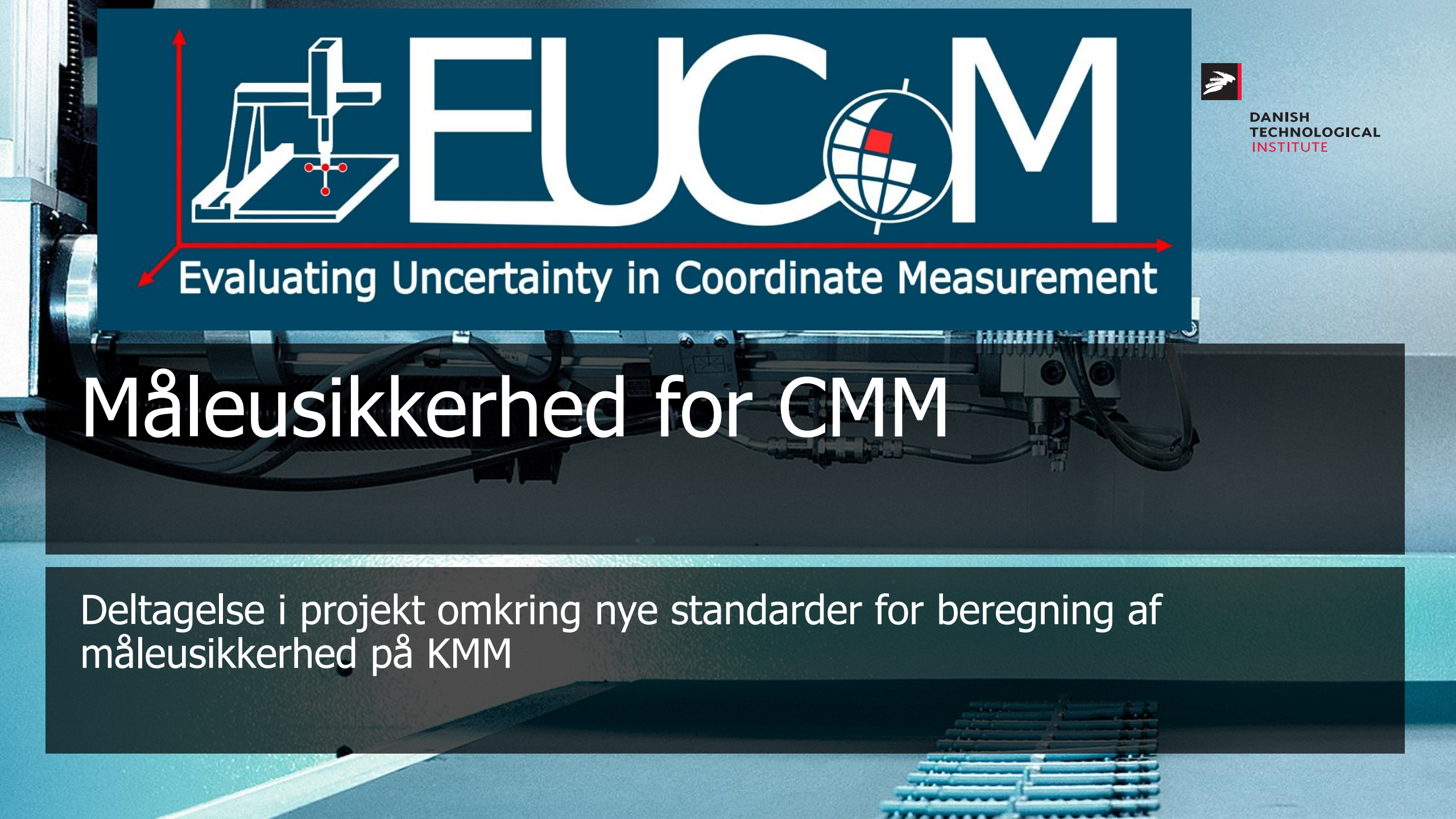
Afsluttende møde for

Standards for the evaluation of the uncertainty of coordinate measurements in industry

Agenda

- 9:00 Velkommen
- 9:00 – 9:30 Projekt overview
- 9:30 – 10:00 Præsentation af Work Package 1 og 2
- 10:00 – 10:10 Kort Pause
- 10:10 – 10:45 Hvordan er den praktiske udførsel
- 10:45 – 11:00 Introduktion til regneark
- 11:00 – 11:10 Kort Pause
- 11:10 – 11:30 Vores erfaringer med vores egne maskiner
- 11:30 – 12:00 Spørgsmål og snak



DANISH
TECHNOLOGICAL
INSTITUTE

Måleusikkerhed for CMM

Deltagelse i projekt omkring nye standarder for beregning af måleusikkerhed på KMM

JRP 11 EUCoM

DANISH TECHNOLOGICAL INSTITUTE

Standards for the evaluation of the uncertainty of coordinate measurements in industry

- Start date: 01 May 2018
- End date: 01 May 2021 – nu ved udgangen af 2021
- Duration: 36 months (oprindeligt)
- Coordinator: Alessandro Balsamo (INRIM - Italy)

EUCoM
Evaluating Uncertainty in Coordinate Measurement

Participants

Inrim – Italy

PTB – Tyskland

NPL – UK

Tubitak – Tyrkiet

CIM og Skoda– Tjekkoslovakiet

DTI – DK

Metrosert – Estland

GUM og ATH – Polen

IK4-TEKNIKER - Spanien

NMIJ - Japan

EUCoM
Evaluating Uncertainty in Coordinate Measurement

Overview

DANISH TECHNOLOGICAL INSTITUTE

The project aims to **deliver two methods for evaluating the uncertainty of coordinate measurements**. These methods will be suitable for inclusion in international standards and applicable to common cases in industry. Correct evaluation of uncertainty during inspections is necessary to avoid false decisions such as accepting nonconforming parts. The most popular technique for dimensional inspection in industry is coordinate measurement. Recognized and viable methods for uncertainty evaluation will improve quality assurance and impact positively the European manufacturing sector.

EUCoM
Evaluating Uncertainty in Coordinate Measurement

Objectives

DANISH TECHNOLOGICAL INSTITUTE

The overall objective of the project is to **develop viable methods for evaluating the measurement uncertainty in coordinate measurement in industry** to support the competent standardization body (ISO/TC213/WG10) in further development of related standards (in the ISO 15530 series).

The specific objectives of the project are:

1. To develop traceable and standardized methods for evaluating the uncertainty of coordinate measurement **a posteriori using type A evaluation**.
2. To develop a simplified and validated method for predicting the uncertainty of coordinate measurements **a priori using type B evaluation** (i.e. expert judgement).
3. To **demonstrate the validity of existing methods** and those from objectives 1 & 2 in industrial conditions and evaluate their consistency and accuracy against the Guide to the Expression of Uncertainty in Measurement (GUM) and its supplements.
4. To **contribute to revisions of the EN ISO 15530 and the EN ISO 14253-2** by providing the necessary data, methods, guidelines and recommendations, in a form that can be incorporated into the standards at the earliest opportunity. In addition, to collaborate with the technical committees CEN/TC290 and ISO/TC213/WG10 and the users of the standards they develop to ensure that the outputs of the project are aligned with their needs and recommendations for incorporation of this information into future standards at the earliest opportunity. To promote early dissemination of the developed methods to industry.

EUCoM
Evaluating Uncertainty in Coordinate Measurement

WP summary

DANISH TECHNOLOGICAL INSTITUTE

WP No	Work Package Title	Active Partners (WP leader in bold)
WP1	*A posteriori* (type A) methods	**INRIM**, PTB, NPL, CMI, GUM, UNIPD, ATH, AIST
WP2	*A priori* (type B) methods	INRIM, PTB, **NPL**, GUM, UNIPD, ATH
WP3	Experimental validation of methods	INRIM, **PTB**, NPL, TUBITAK, CMI, **DTI**, Mettrosert, GUM, TEKNIKER, UNIPD, ATH, AIST
WP4	Creating impact	INRIM, PTB, NPL, TUBITAK, CMI, **DTI**, Mettrosert, GUM, **TEKNIKER**, UNIPD, ATH, AIST
WP5	Management and coordination	**INRIM**, PTB, NPL, TUBITAK, CMI, **DTI**, Mettrosert, GUM, TEKNIKER, UNIPD, ATH, AIST

EUCoM
Evaluating Uncertainty in Coordinate Measurement

Hvad har vi lavet.

DANISH TECHNOLOGICAL INSTITUTE

- Deltaget i et Kick-off møde i Torino, Italien
- Afholdt en workshop den 20. sep. 2018 i Tåstrup med Professor Alistair Forbes for at give vores besyv med.
- Vi afholder næste møde en 7. maj 2019 hvor vi informere om projektet og hvordan 3D printere understøtter 3-koordinatmåling
- Næste møde er 5. marts 2019 i Prag

EUCoM
Evaluating Uncertainty in Coordinate Measurement

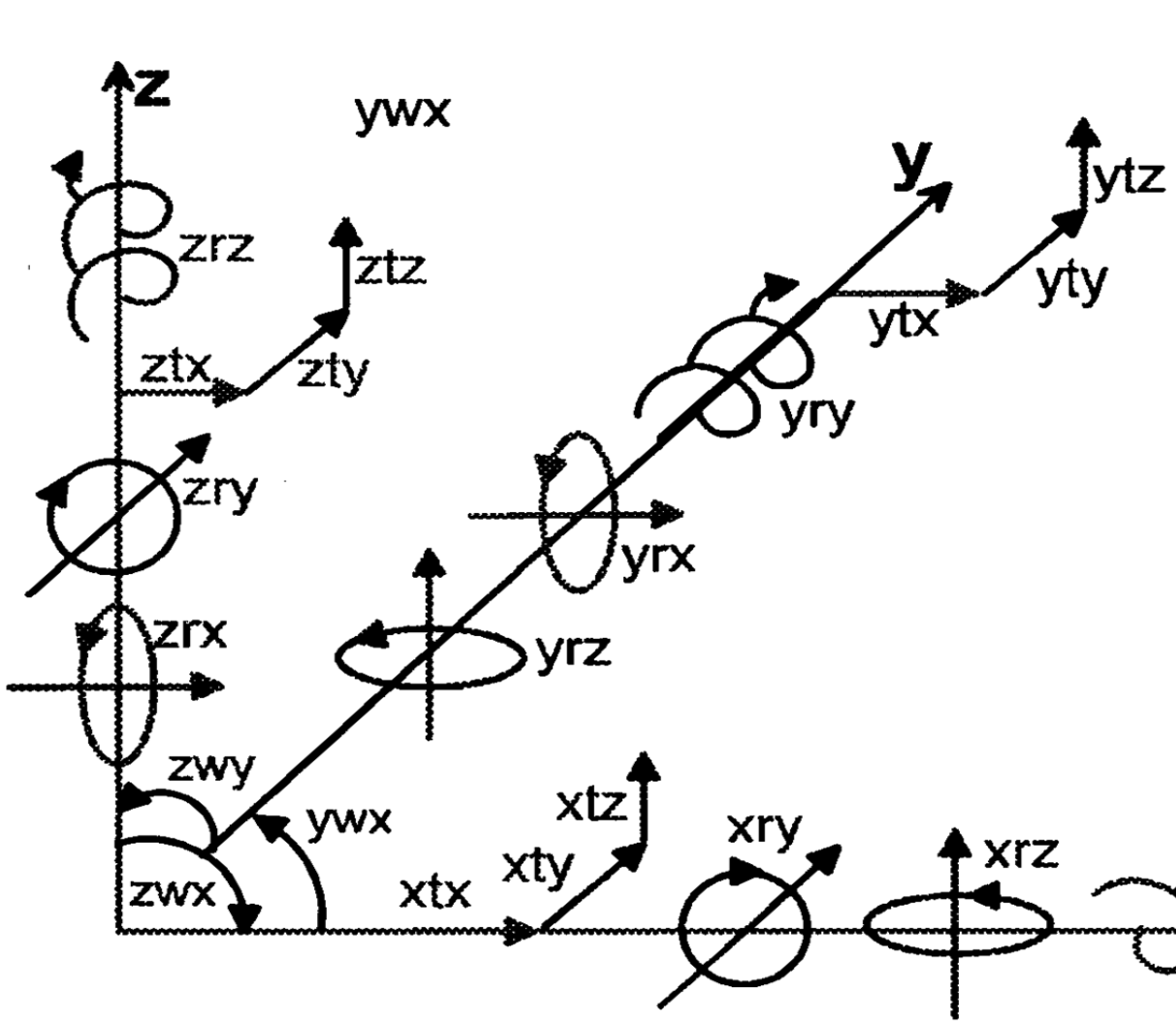
Hvad vil vi lave.

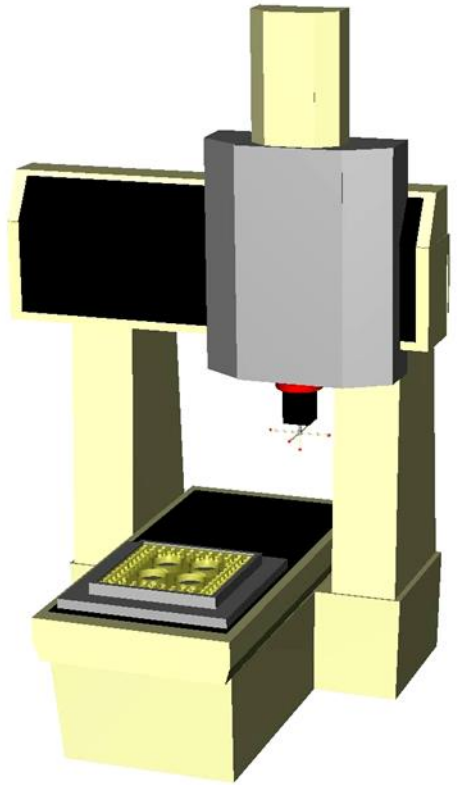
DANISH TECHNOLOGICAL INSTITUTE

- Vi forventer at procedurerne er klar og vi har en tidsplan for målingerne

- Vi afholder næste møde en 7. maj 2019 hvor vi informere om projektet og hvordan 3D printere understøtter 3-koordinatmåling

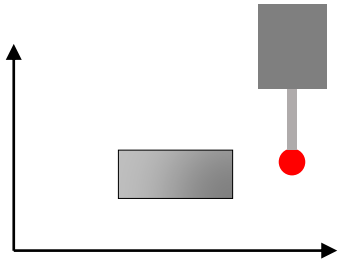
EUCoM
Evaluating Uncertainty in Coordinate Measurement


z
ywx
zrz
ztz
ztx
zty
zry
zrx
zwy
zwx
ywx
y
ytz
yty
ytx
yry
yrx
yrz
xtz
xry
xrz
xrx
xty
xtx
x



Metode „A forudsig usikkerheden“

MPE	$2 + 2L$

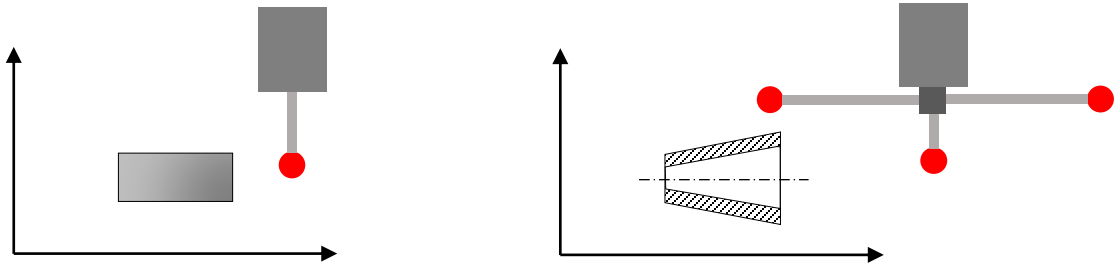


Simpelt emme – 1 tast

$2{,}2\ \mu m$

Metode „A forudsig usikkerheden“

MPE	$2 + 2L$

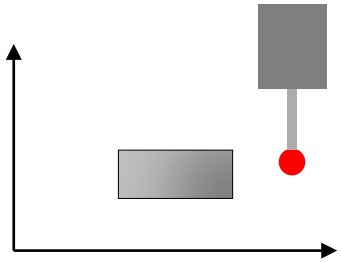


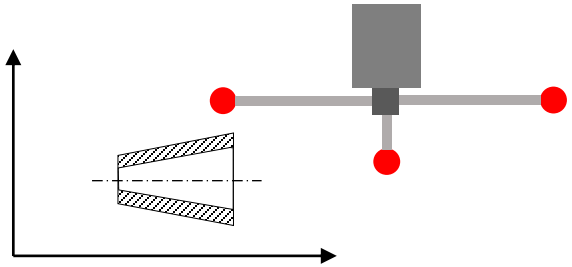
Lidt mere komplekst + flere taster

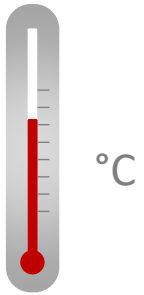
$2{,}2\ \mu m$ $2{,}8\ \mu m$

Metode „A forudsig usikkerheden“

MPE	$2 + 2L$





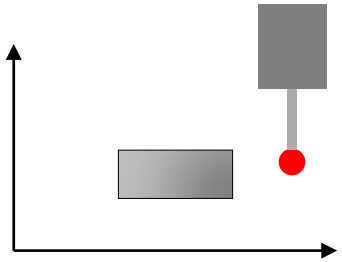


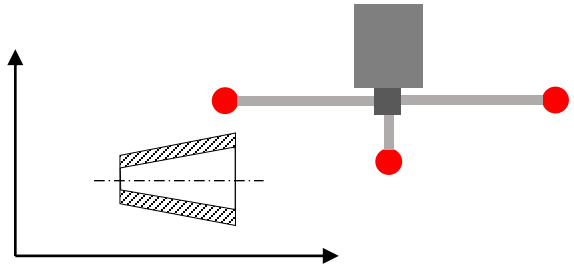
+ noget temperatur

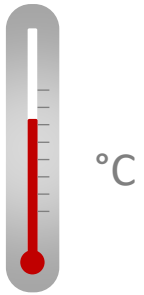
$2{,}2\ \mu m$ $2{,}8\ \mu m$ $2{,}9\ \mu m$

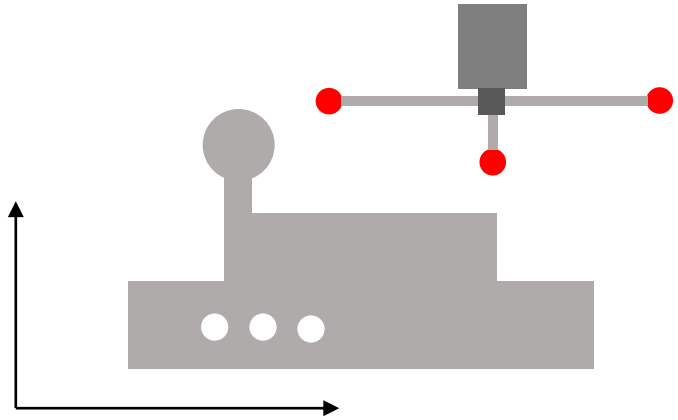
Metoda „A priori“

MPE	$2 + 2L$







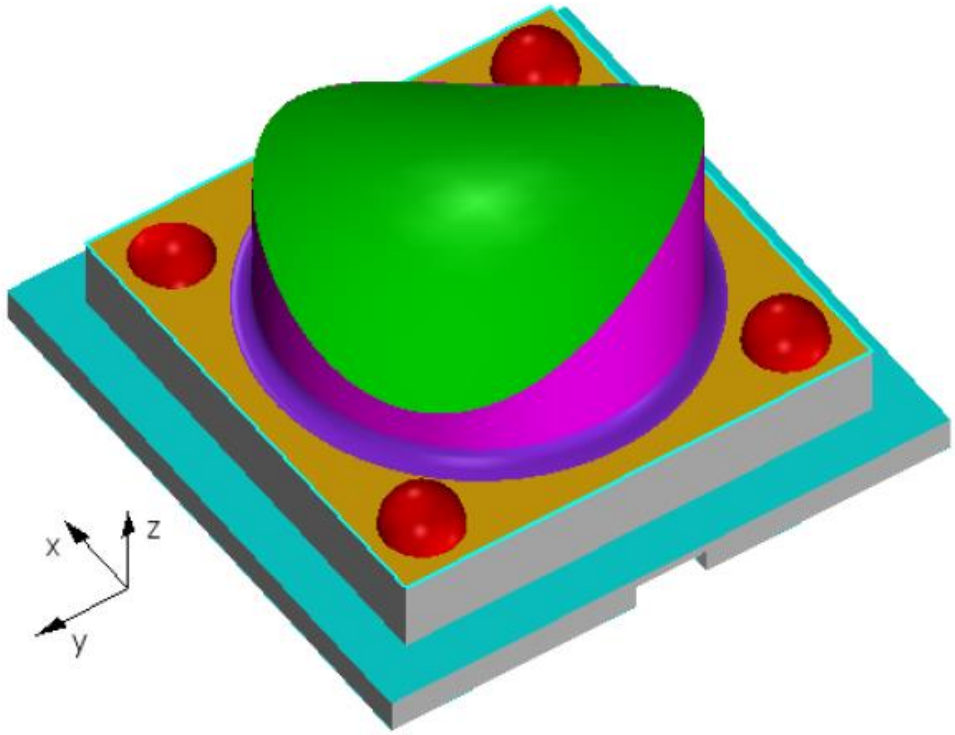


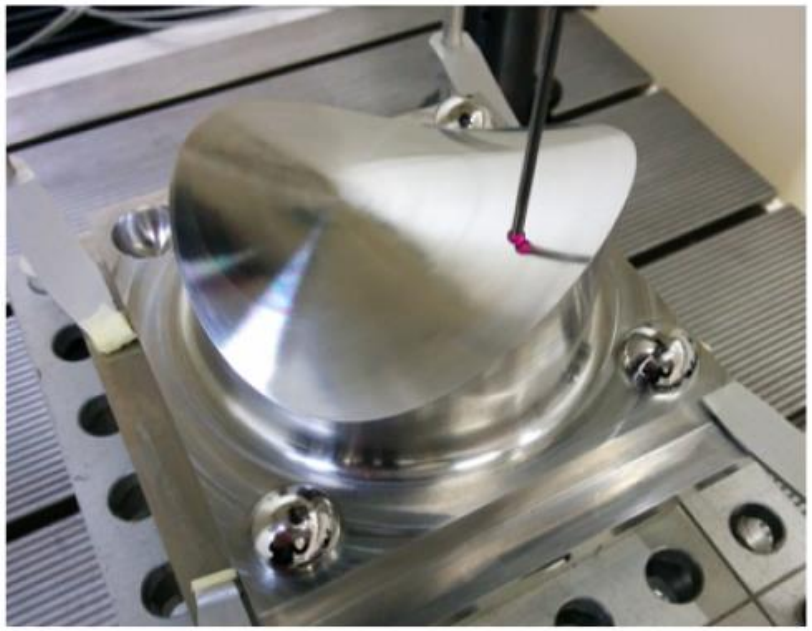
Høj kompleksiset + flere retninger og niveauer

$2{,}2\ \mu m$ $2{,}8\ \mu m$ $2{,}9\ \mu m$ $3{,}4\ \mu m$

Måleemner

DANISH TECHNOLOGICAL INSTITUTE

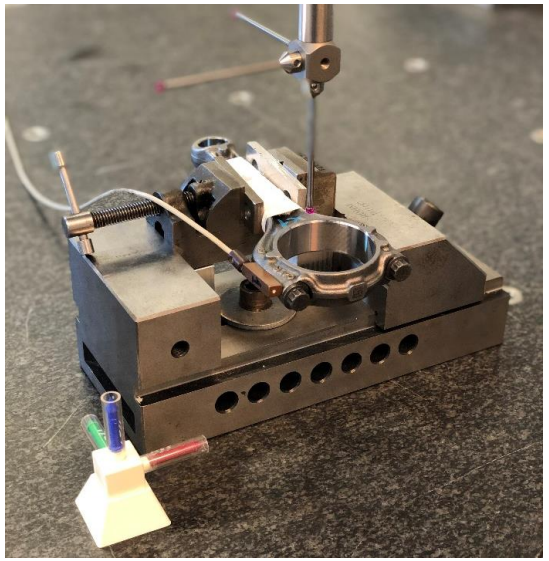




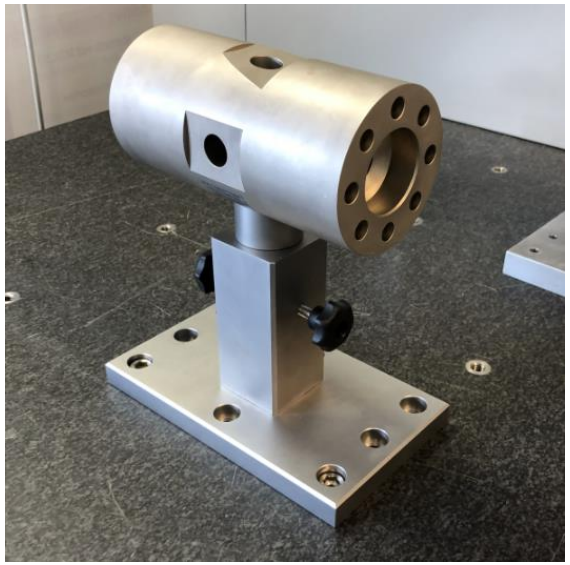
Evaluating Uncertainty in Coordinate Measurement

COMPONENTI PRISMATICI

Connecting Rod

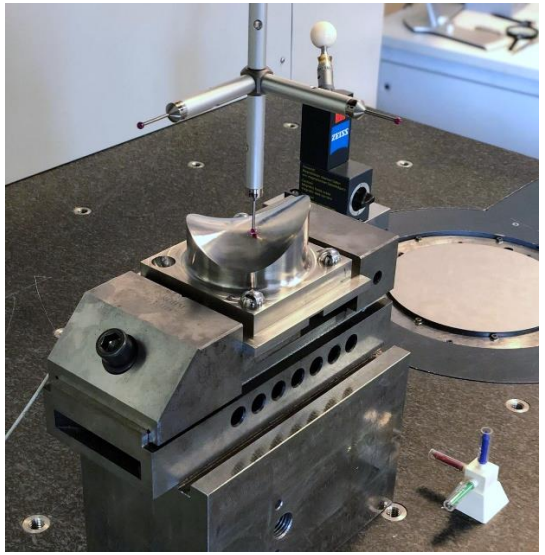


Multi Feature Check



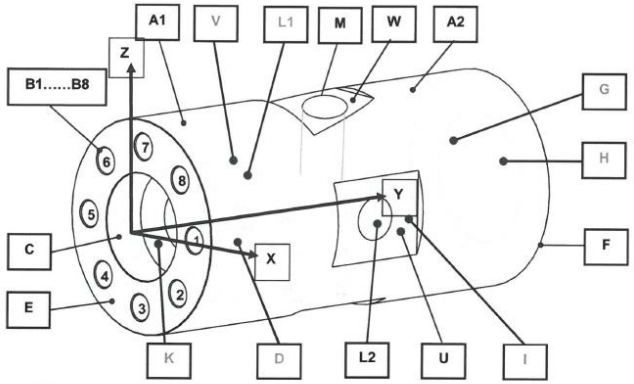
COMPONENTI FREEFORM

Hyperbolic Paraboloid

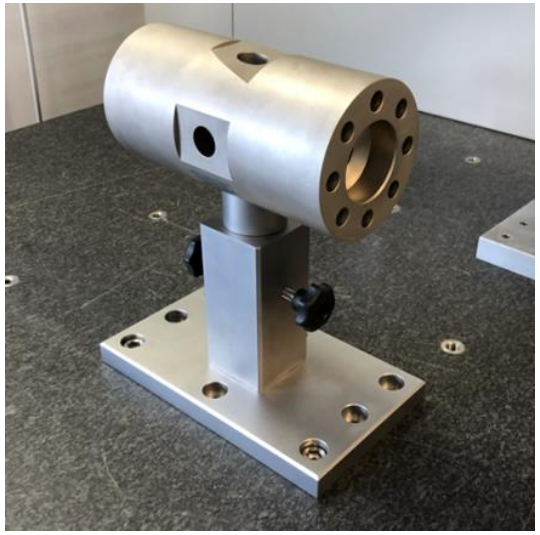


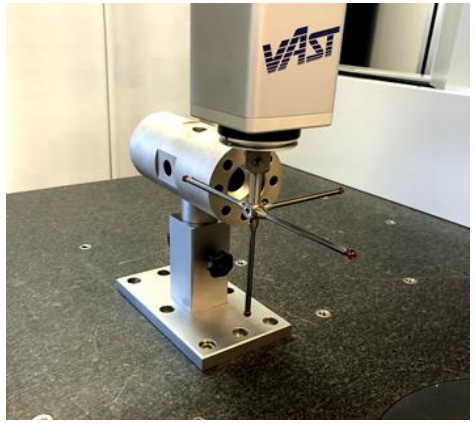
gear

PTB Multi feature check

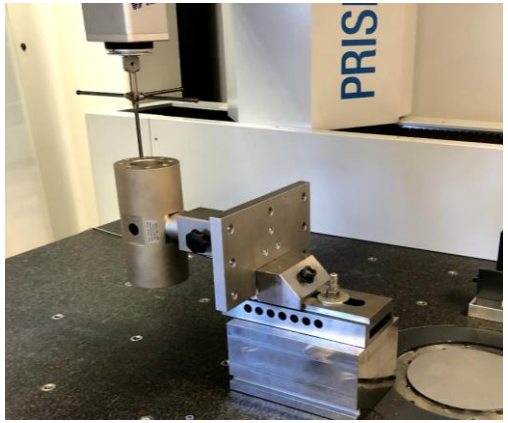


Feature	Element	Dimension
A1 + A2	2 Cylinders (external)	2 Cylinders: D = 100 mm, L = 70 mm
B1 - B8	Pitch circle	D = 12 mm, L = 20 mm, (8 • 45°)
C	Cylinder (internal)	D = 50 mm, L = 20 mm
D	Cylinder (internal)	D = 30 mm , L = 45 mm
E	Plane (ring)	D_internal = 50 mm, D_external = 100 mm
F	Plane (ring)	D_internal = 60 mm, D_external = 100 mm
G	Plane (ring)	D_internal = 40 mm, D_external = 60 mm
H	Cylinder (internal)	D = 60 mm, L = 25 mm
I	Cone (internal)	Angle = 11,4°, L = 45 mm
K	Cone (internal, short)	Angle = 120°, L = 8 mm
L1 + L2	Cylinder (internal)	D = 20 mm, L = 90 mm
M	Cylinder (internal)	D = 20 mm, L = 35 mm
U	Plane	L = 50 mm • 40 mm
V	Plane	L = 50 mm • 40 mm
W	Plane (inclination)	Angle = 10°, L = 50 • (20 – 60) mm

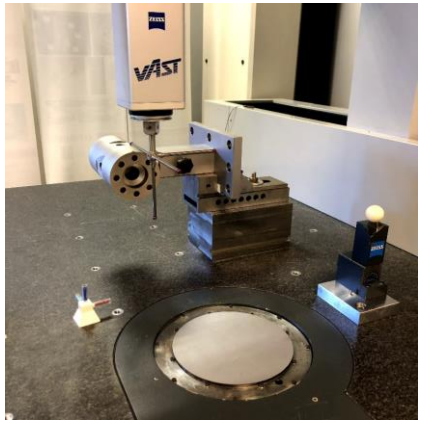




Home Position



X Rotation



Y Rotation

Z Rotation

- Hvad tages med i forberegningerne

Grundfomel

$$y = \frac{1}{n_1 \cdot n_2} \cdot \sum_{j=1}^{n_2} \sum_{i=1}^{n_1} {}^{ij}y$$

Med bidrag

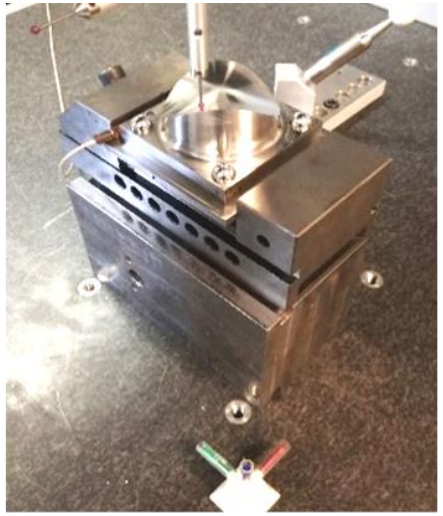
$$U = k \cdot \sqrt{E_L{}^2 + E_D{}^2 + E_{PrbLoc}{}^2 + \frac{u_{rep}^2}{n_1} + \frac{u_{geo}^2}{n_2} + u_{geo\times dist}^2 + u_L^2 + u_D^2 + u_{PrbLoc}^2 + u_{temp}^2}$$

	Taken into account by the U contributors				
Sources of error	u_{rep}	u_{geo} $u_{geo\times dist}$	E_L , u_L	E_D , u_D $E_{PrbLoc,}$ u_{PrbLoc}	u_{temp}
Point-to-point repeatability	■				
Resolution	■				
Dirt on surface and roughness	■				
Geometry errors of the CMM		■			
Relative probe tip location		■		■	
Probe tip directional characteristic		■		■	
Probe tip diameter uncertainty		■		■	
Under-sampling of surfaces	■				
Artefact alignment	■	■			
Temperature gradient variation, drift	■	■	■		■
Clamping, handling		■			
Temp. correction of CMM		■	■		■
Temp. correction of artefact		■	■		■

Regneark

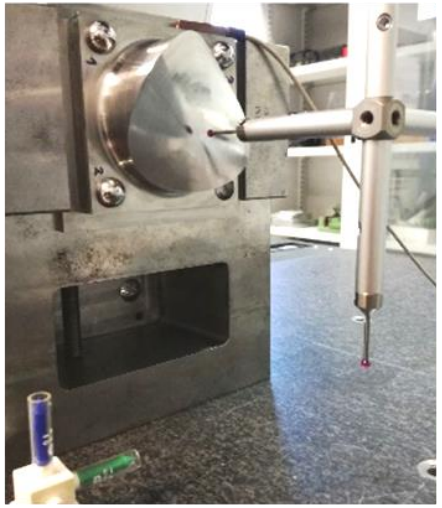
- Et for alm emnegeometri
- Et for friformsgeometri

Friformsgeometri



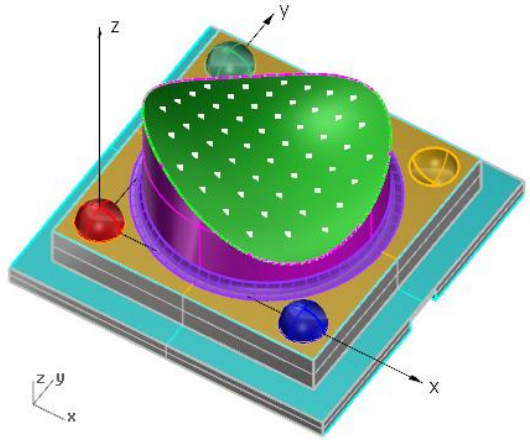
Home position

Rx



Ry

Rz



52 probing points disposition

A23

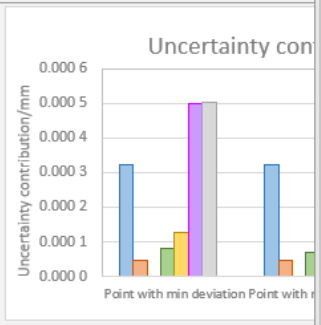
	A	B	C	D	E	F	G	H	I	J	K	L
1	**LENGTH STANDARD MEASUREMENT**						**DIAMETER STANDARD MEASUREMENT**					
2		Cycle	X	Y	Z			Cycle	Probe 1	Probe 2	Probe 3	Probe 4
3		1	199.8875	199.8873	199.8864			1	15.0012	15.0012	15.0011	
4	Measuremet results of length	2	199.8876	199.8873	199.8864		Measuremet results of diameter	2	15.0012	15.0011	15.0011	
5	standard	3	199.8875	199.8873	199.8864		standard	3	15.0011	15.0012	15.0011	
6		4	199.8875	199.8873	199.8864			4	15.0012	15.0012	15.0011	
7		5	199.8875	199.8873	199.8864			5	15.0012	15.0012	15.0011	
8	Calibrated value	Lc	199.8874				Calibrated value	Dc	15.0012			
9	Expanded calibration uncertainty	U L,c	0.0007				Expanded calibration uncertainty	U D,c	0.0010			
10	Number of cycles	n3	5				Number of cycles	n5	5			
11	Number of orientations	n4	3				Number of probes	n6	3			
12	Average per orientation	jLm	199.8875	199.8873	199.8864		Average per orientation	jDm	15.0012	15.0012	15.0011	
13	Average total	Lm	199.8871				Average total	Dm	15.0012			
14	Consider scale error	Yes					Consider probe error	Yes				
15	**Scale error**	**EL**	**-0.0003**				**Probe size error**	**ED**	0.0000			
16	Repeatebility uncertainty	u L,rep	0.00001				Repeatebility uncertainty	u D,rep	0.00004			
17	Orientation uncertainty	u L,geo	0.00062				Orientation uncertainty	u D,geo	0.00004			
18	**Scale error uncertainty**	**uL**	**0.0005**				**Probe size error uncertainty**	**uD**	**0.00050**			
19							Multi-stylus measurement	Yes				
20							**Probe location error**	**E D,Loc**	**0.00000**			
21							**Probe location error uncertainty**	**u D,Loc**	**0.00000**			
22							Coordinates of LSM spheres	Coords	Probe 1	Probe 2	Probe 3	Probe 4
23							Cycle 1	x	0.0000	0.0000	0.0000	
24								y	0.0000	0.0000	0.0000	
25								z	0.0000	0.0000	0.0000	
26								x	0.0000	0.0000	0.0000	

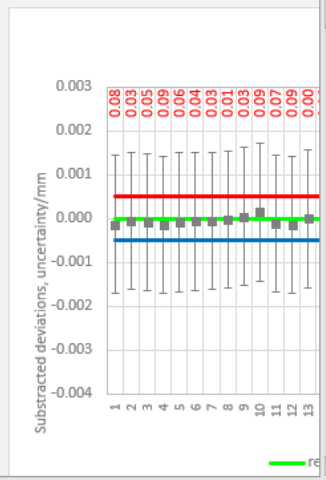
Hyperbolic_Paraboloid_UMPC deviations.xlsm

HYPERBOLIC PARABOLOID MEASUREMENT

	Coverage factor k	2	Cycle 1				Cycle 2				Cycle 3				Cycle 4				Cycle 5				Point deviation	Expanded point uncertainty	Calibrated value	Uncertainty of calibrated value	En number
		min	-0.0074	-0.0079	-0.0078	-0.0075	-0.0074	-0.0077	-0.0075	-0.0076	-0.0074	-0.0077	-0.0075	-0.0076	-0.0075	-0.0077	-0.0076	-0.0076	-0.0074	-0.0078	-0.0076	-0.0076	-0.007 59	0.001 56	-0.006 10	0.000 50	0.002 18
		max	0.0079	0.0077	0.0078	0.0083	0.0079	0.0077	0.0080	0.0083	0.0079	0.0077	0.0080	0.0083	0.0078	0.0077	0.0081	0.0082	0.0078	0.0076	0.0080	0.0083	0.007 82	0.001 62	0.008 05	0.000 50	0.915 96
	Measured feature		11 y	12 y	13 y	14 y	21 y	22 y	23 y	24 y	31 y	32 y	33 y	34 y	41 y	42 y	43 y	44 y	51 y	52 y	53 y	54 y	y Point	U point	y point, ref	U ref	En
	Point	1	0.0061	0.0059	0.0058	0.0059	0.0060	0.0060	0.0058	0.0059	0.0060	0.0060	0.0060	0.0059	0.0060	0.0059	0.0059	0.0059	0.0059	0.0059	0.0059	0.0059	0.005 93	0.001 56	0.006 06	0.000 50	0.08
	Point	2	0.0038	0.0040	0.0038	0.0039	0.0038	0.0040	0.0039	0.0040	0.0039	0.0041	0.0040	0.0039	0.0038	0.0041	0.0039	0.0038	0.0038	0.0040	0.0039	0.0038	0.003 91	0.001 56	0.003 95	0.000 50	0.03
	Point	3	0.0024	0.0027	0.0022	0.0024	0.0022	0.0027	0.0023	0.0024	0.0023	0.0027	0.0023	0.0023	0.0023	0.0026	0.0022	0.0023	0.0022	0.0026	0.0022	0.0021	0.002 37	0.001 57	0.002 46	0.000 50	0.05
	Point	4	0.0009	0.0009	0.0009	0.0005	0.0008	0.0009	0.0005	0.0006	0.0008	0.0010	0.0006	0.0006	0.0008	0.0009	0.0005	0.0005	0.0008	0.0009	0.0006	0.0006	0.000 73	0.001 57	0.000 88	0.000 50	0.09
	Point	5	-0.0008	-0.0009	-0.0014	-0.0014	-0.0008	-0.0008	-0.0013	-0.0014	-0.0008	-0.0008	-0.0013	-0.0013	-0.0008	-0.0008	-0.0013	-0.0014	-0.0008	-0.0008	-0.0013	-0.0014	-0.001 09	0.001 59	-0.001 00	0.000 50	0.06
	Point	6	0.0016	0.0012	0.0013	0.0014	0.0016	0.0013	0.0014	0.0014	0.0015	0.0013	0.0014	0.0014	0.0016	0.0013	0.0014	0.0013	0.0015	0.0013	0.0014	0.0014	0.001 40	0.001 56	0.001 46	0.000 50	0.04
	Point	7	0.0006	0.0006	0.0005	0.0004	0.0005	0.0006	0.0004	0.0006	0.0005	0.0008	0.0005	0.0005	0.0005	0.0007	0.0004	0.0005	0.0005	0.0006	0.0004	0.0005	0.000 53	0.001 56	0.000 57	0.000 50	0.03
	Point	8	0.0009	0.0007	0.0007	0.0007	0.0009	0.0007	0.0006	0.0007	0.0009	0.0007	0.0006	0.0007	0.0008	0.0007	0.0007	0.0007	0.0008	0.0007	0.0006	0.0007	0.000 73	0.001 56	0.000 75	0.000 50	0.01
	Point	9	0.0024	0.0020	0.0021	0.0023	0.0023	0.0021	0.0023	0.0023	0.0024	0.0021	0.0023	0.0023	0.0023	0.0021	0.0022	0.0023	0.0023	0.0020	0.0023	0.0023	0.002 24	0.001 57	0.002 18	0.000 50	0.03
	Point	10	0.0031	0.0033	0.0032	0.0034	0.0031	0.0033	0.0034	0.0034	0.0032	0.0033	0.0035	0.0033	0.0031	0.0033	0.0035	0.0033	0.0031	0.0033	0.0034	0.0033	0.003 28	0.001 56	0.003 13	0.000 50	0.09
	Point	11	0.0033	0.0033	0.0031	0.0035	0.0032	0.0034	0.0033	0.0034	0.0034	0.0033	0.0034	0.0034	0.0032	0.0033	0.0034	0.0034	0.0032	0.0032	0.0033	0.0034	0.003 32	0.001 56	0.003 44	0.000 50	0.07
	Point	12	0.0078	0.0077	0.0078	0.0079	0.0077	0.0077	0.0080	0.0080	0.0078	0.0077	0.0080	0.0079	0.0077	0.0076	0.0081	0.0079	0.0077	0.0076	0.0080	0.0079	0.007 82	0.001 57	0.007 96	0.000 50	0.09
	Point	13	0.0057	0.0057	0.0056	0.0055	0.0056	0.0058	0.0057	0.0056	0.0057	0.0058	0.0058	0.0056	0.0057	0.0058	0.0058	0.0056	0.0056	0.0058	0.0058	0.0056	0.005 69	0.001 56	0.005 69	0.000 50	0.00
	Point	14	0.0042	0.0042	0.0039	0.0039	0.0041	0.0043	0.0039	0.0040	0.0042	0.0043	0.0039	0.0040	0.0041	0.0043	0.0041	0.0039	0.0040	0.0042	0.0042	0.0039	0.004 08	0.001 57	0.003 99	0.000 50	0.06
	Point	15	0.0051	0.0051	0.0050	0.0050	0.0049	0.0053	0.0051	0.0050	0.0050	0.0052	0.0051	0.0050	0.0050	0.0052	0.0051	0.0049	0.0050	0.0052	0.0050	0.0049	0.005 05	0.001 56	0.004 95	0.000 50	0.06
	Point	16	-0.0019	-0.0020	-0.0021	-0.0023	-0.0020	-0.0019	-0.0021	-0.0022	-0.0020	-0.0019	-0.0021	-0.0022	-0.0020	-0.0019	-0.0020	-0.0023	-0.0020	-0.0019	-0.0021	-0.0023	-0.002 06	0.001 57	-0.001 96	0.000 50	0.06
	Point	17	0.0000	-0.0005	-0.0007	-0.0005	0.0000	-0.0002	-0.0006	-0.0004	0.0000	-0.0004	-0.0006	-0.0005	0.0000	-0.0003	-0.0006	-0.0005	0.0000	-0.0003	-0.0006	-0.0005	-0.000 36	0.001 58	-0.000 32	0.000 50	0.02
	Point	18	-0.0018	-0.0022	-0.0024	-0.0025	-0.0019	-0.0021	-0.0024	-0.0024	-0.0017	-0.0021	-0.0024	-0.0024	-0.0018	-0.0022	-0.0023	-0.0024	-0.0018	-0.0021	-0.0024	-0.0025	-0.002 19	0.001 59	-0.002 07	0.000 50	0.07
	Point	19	-0.0008	-0.0013	-0.0017	-0.0014	-0.0008	-0.0012	-0.0014	-0.0013	-0.0008	-0.0012	-0.0015	-0.0013	-0.0008	-0.0013	-0.0015	-0.0014	-0.0008	-0.0013	-0.0013	-0.0013	-0.001 22	0.001 59	-0.001 23	0.000 50	0.01
	Point	20	-0.0023	-0.0029	-0.0028	-0.0026	-0.0024	-0.0028	-0.0027	-0.0025	-0.0023	-0.0028	-0.0028	-0.0025	-0.0023	-0.0028	-0.0028	-0.0026	-0.0023	-0.0028	-0.0028	-0.0026	-0.002 62	0.001 57	-0.002 68	0.000 50	0.04
	Point	21	0.0031	0.0028	0.0027	0.0028	0.0030	0.0029	0.0026	0.0029	0.0030	0.0029	0.0027	0.0029	0.0030	0.0029	0.0029	0.0029	0.0030	0.0028	0.0027	0.0029	0.002 87	0.001 57	0.002 87	0.000 50	0.00
	Point	22	0.0018	0.0017	0.0017	0.0019	0.0018	0.0018	0.0018	0.0020	0.0019	0.0018	0.0018	0.0019	0.0018	0.0018	0.0017	0.0019	0.0018	0.0018	0.0017	0.0019	0.001 81	0.001 56	0.001 78	0.000 50	0.01
	Point	23	-0.0002	-0.0004	-0.0005	0.0000	-0.0002	-0.0003	-0.0003	-0.0002	-0.0002	-0.0003	-0.0003	-0.0002	-0.0003	-0.0003	-0.0003	-0.0002	-0.0003	-0.0003	-0.0004	-0.0002	-0.000 27	0.001 56	-0.000 44	0.000 50	0.10
	Point	24	0.0024	0.0017	0.0015	0.0021	0.0020	0.0018	0.0017	0.0020	0.0021	0.0017	0.0017	0.0019	0.0019	0.0018	0.0019	0.0019	0.0018	0.0017	0.0017	0.0019	0.001 86	0.001 57	0.001 72	0.000 50	0.08
	Point	25	0.0046	0.0043	0.0046	0.0048	0.0045	0.0044	0.0047	0.0049	0.0046	0.0044	0.0048	0.0047	0.0045	0.0044	0.0049	0.0048	0.0045	0.0043	0.0048	0.0048	0.004 61	0.001 57	0.004 55	0.000 50	0.03
	Point	26	0.0041	0.0039	0.0040	0.0045	0.0040	0.0040	0.0043	0.0044	0.0042	0.0040	0.0043	0.0043	0.0040	0.0041	0.0044	0.0044	0.0040	0.0040	0.0042	0.0044	0.004 17	0.001 57	0.004 08	0.000 50	0.06
	Point	27	0.0053	0.0055	0.0055	0.0057	0.0053	0.0056	0.0058	0.0056	0.0054	0.0056	0.0058	0.0056	0.0052	0.0056	0.0059	0.0057	0.0053	0.0056	0.0057	0.0056	0.005 57	0.001 57	0.005 71	0.000 50	0.08
	Point	28	0.0017	0.0017	0.0018	0.0019	0.0017	0.0018	0.0020	0.0018	0.0017	0.0018	0.0021	0.0018	0.0016	0.0018	0.0021	0.0018	0.0016	0.0018	0.0019	0.0018	0.001 82	0.001 57	0.001 76	0.000 50	0.03
	Point	29	-0.0033	-0.0034	-0.0034	-0.0030	-0.0022	-0.0032	-0.0031	-0.0030	-0.0026	-0.0033	-0.0032	-0.0031	-0.0031	-0.0033	-0.0031	-0.0032	-0.0032	-0.0033	-0.0032	-0.0032	-0.003 11	0.001 58	-0.002 53	0.000 50	0.35
	Point	30	-0.0074	-0.0079	-0.0078	-0.0075	-0.0074	-0.0077	-0.0075	-0.0076	-0.0074	-0.0077	-0.0075	-0.0076	-0.0075	-0.0077	-0.0076	-0.0076	-0.0074	-0.0078	-0.0076	-0.0076	-0.007 59	0.001 57	-0.006 10	0.000 50	0.91

$$U = k\sqrt{E_L^2 + E_D^2 + E_{D,Loc}^2 + \frac{u_{rep}^2}{n_1} -}$$

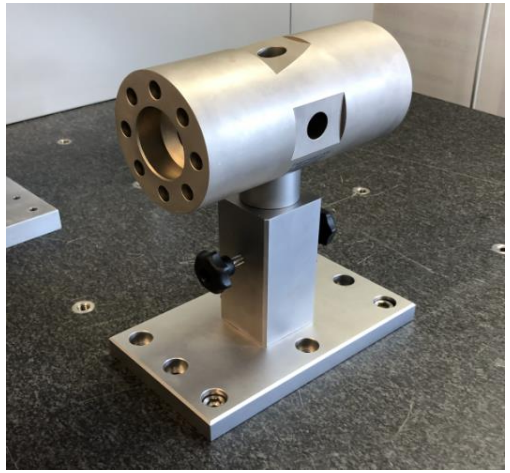


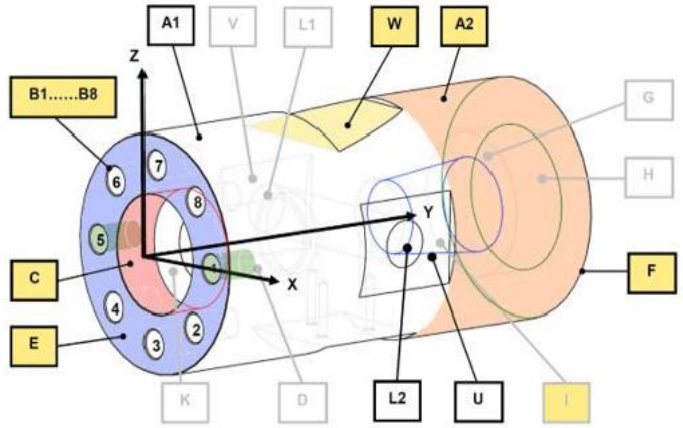


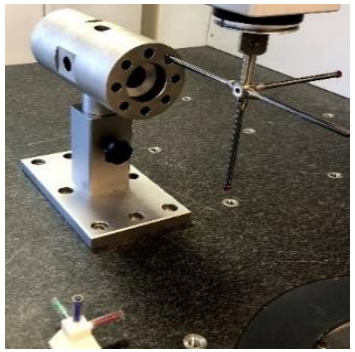
UPMC 850 | Scale-Probe | HP

Ready

Standard geometri

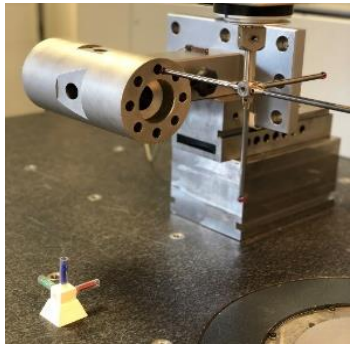




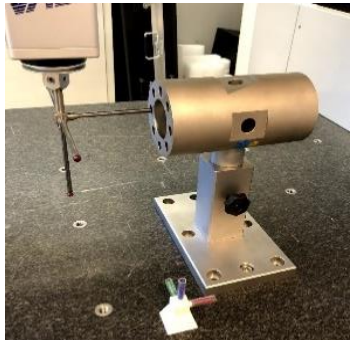


Home position

Rx



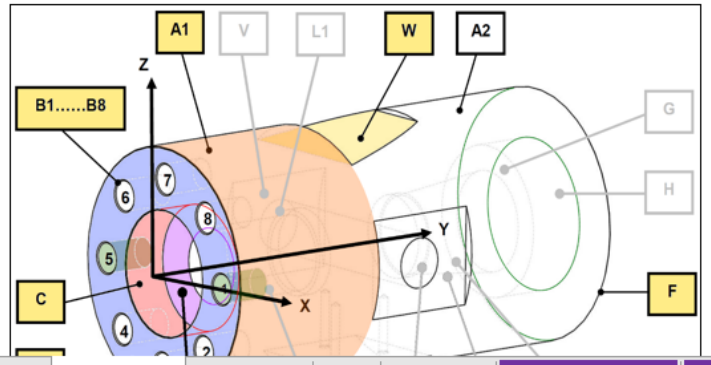
Ry



Rz

Instructions

	Length standard measurement
1	Enter the measurement and calibration data (in **millimetres**) of the length standard in the yellow cells on Scale-Probe sheet (section LENGTH STANDARD MEASUREMENT)
2	The scale error EL and scale error uncertainty uL are calculated
	Diameter standard measurement
3	Enter the measurement and calibration data (in **millimetres**) of the diameter standard in the Scale-Probe sheet (section DIAMETER STANDARD
4	In case of a multi-stylus measurement, enter the cartesian coordinates of LSM spheres centres (in **millimetres**) in the yellow cells
5	The probe errors ED, ED,Loc and uncertainties uD, uD,Loc are calculated
	Multi-feature check measurement
6	Enter the value of coverage factor k
7	Select how individual contributions should be treated. They can be included in the combined uncertainty, corrected or be turned off to be ignored. A corrected value is only displayed if at least one contribution is
8	Enter the measurements (in **millimetres** or **degrees**) in the yellow cells on MFC sheet
9	Graph of uncertainty contributions is updated
10	Graph of subtracted deviations is updated



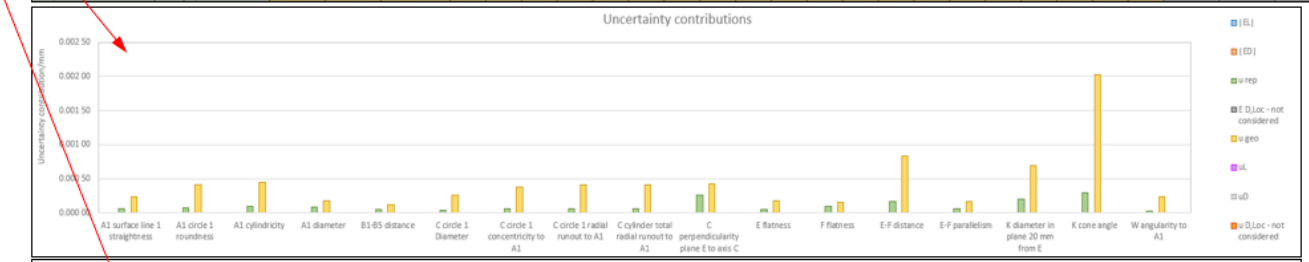
DIAMETER STANDARD MEASUREMENT

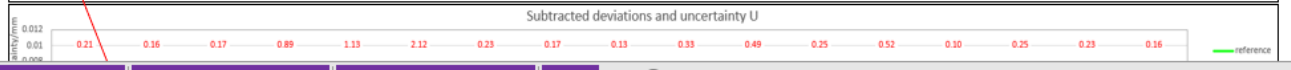
	Cycle	Probe 1	Probe 2	Probe 3	Probe 4	Probe 5
Measuremet results of diameter standard	1	29.991 244 8	29.992 018 6	29.991 988 2	29.992 188 2	
	2	29.991 295 1	29.992 048 5	29.992 009 5	29.992 224 8	
	3	29.991 263 4	29.992 110 3	29.991 961 3	29.992 151 7	
	4	29.991 270 2	29.992 059 8	29.992 060 8	29.992 185 3	
	5	29.991 292 9	29.992 054 2	29.992 035 2	29.992 146 1	
Calibrated value	Dc	29.991 43				
Expanded calibration uncertainty	U D,c	0.000 3				
Probe size error	ED	0.000 450 445				
Probe size error uncertainty	uD	0.000 256 350				
Probe location error	E D,Loc	0.000 000 000				
Probe location error uncertainty	u D,Loc	0.000 000 000				
coordinates of LSM spheres centres	Coords	Probe 1	Probe 2	Probe 3	Probe 4	Probe 5
Cycle 1	x	0.000 000 0	0.000 000 0	0.000 000 0	0.000 000 0	
	y	0.000 000 0	0.000 000 0	0.000 000 0	0.000 000 0	
	z	0.000 000 0	0.000 000 0	0.000 000 0	0.000 000 0	
Cycle 2	x	0.000 033 1	-0.000 007 4	-0.000 000 5	-0.000 044 6	
	y	0.000 017 1	0.000 030 7	0.000 025 2	0.000 072 8	
	z	-0.000 030 8	-0.000 019 5	-0.000 021 8	0.000 012 6	
Cycle 3	x	0.000 020 5	-0.000 086 0	0.000 004 8	-0.000 025 1	
	y	-0.000 006 6	0.000 064 5	0.000 034 8	0.000 047 9	
	z	-0.000 035 5	-0.000 026 6	-0.000 020 5	0.000 014 6	
Cycle 4	x	0.000 069 6	-0.000 026 3	0.000 000 6	-0.000 045 3	
	y	0.000 008 2	0.000 076 5	-0.000 033 0	0.000 098 0	
	z	-0.000 043 0	-0.000 014 0	-0.000 028 8	0.000 046 9	
Cycle 5	x	0.000 058 0	-0.000 028 9	0.000 000 3	-0.000 026 4	
	y	-0.000 000 4	0.000 069 6	-0.000 006 9	0.000 083 9	
	z	-0.000 059 7	-0.000 044 1	-0.000 069 7	0.000 039 9	

CONNECTING ROD MEASUREMENT

Coverage factor k = 2

Measured feature	#	Measurand type	Include uncertainty contributions: Scale, EL	Probe, ED	Multi-stylus, Loc	Cycle 1: 11 y	12 y	13 y	14 y	Cycle 2: 21 y	22 y	23 y	24 y	Cycle 3: 31 y	32 y	33 y	34 y	Cycle 4: 41 y	42 y	43 y	44 y	Cycle 5: 51 y	52 y	53 y	54 y	Measurement value: y	Corrected measurement value: y corr	Expanded combined standard uncertainty: U	Calibrated value: y ref	Uncertainty of calibrated value: U ref	En number: En
A1 surface line 1 straightness	A1	CAD deviation, Geom. fe	as uncertainty	as uncertainty	Off	0.0033	0.0034	0.0031	0.0032	0.0034	0.0034	0.0032	0.0033	0.0035	0.0034	0.0031	0.0033									0.005 30	---	0.000 56	0.007 66	0.000 60	-5.31
A1 circle 1 roundness	A1	Deviation from LS Eleme	as uncertainty	as uncertainty	Off	0.0029	0.0028	0.0027	0.0025	0.0029	0.0028	0.0028	0.0025	0.0037	0.0029	0.0027	0.0026									0.002 83	---	0.000 65	0.007 68	0.000 60	-5.46
A1 cylindricity	A1	Deviation from LS Eleme	as uncertainty	as uncertainty	Off	0.0057	0.0041	0.0047	0.0044	0.0054	0.0041	0.0046	0.0047	0.0055	0.0042	0.0046	0.0043									0.004 68	---	0.000 82	0.008 42	0.000 60	-3.68
A1 diameter	A1	Diameter (internal)	as uncertainty	as uncertainty	Off	99.8974	99.8993	99.8983	99.8983	99.8974	99.8993	99.8983	99.8983	99.8974	99.8993	99.8983	99.8983									99.898 31	---	0.000 96	99.895 28	0.000 67	2.59
B1-B5 distance	B1, B5	Length distance	as uncertainty	as uncertainty	Off	74.9977	74.9983	74.9979	74.9982	74.9976	74.9983	74.9978	74.9983	74.9978	74.9978	74.9983	74.9983									74.998 02	---	0.000 64	74.998 06	0.000 65	-0.04
C circle 1 Diameter	C	Diameter (internal)	as uncertainty	as uncertainty	Off	50.0348	50.0337	50.0347	50.0343	50.0348	50.0336	50.0347	50.0343	50.0348	50.0336	50.0347	50.0344									50.034 37	---	0.000 75	50.034 99	0.000 64	-0.63
C circle 1 concentricity to A1	C, A1	CAD deviation, Geom. fe	as uncertainty	as uncertainty	Off	0.0026	0.0023	0.0030	0.0029	0.0026	0.0022	0.0027	0.0027	0.0026	0.0026	0.0030	0.0025									0.002 64	---	0.000 61	0.002 18	0.000 60	0.54
C circle 1 radial runout to A1	C, A1	CAD deviation, Geom. fe	as uncertainty	as uncertainty	Off	0.0041	0.0038	0.0046	0.0043	0.0041	0.0038	0.0043	0.0042	0.0042	0.0037	0.0048	0.0040									0.004 16	---	0.000 65	0.003 58	0.000 65	0.85
C cylinder total radial runout to A1	C, A1	CAD deviation, Geom. fe	as uncertainty	as uncertainty	Off	0.0068	0.0039	0.0049	0.0045	0.0079	0.0040	0.0044	0.0043	0.0042	0.0039	0.0048	0.0045									0.004 83	---	0.001 51	0.003 46	0.000 85	0.79
C perpendicularity plane E to axis C	C, E	CAD deviation, Geom. fe	as uncertainty	as uncertainty	Off	0.0118	0.0117	0.0108	0.0128	0.0113	0.0112	0.0109	0.0127	0.0113	0.0117	0.0105	0.0133									0.011 75	---	0.001 09	0.011 55	0.001 48	0.08
E flatness	E	Deviation from LS Eleme	as uncertainty	as uncertainty	Off	0.0053	0.0051	0.0044	0.0050	0.0052	0.0051	0.0044	0.0051	0.0052	0.0055	0.0044	0.0050									0.004 97	---	0.000 68	0.003 58	0.000 60	1.53
F flatness	F	Deviation from LS Eleme	as uncertainty	as uncertainty	Off	0.0040	0.0031	0.0024	0.0030	0.0030	0.0035	0.0024	0.0032	0.0028	0.0037	0.0027	0.0026									0.003 03	---	0.000 79	0.001 91	0.000 60	1.13
E-F distance	E, F	Length distance	as uncertainty	as uncertainty	Off	199.6272	199.6281	199.6279	199.6267	199.6272	199.6281	199.6279	199.6267	199.6272	199.6281	199.6280	199.6268									199.627 49	---	0.000 85	199.626 77	0.000 74	0.64
E-F parallelism	E, F	CAD deviation, Geom. fe	as uncertainty	as uncertainty	Off	0.0079	0.0079	0.0080	0.0071	0.0078	0.0078	0.0080	0.0074	0.0075	0.0077	0.0081	0.0074									0.007 71	---	0.000 64	0.006 46	0.000 60	1.42
K diameter in plane 20 mm from E	K, E	Diameter (internal)	as uncertainty	as uncertainty	Off	49.4631	49.4645	49.4641	49.4601	49.4577	49.4650	49.4654	49.4634	49.4627	49.4651	49.4661	49.4643									49.463 45	---	0.002 79	49.461 94	0.000 63	0.53
K cone angle	K	Angle size	as uncertainty	as uncertainty	Off	120.0410	120.0319	120.0270	120.0191	120.0211	120.0139	120.0299	120.0268	120.0425	120.0338	120.0323	120.0328									120.031 01	---	0.000 14	120.024 50	0.002 50	0.76
W angularity to A1	W, A1	Angle distance	as uncertainty	as uncertainty	Off	0.0306	0.0302	0.0305	0.0304	0.0307	0.0303	0.0305	0.0127	0.0308	0.0304	0.0304	0.0308									0.029 02	---	0.000 61	0.028 98	0.000 60	0.01





Cut Copy Format Painter | Calibri 11 | Wrap Text | General | Merge & Center | Conditional Formatting | Format as Table | Normal 2 | Normal 2 2 | Normal 2 2 2 | Normal 3 | Normal 3 2 | Normal 4 | Insert | Delete | Format | AutoSum | Fill | Clear | Sort & Filter | Find & Select | Analyze Data | Sensitivity

A31

LENGTH STANDARD MEASUREMENT

	Cycle	X	Y	Z
Measuremet results of length standard	1	199.8875	199.8873	199.8864
	2	199.8876	199.8873	199.8864
	3	199.8875	199.8873	199.8864
	4	199.8875	199.8873	199.8864
	5	199.8875	199.8873	199.8864
Calibrated value	Lc	199.8874		
Expanded calibration uncertainty	U L,c	0.0007		
Scale error	**EL**	**-0.0003**		
Scale error uncertainty	**uL**	**0.0005**		

DIAMETER STANDARD MEASUREMENT

	Cycle	Probe 1	Probe 2	Probe 3	Probe 4	Probe 5
Measuremet results of diameter standard	1	15.0011	15.0011			
	2	15.0011	15.0012			
	3	15.0011	15.0012			
	4	15.0011	15.0012			
	5	15.0011	15.0011			
Calibrated value	Dc	15.0012				
Expanded calibration uncertainty	U D,c	0.0001				
Probe size error	**ED**	**-0.0001**				
Probe size error uncertainty	**uD**	**0.0001**				
Multi-stylus measurement	Yes					
Probe location error	**E D,Loc**	**0.0003**				
Probe location error uncertainty	**u D,Loc**	**0.0001**				
Coordinates of LSM spheres centres	Coords	Probe 1	Probe 2	Probe 3	Probe 4	Probe 5
Cycle 1	x	0.0000	0.0001			
	y	0.0000	-0.0002			
	z	0.0000	0.0000			
Cycle 2	x	0.0000	0.0001			
	y	0.0000	-0.0003			
	z	0.0000	0.0000			
Cycle 3	x	0.0000	0.0000			
	y	0.0000	-0.0003			
	z	0.0000	0.0000			
Cycle 4	x	0.0000	0.0000			
	y	0.0000	-0.0003			
	z	0.0000	0.0000			
Cycle 5	x	0.0000	0.0000			
	y	0.0000	-0.0002			
	z	0.0000	-0.0001			

AutoSave Off | UMPC 850 PTB MFC_LQ.xlsm | Search | Jens Bo Toftegaard

File Home Insert Page Layout Formulas Data Review View Help Kofax PDF SOLIDWORKS PDM | Share | Comments

Paste Cut Copy Format Painter | Calibri 11 | Wrap Text | Merge & Center | Number | Conditional Formatting | Format as Table | Normal 3 | Normal 3 2 | Normal 4 | Normal 4 2 | Normal 5 | Normal | Insert | Delete | Format | AutoSum | Fill | Clear | Sort & Filter | Find & Select | Analyze Data | Sensitivity

Clipboard | Font | Alignment | Number | Styles | Cells | Editing | Analysis | Sensitivity

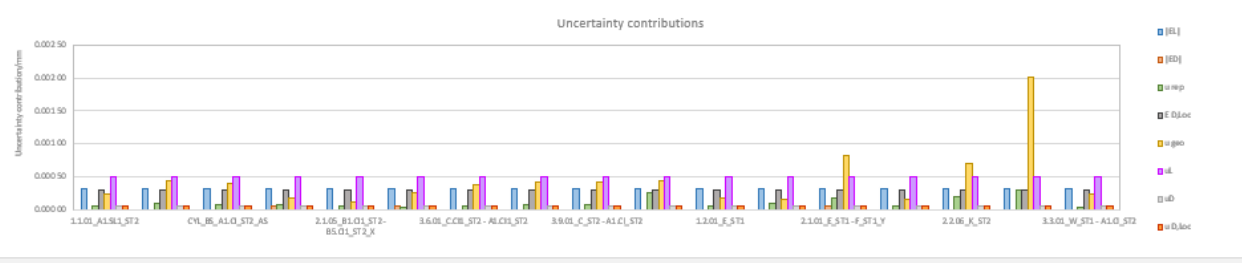
AG4 0.0024

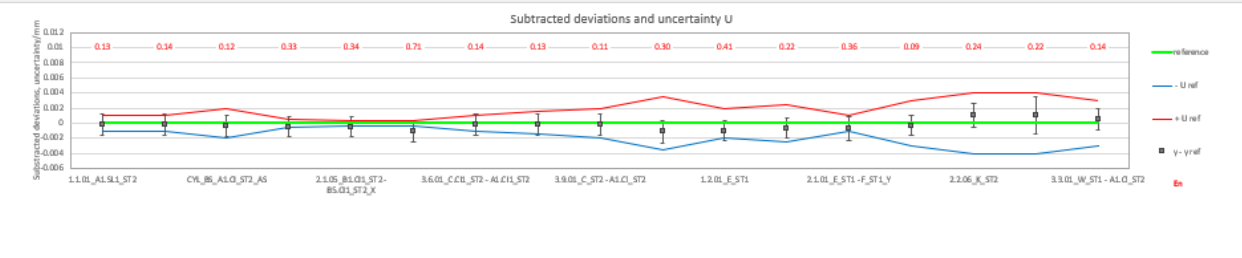
DTI UPMC 850

Coverage factor k	2		Cycle 1				Cycle 2				Cycle 3				Cycle 4				Cycle 5				Measurement value	Averages per orientations				Repeatability uncertainty	Geometry uncertainty	Combined standard uncertainty	Expanded combined standard uncertainty	Calibrated value	Uncertainty of calibrated value	En number
Measured feature			11 y	12 y	13 y	14 y	21 y	22 y	23 y	24 y	31 y	32 y	33 y	34 y	41 y	42 y	43 y	44 y	51 y	52 y	53 y	54 y	y	1y	2y	3y	4y	u rep	u geo	u	U	y ref	U ref	En
1.1.01_A1.Sl1_ST2	A1	Straightness (ISO 1101) of external generating line on Ø100 based on 1100 points	0.0023	0.0021	0.0019	0.0025	0.0023	0.0021	0.0019	0.0024	0.0025	0.0021	0.0019	0.0025	0.0022	0.0021	0.0019	0.0023	0.0023	0.0021	0.0019	0.0024	**0.002 18**	0.0023	0.0021	0.0019	0.0024	0.0001	0.0002	0.0007	**0.0014**	**0.0024**	**0.0010**	**0.13**
1.3.01_A1_Cl1_ST2	A1	Roundness (ISO 1101) of Ø100 external bore based on 3200 points	0.0097	0.0106	0.0095	0.0099	0.0098	0.0105	0.0094	0.0099	0.0102	0.0105	0.0094	0.0099	0.0097	0.0105	0.0094	0.0100	0.0099	0.0105	0.0095	0.0100	**0.009 95**	0.0099	0.0105	0.0095	0.0100	0.0001	0.0004	0.0007	**0.0014**	**0.0102**	**0.0011**	**0.14**
CYL_BS_A1.Cl_ST2_AS	A1	Form error of external cylinder. 5 sections in all 16000 point	0.0098	0.0106	0.0096	0.0100	0.0098	0.0105	0.0095	0.0099	0.0101	0.0106	0.0096	0.0101	0.0098	0.0106	0.0096	0.0100	0.0098	0.0106	0.0097	0.0100	**0.010 02**	0.0099	0.0106	0.0096	0.0100	0.0001	0.0004	0.0007	**0.0014**	**0.0103**	**0.0020**	**0.12**
2.2.01_A1.Cl_ST2	A1	GG Calculated diameter of external cylinder based on 5 sections with 16000 points in all	100.0162	100.0158	100.0164	100.0160	100.0162	100.0158	100.0163	100.0160	100.0162	100.0158	100.0162	100.0160	100.0161	100.0157	100.0161	100.0160	100.0161	100.0157	100.0160	100.0160	**100.016 02**	100.0162	100.0158	100.0162	100.0160	0.0001	0.0002	0.0007	**0.0014**	**88888**	**0.0005**	**0.33**
2.1.05_B1.Cl1_ST2 - B5.Cl1_ST2_X	B1, B5	Distance between the center of 2 Ø12 bores	74.9998	74.9996	74.9998	74.9995	74.9998	74.9995	74.9997	74.9995	74.9998	74.9995	74.9997	74.9996	74.9997	74.9994	74.9996	74.9996	74.9997	74.9994	74.9996	74.9996	**74.999 62**	74.9998	74.9995	74.9997	74.9996	0.0001	0.0001	0.0007	**0.0014**	**75.0001**	**0.0004**	**0.34**
2.2.04_C.Cl1_ST2	C	GG Calculated diameter of internal diameter 5mm from front with 3200 points	50.0535	50.0539	50.0537	50.0541	50.0535	50.0538	50.0537	50.0541	50.0536	50.0538	50.0536	50.0541	50.0536	50.0538	50.0536	50.0541	50.0536	50.0538	50.0535	50.0542	**50.053 79**	50.0535	50.0538	50.0536	50.0541	0.0000	0.0003	0.0007	**0.0014**	**88888**	**0.0004**	**0.71**
3.6.01_C.Cl1_ST2 - A1.Cl1_ST2	C, A1	Concentricity (ISO 1101) of Ø50 with Ø100external diameter as Datum 5mm from front face	0.0574	0.0565	0.0565	0.0570	0.0573	0.0565	0.0565	0.0570	0.0573	0.0565	0.0565	0.0570	0.0573	0.0566	0.0566	0.0570	0.0573	0.0566	0.0567	0.0571	**0.056 85**	0.0573	0.0565	0.0566	0.0570	0.0001	0.0004	0.0007	**0.0014**	**0.0571**	**0.0010**	**0.14**
3.8.01_C.Cl1_ST2 - A1.Cl_ST2	C, A1	Radial Runout as section (ISO 1101) of internal Ø50 bore with external Cylinder as datum	0.0579	0.0572	0.0569	0.0577	0.0578	0.0571	0.0569	0.0577	0.0579	0.0572	0.0569	0.0577	0.0579	0.0573	0.0570	0.0577	0.0579	0.0573	0.0571	0.0577	**0.057 44**	0.0579	0.0572	0.0570	0.0577	0.0001	0.0004	0.0007	**0.0014**	**0.0577**	**0.0015**	**0.13**
3.9.01_C_ST2 - A1.Cl_ST2	C, A1	Total Radial Runout (ISO 1101) of internal Ø50 bore with external Cylinder as datum	0.0579	0.0572	0.0569	0.0577	0.0578	0.0571	0.0569	0.0577	0.0579	0.0572	0.0569	0.0577	0.0579	0.0573	0.0570	0.0577	0.0579	0.0573	0.0571	0.0577	**0.057 44**	0.0579	0.0572	0.0570	0.0577	0.0001	0.0004	0.0007	**0.0014**	**0.0577**	**0.0020**	**0.11**
3.2.03_E_ST1 - C_ST2	C, E	Perpendicularity (ISO1101) between fron plane and internal cylinder	0.0095	0.0098	0.0099	0.0107	0.0095	0.0097	0.0100	0.0107	0.0100	0.0097	0.0102	0.0106	0.0104	0.0099	0.0105	0.0110	0.0101	0.0097	0.0103	0.0108	**0.010 15**	0.0099	0.0098	0.0102	0.0108	0.0003	0.0004	0.0007	**0.0014**	**0.0113**	**0.0035**	**0.30**
1.2.01_E_ST1	E	Flatness (ISO 1101) of Fron plan based 2 circular section with in all 6400 points	0.0065	0.0063	0.0062	0.0066	0.0064	0.0063	0.0062	0.0068	0.0065	0.0063	0.0062	0.0066	0.0065	0.0063	0.0062	0.0066	0.0065	0.0063	0.0062	0.0066	**0.006 42**	0.0065	0.0063	0.0062	0.0066	0.0001	0.0002	0.0007	**0.0014**	**0.0074**	**0.0020**	**0.41**
1.2.02_F_ST1	F	Flatness (ISO 1101) of back plan based 2 circular section with in all 7000 points	0.0048	0.0046	0.0052	0.0052	0.0048	0.0046	0.0050	0.0050	0.0048	0.0048	0.0048	0.0049	0.0048	0.0046	0.0050	0.0049	0.0048	0.0048	0.0050	0.0049	**0.004 87**	0.0048	0.0047	0.0050	0.0050	0.0001	0.0002	0.0007	**0.0014**	**0.0055**	**0.0025**	**0.22**
2.1.01_E_ST1 - F_ST1_Y	E, F	Distance between 2 point created from the intersection of the intersection between a plane in each end and a centerline	200.0232	200.0236	200.0239	200.0218	200.0232	200.0236	200.0237	200.0217	200.0232	200.0236	200.0234	200.0217	200.0231	200.0236	200.0233	200.0218	200.0231	200.0235	200.0231	200.0219	**200.023 02**	200.0232	200.0236	200.0235	200.0218	0.0002	0.0008	0.0008	**0.0016**	**88888**	**0.0010**	**0.36**
3.1.01_E_ST1 - F_ST1	E, F	Parallelism (ISO 1101) between 2 outer planes	0.0116	0.0115	0.0115	0.0118	0.0117	0.0114	0.0114	0.0118	0.0117	0.0115	0.0114	0.0118	0.0117	0.0115	0.0115	0.0120	0.0117	0.0116	0.0114	0.0118	**0.011 60**	0.0117	0.0115	0.0114	0.0118	0.0001	0.0002	0.0007	**0.0014**	**0.0119**	**0.0030**	**0.09**
2.2.06_K_ST2	K, E	GG Calculated diameter where the Cone intersects with a plane 20mm from front with 7500 point in all	49.8554	49.8550	49.8559	49.8545	49.8555	49.8552	49.8560	49.8541	49.8558	49.8549	49.8556	49.8540	49.8555	49.8553	49.8554	49.8539	49.8556	49.8552	49.8555	49.8540	**49.855 12**	49.8556	49.8551	49.8557	49.8541	0.0002	0.0007	0.0008	**0.0015**	**49.8541**	**0.0040**	**0.24**
2.3.02_K_ST2	K	Cone angle based on 7500 points	120.0096	120.0133	120.0080	120.0105	120.0101	120.0130	120.0082	120.0103	120.0108	120.0126	120.0082	120.0101	120.0099	120.0132	120.0081	120.0103	120.0104	120.0134	120.0084	120.0104	**120.010 45**	120.0102	120.0131	120.0082	120.0103	0.0003	0.0020	0.0012	**0.0024**	**88888**	**0.0040**	**0.22**
3.3.01_W_ST1 - A1.Cl_ST2	W, A1	Angularity (ISO 1101) between external cylinder and a plane	0.0245	0.0240	0.0246	0.0244	0.0245	0.0240	0.0245	0.0245	0.0245	0.0240	0.0246	0.0244	0.0245	0.0240	0.0246	0.0244	0.0245	0.0240	0.0245	0.0244	**0.024 37**	0.0245	0.0240	0.0246	0.0244	0.0000	0.0002	0.0007	**0.0014**	**0.0239**	**0.0030**	**0.14**
Number of cycles	n1		5				5				5				5				5											0.0007			
Number of orientations	n2		4				4				4				4				4											0.0007			

$$U = k\sqrt{E_L^2 + E_B^2 + E_{D,Loc}^2 + \frac{u_{rep}^2}{n_1} + \frac{u_{geo}^2}{n_2} + u_L^2 + u_D^2 + u_{D,Loc}^2}$$

u values in red omit E_D as it shouldn't have (significant) effect.
Affects straightness, roundness, cylindricity, distance between fitted elements,





Introduction | Scale-Probe | MFC | MFC (DTI) | Dataark Home Pos | Dataark Rot Z 90 deg | Dataark Rot Y 90 deg | Dataark Rot X 90 deg | Dataa ...

Ready | 55 %