Some physical aspects of tactile probes

Jürgen Schneider

1st PACMAN-Workshop, CERN 03.02.2015

AGENDA

01 Introduction

02 Basic principles of Touch-Trigger-Probes

03 Basic principles of Scanning-Probes

04 Aspects of calibration

05 Touching deformable surfaces

06 Checking stability/quality/repeatability of probes (ISO-Tests)

07 Concluding remarks

HEXAGON METROLOGY

Hexagon Group

GLOBAL COVERAGE, LOCAL PRESENCE

Hexagon has a strong local presence across a well-diversified geographical customer base in nearly all industries throughout the world. No individual customer represents more than 1.5 per cent of Hexagon's net sales.

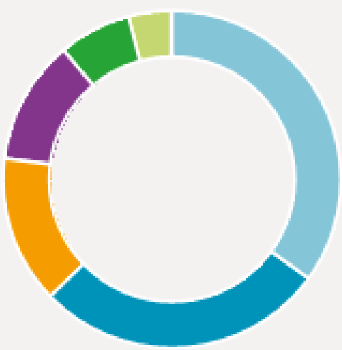
2011 NET SALES

2.2 BN EUR

OPERATIONS IN OVER

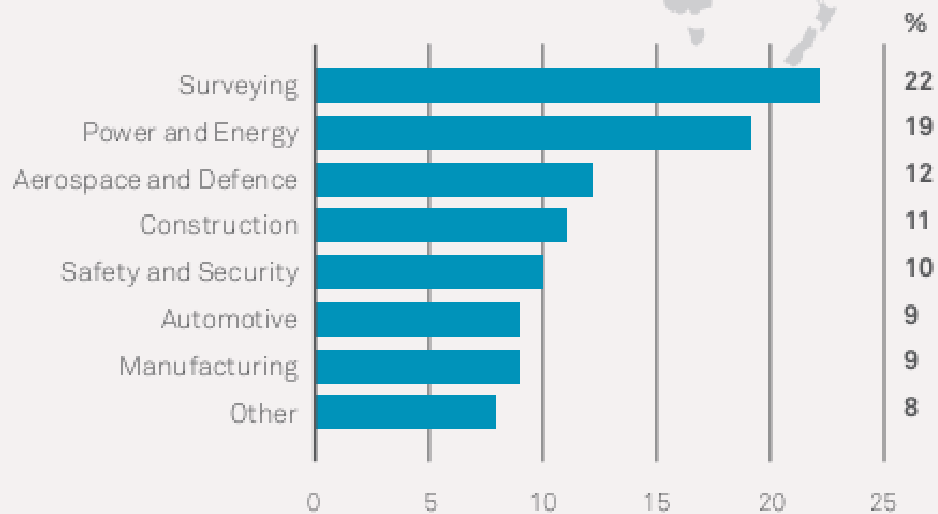
40 COUNTRIES

NET SALES BY REGION 2011



- Western Europe **35 %**
- North America **28 %**
- China **14 %**
- Asia Pacific **12 %**
- EMEA **7 %**
- South America **4 %**

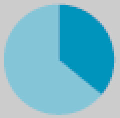
NET SALES BY CUSTOMER GROUP 2011



Hexagon Divisions

GEOSYSTEMS

SHARE OF NET SALES

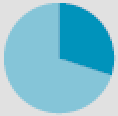


36%

Measurement of Environment and Infrastructure

METROLOGY

SHARE OF NET SALES

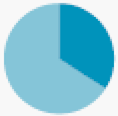


30%

High precision measurement of industry components

TECHNOLOGY

SHARE OF NET SALES



34%

Software for company engineering; navigation and satellite systems

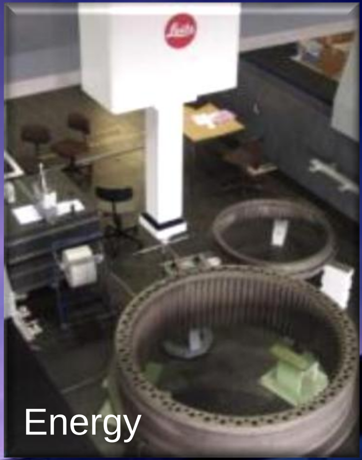
Hexagon Metrology GmbH: Leitz Factory

Industies served:

- Automotive
- Machine Tool
- Energy Generation
- Aircraft/Aerospace
- Heavy Industry


Automotive


Aircraft/
Aerospace


Energy

80 million € Turnover - 340 Employees
Commercial Operation and Leitz Factory

HEXAGON METROLOGY

Complete Product Portfolio

(0.3µm) Increasing Accuracy

Leitz PMM-G: Now up to 4.5m in Y – Second Generation

*Sizes (up to **84 m³** measuring volume)*

from	30.20.12
to	**70.45.30**

Accuracies (for Z = 12)

MPE **E**	**2.4 + L/400 µm**
MPE **P**	1.9 µm
MPE **THP**	3.3 µm / 58 s

Systems installed

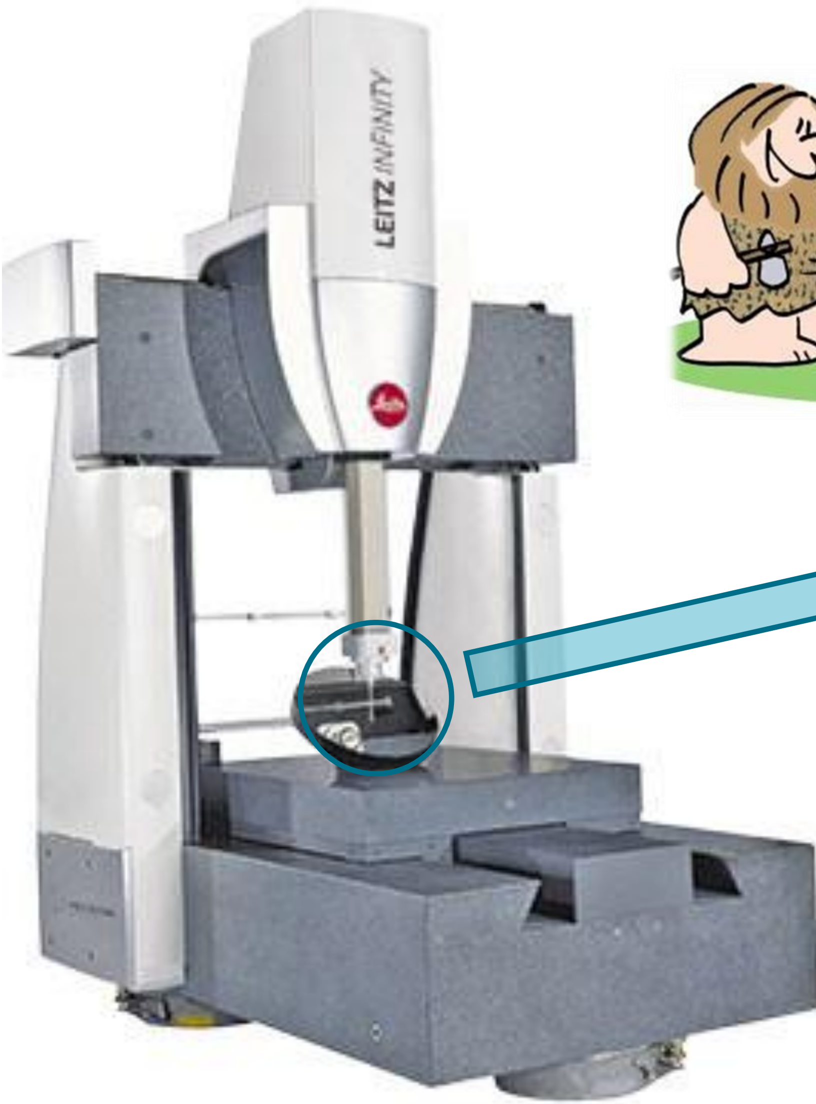
PMM-G	41	↘	Over 100 installed
Gantry	62	↗	systems

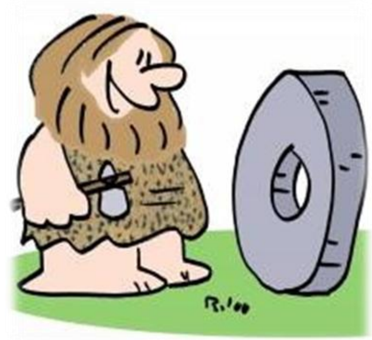
Some references

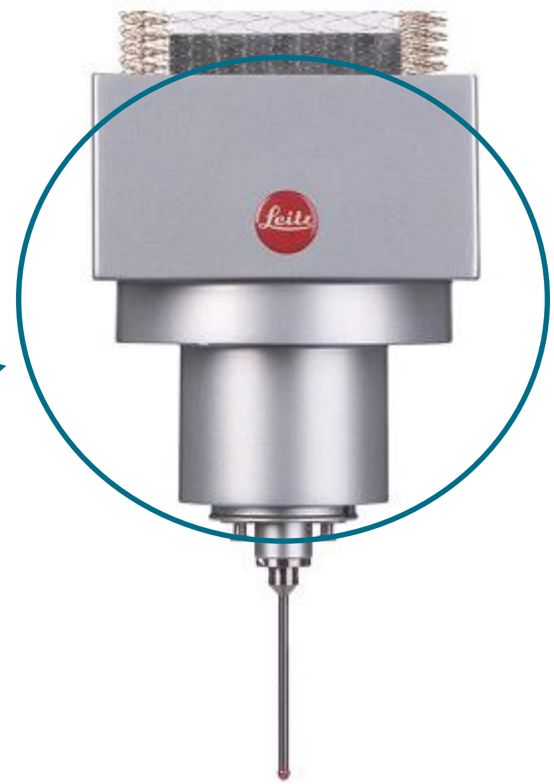
- Flender, Germany
- CMD, France
- Hansen Transmission, Belgium

HEXAGON METROLOGY

Introduction – Machine and probehead

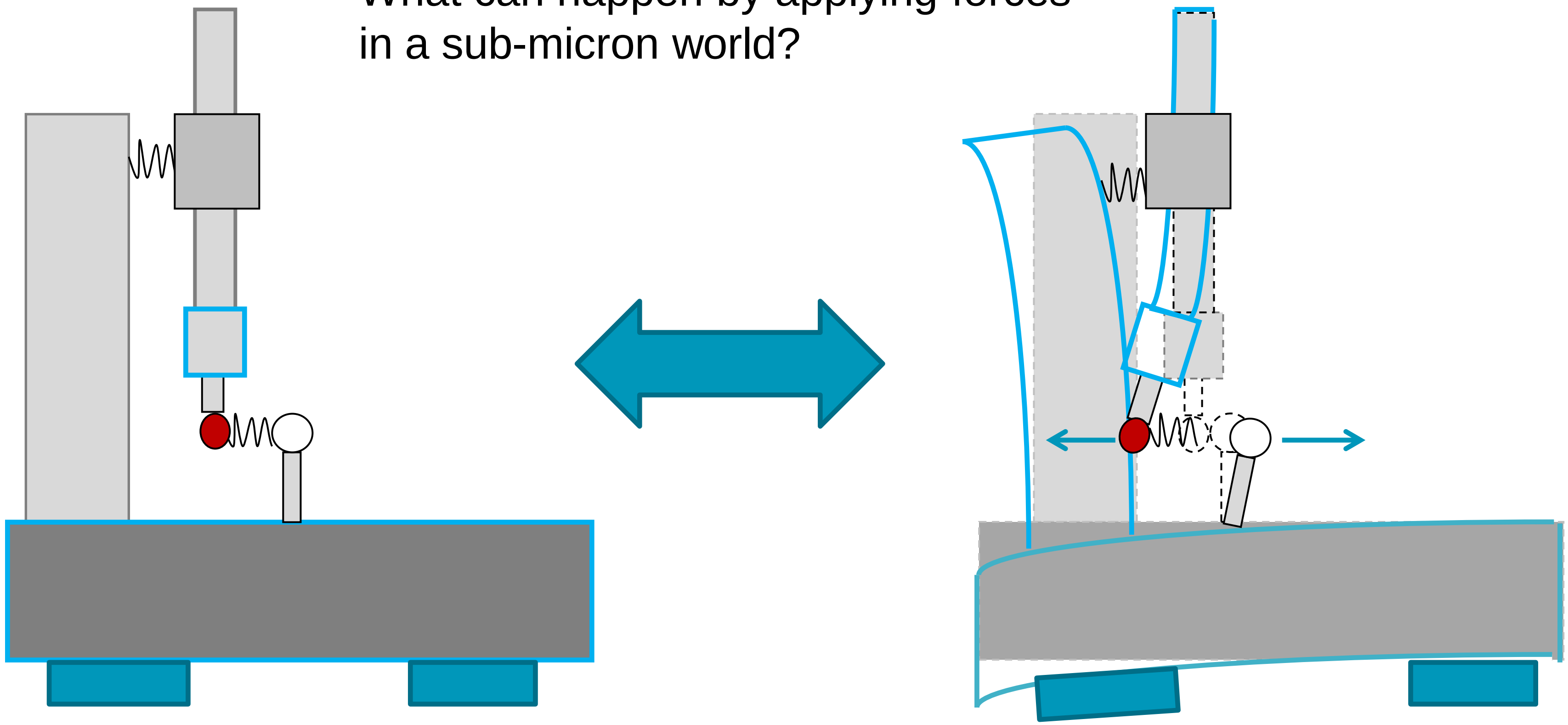




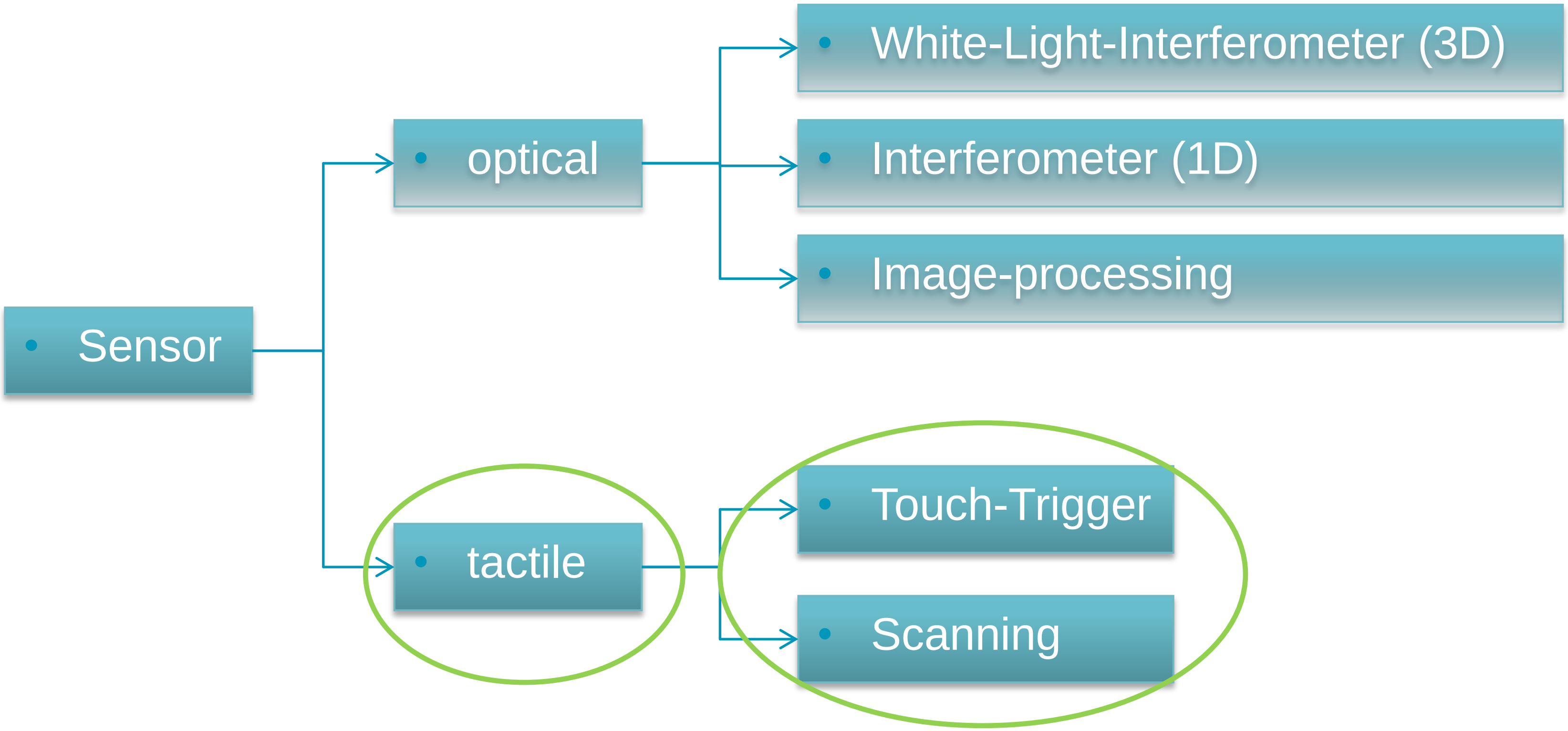


Introduction - Rigid-body vs. deformable-body

What can happen by applying forces in a sub-micron world?



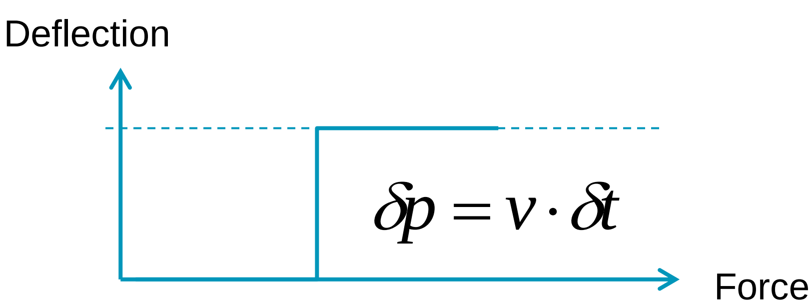
Sensors for a CMM

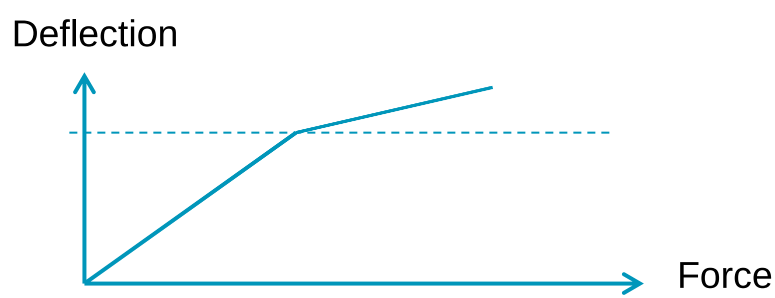


Different types of probeheads for tactile measurement

- **Touch-trigger probes**
  - Some advantages
    - lower cost,
    - smaller size
    - Fast probing
  - Some disadvantages
    - Lower accuracy
    - Surface-normal cannot be determined (Variation due to bending cannot be taken into account)
    - Result depending on sampling-time and probing-speed

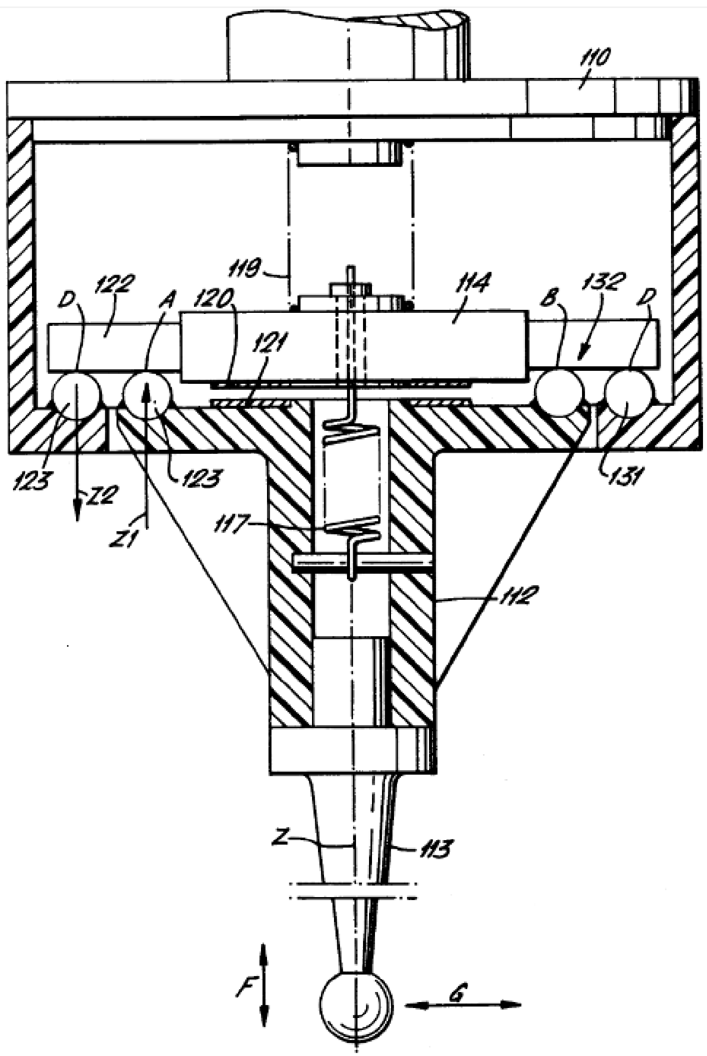
- **Scanning probes**
  - Some advantages
    - Higher accuracy
    - Surface-normal determined
  - Some disadvantages
    - Higher cost
    - Bigger size
    - Probing takes more time

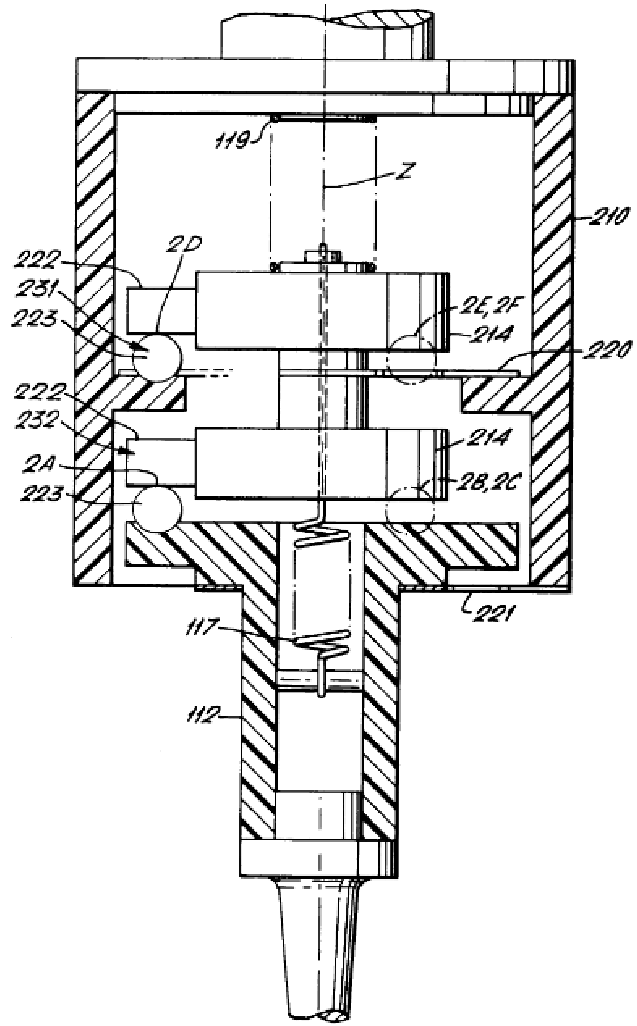




HEXAGON METROLOGY

Touch-Trigger-Probe (McMurty, 1976)





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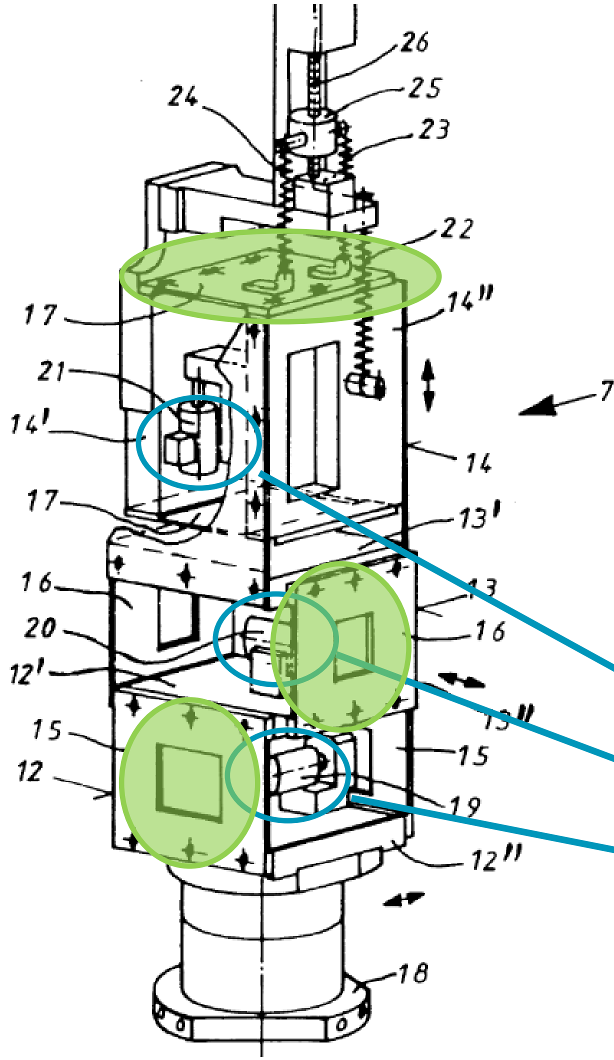
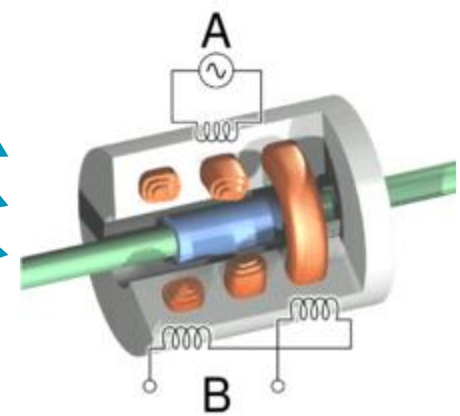
Basic principles of scanning probes



- Leaf-springs to achieve certain forces during probing
- Linear behaviour of springs in a wide range
- Independent movement of the axis
- Compact building
- Damping needed
- Weight balance of probes
- Measuring the displacement in each axis



Example for a compact probehead with leaf-spring

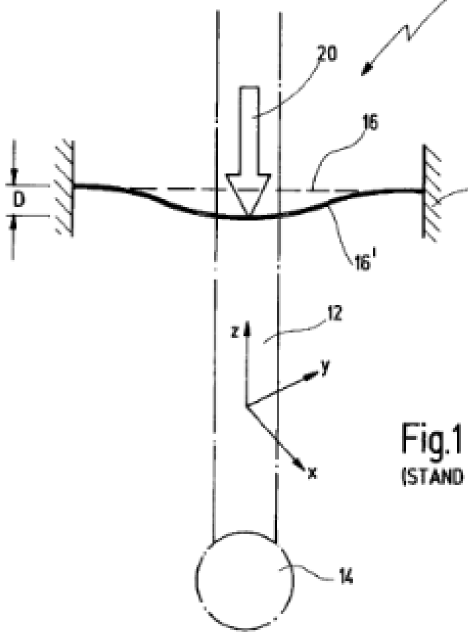


Fig.1
(STAND DER TECHNIK)

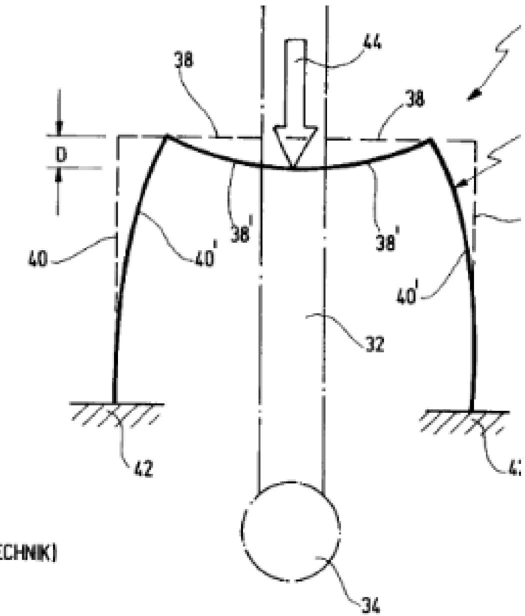


Fig.2

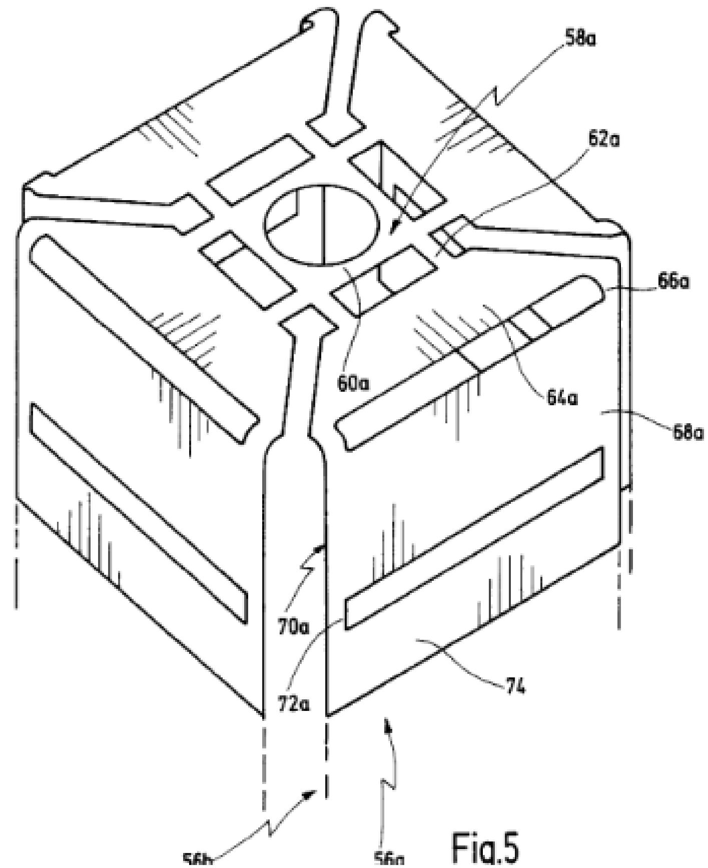


Fig.5

Zeiss: DE 000010250813 B4

Optical measurement of the displacement

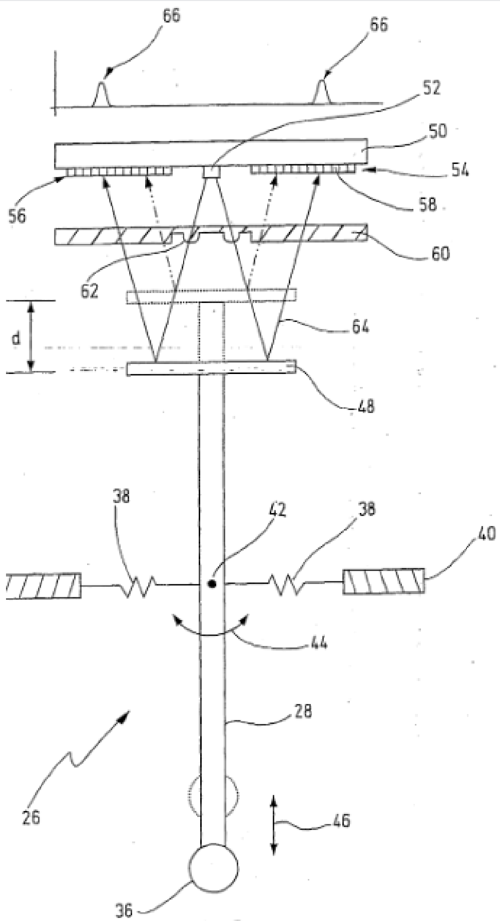
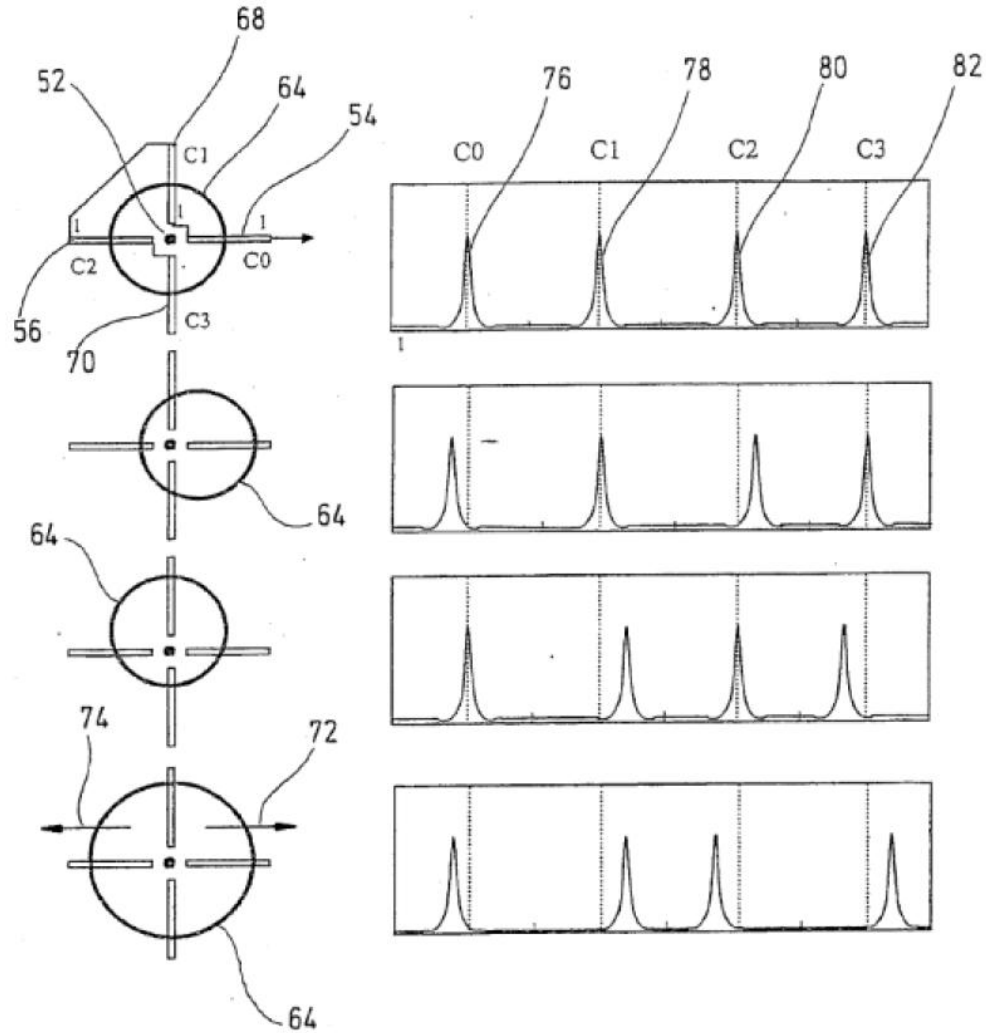


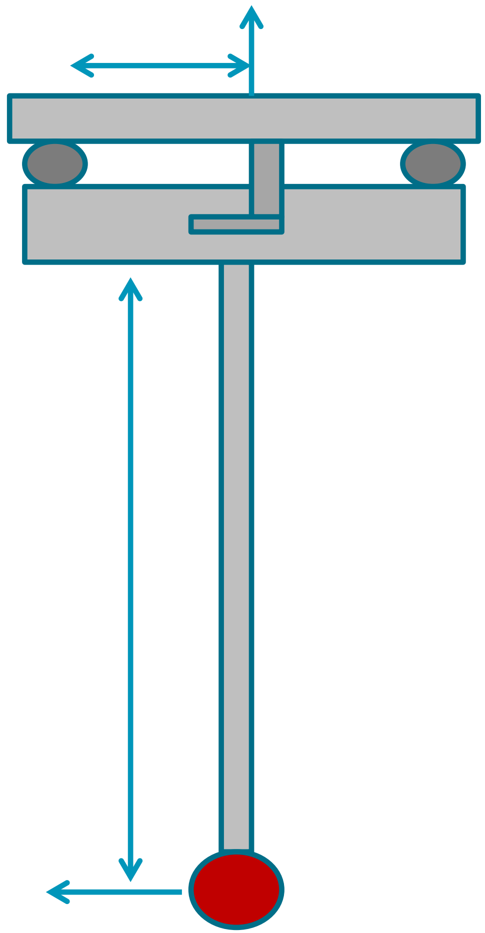
Fig.2



Zeiss: EP000001718925B1

HEXAGON METROLOGY

Max. forces according to momentum

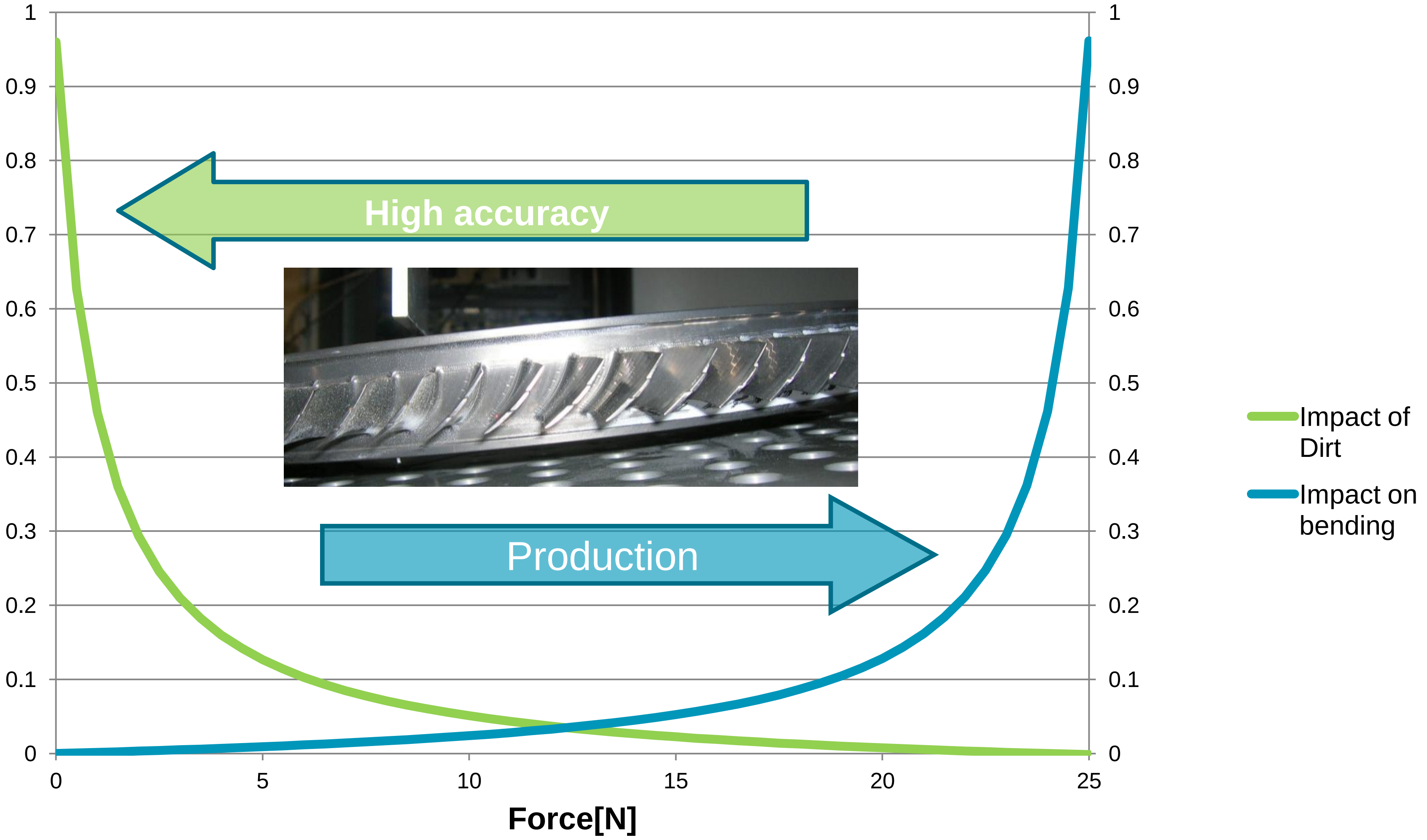


- Angular momentum: e.g. 300N for the gripper
- D1 at platform: 2cm
- Max. length of stylus 1m
- Max. force: 1.2N

- Max. momentum: 1.2Nm
- Max. allowed momentum: 6Nm

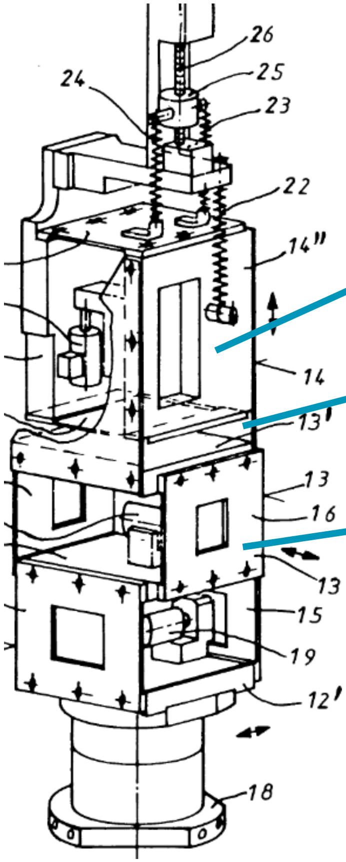
- Use low forces to
  - avoid deforming
  - Avoid critical angular momentum

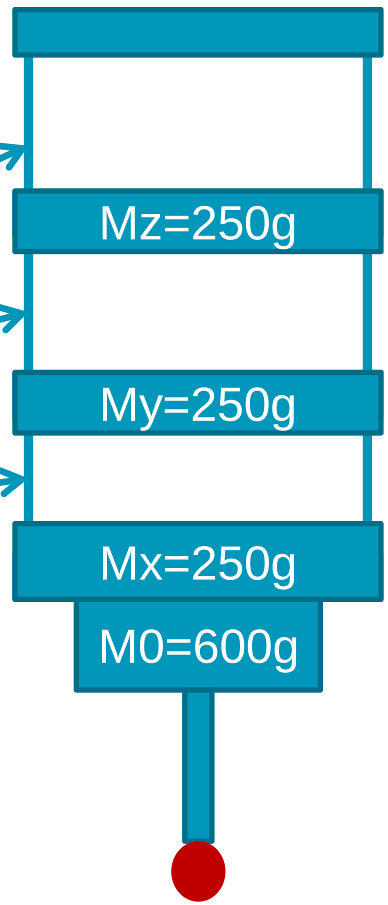
High- and low-force probing



HEXAGON METROLOGY

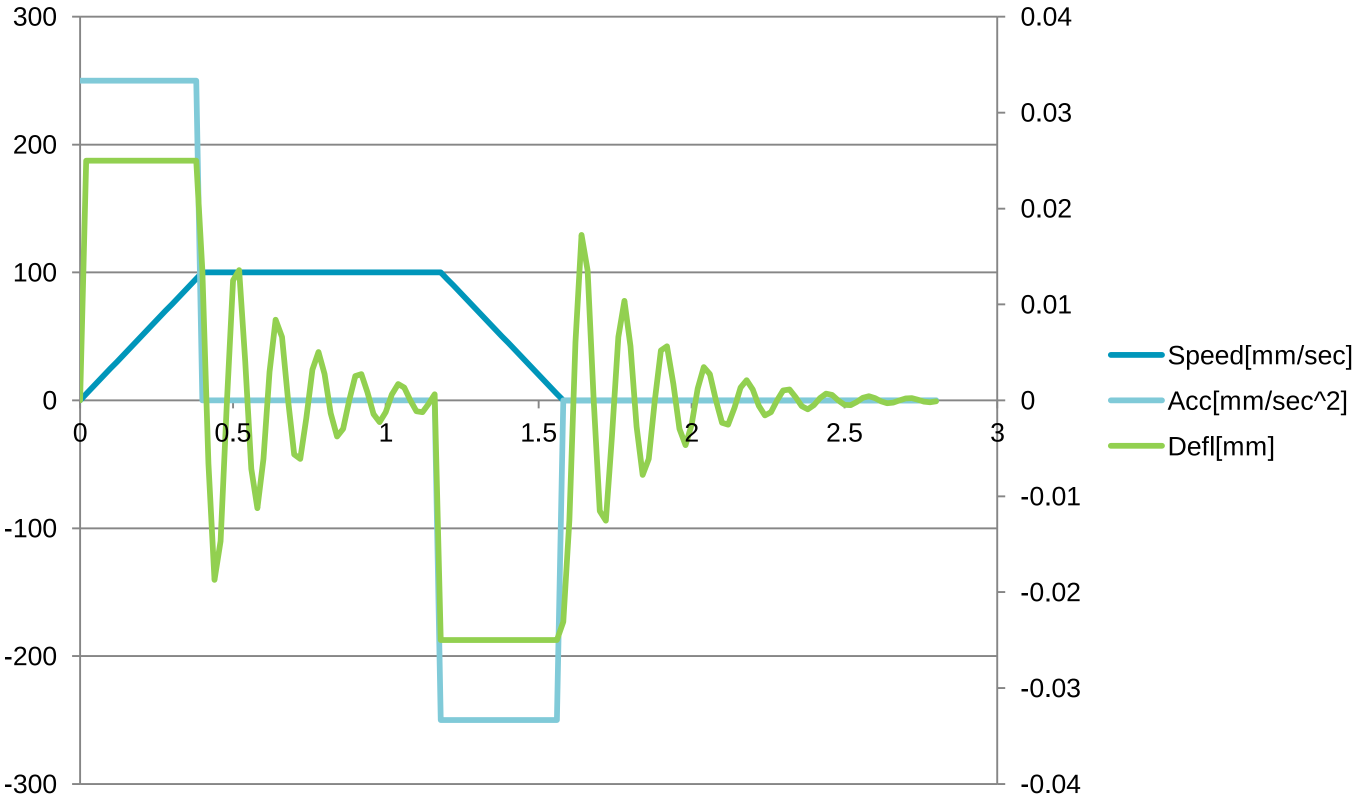
Effects of inertial mass

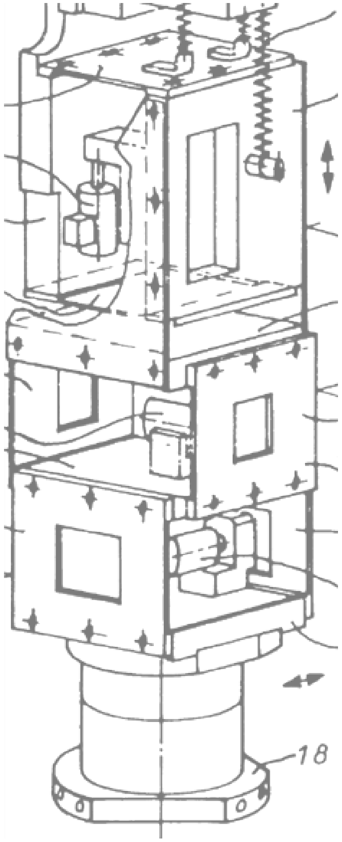




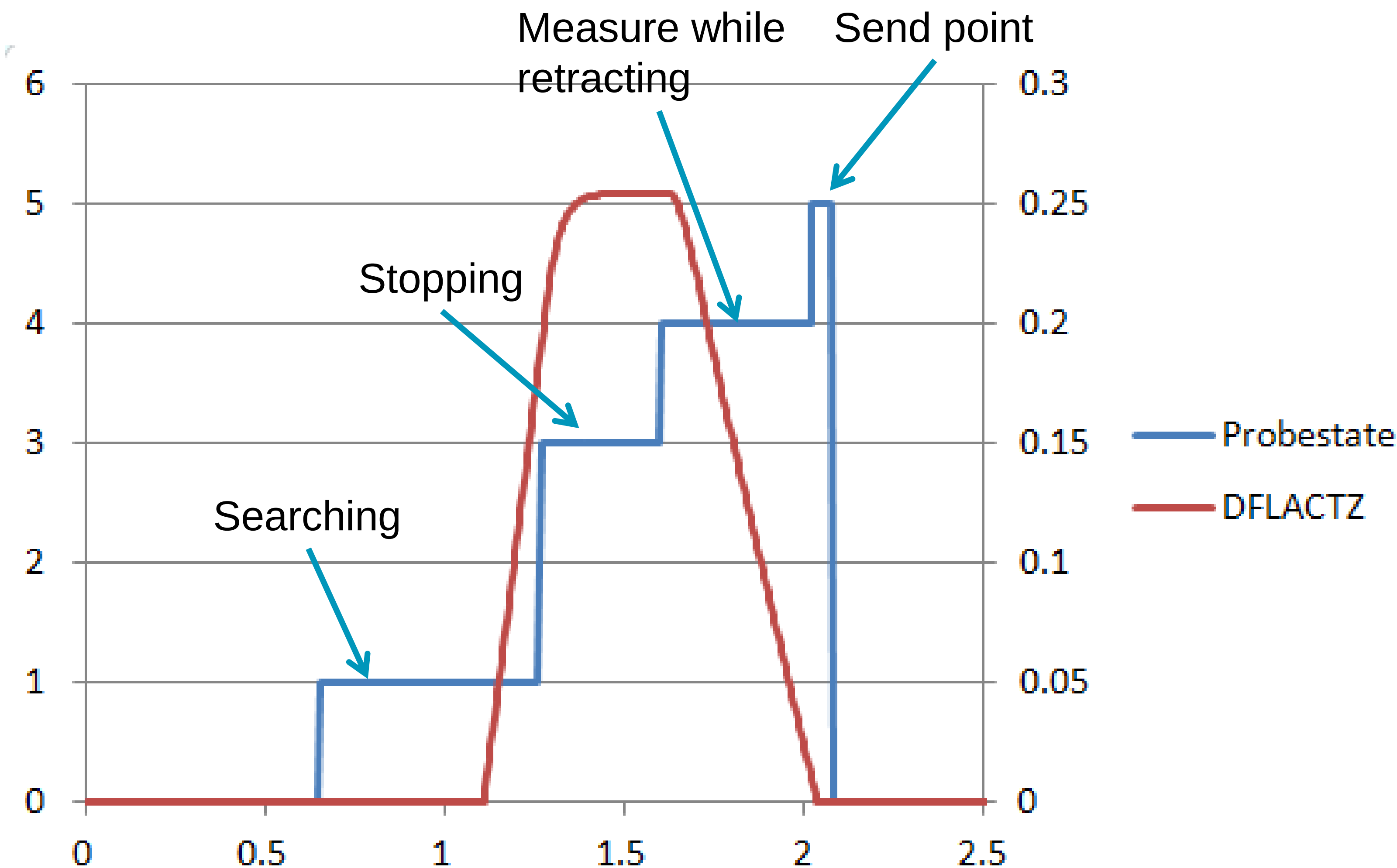
	MTK-4	MTK-5
Mass[kg]	1.45	0.61
Spring-const[N/mm]	1.60	5.00
Accel[mm/s²]	MTK-4 [µm]	MTK-5 [µm]
1.00	0.91	0.12
5.00	4.53	0.61
10.00	9.06	1.22
25.00	22.66	3.05
50.00	45.31	6.10
250.00	226.56	30.50
600.00	543.75	73.20
2000.00	1812.50	244.00

Damping and clamping of a probehead

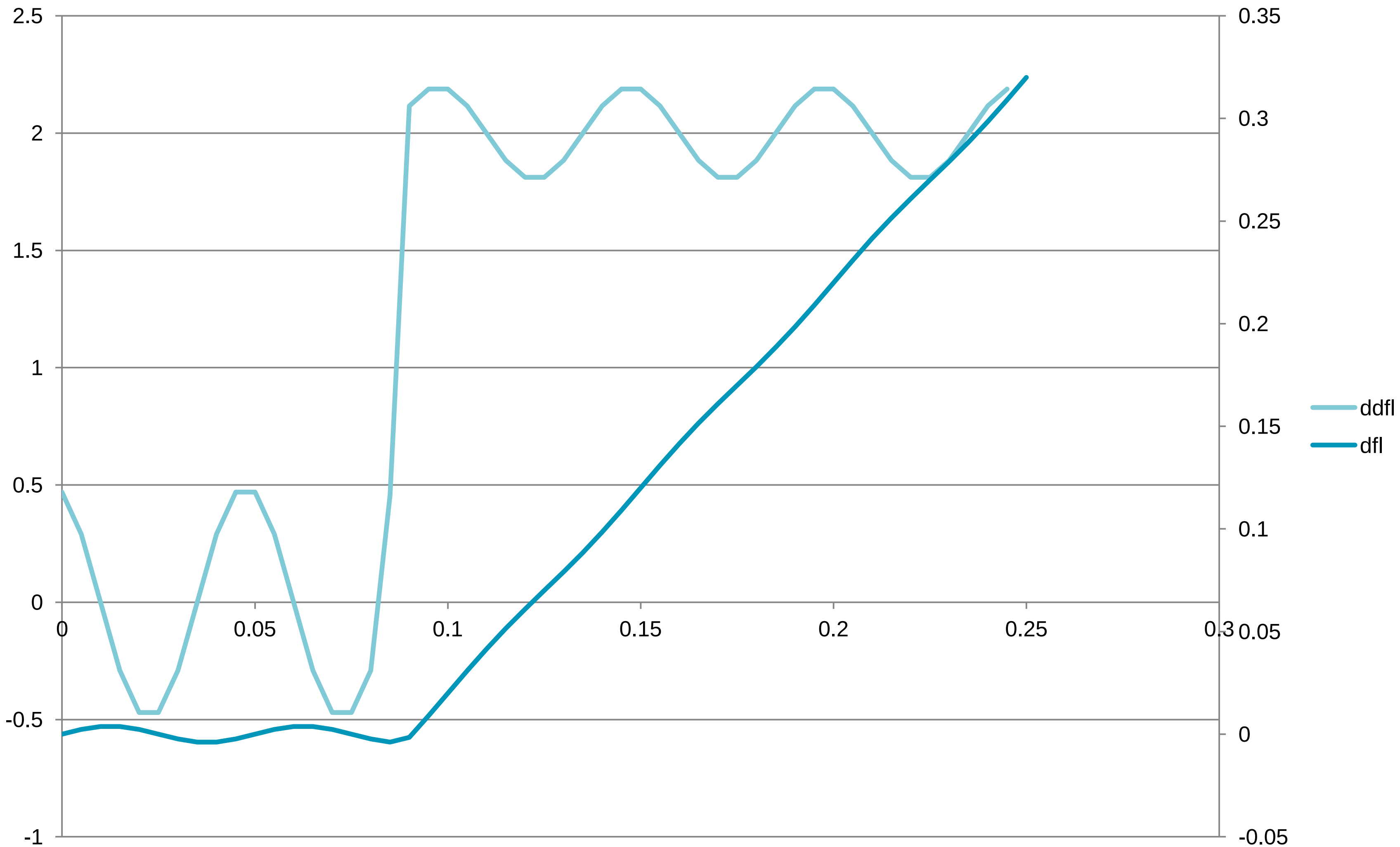




Typical probing of a surface

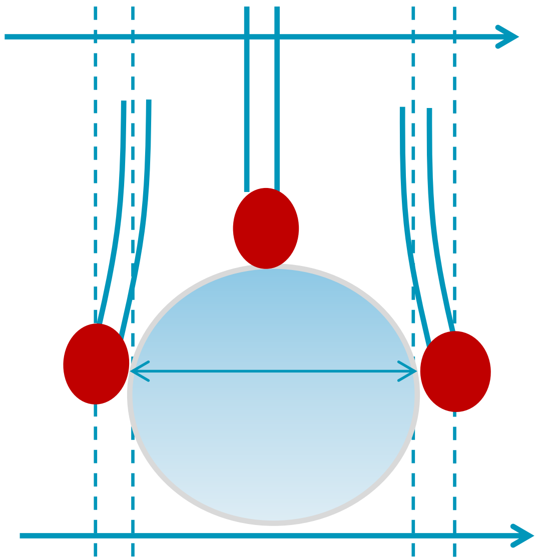


How to detect a probing



Physical aspects of calibration procedures

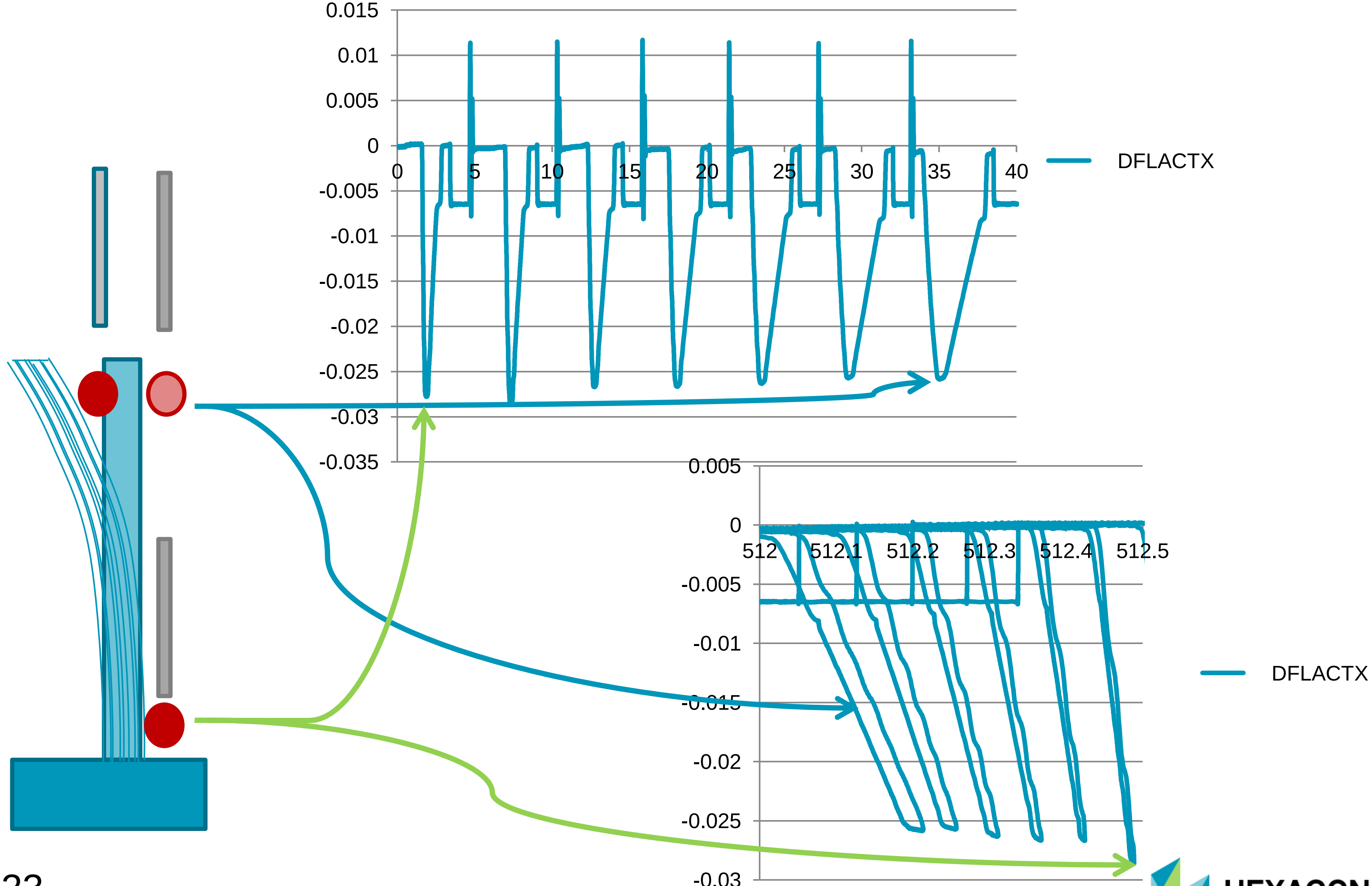
- Preconditons
  - machine has to reproduce in a certain way
  - errors are mapped so that the machine shows the same behaviour at every position
- Calibration takes care of different sensors and probetips or even surfaces



$$p(x_2)+d(x_2)+b_x\cdot d(x_2)-p(x_1)-d(x_1)-b_x\cdot d(x_1)$$
$$=2\cdot(R_{sphere}+R_{\mathrm{Probe}})$$

$$\vec{p}_a=\vec{p}+\vec{d}+\begin{pmatrix} b_{xx} & b_{xy} & b_{xz} \\ b_{yx} & b_{yy} & b_{yz} \\ b_{zx} & b_{zy} & b_{zz} \end{pmatrix}\cdot\vec{d}$$

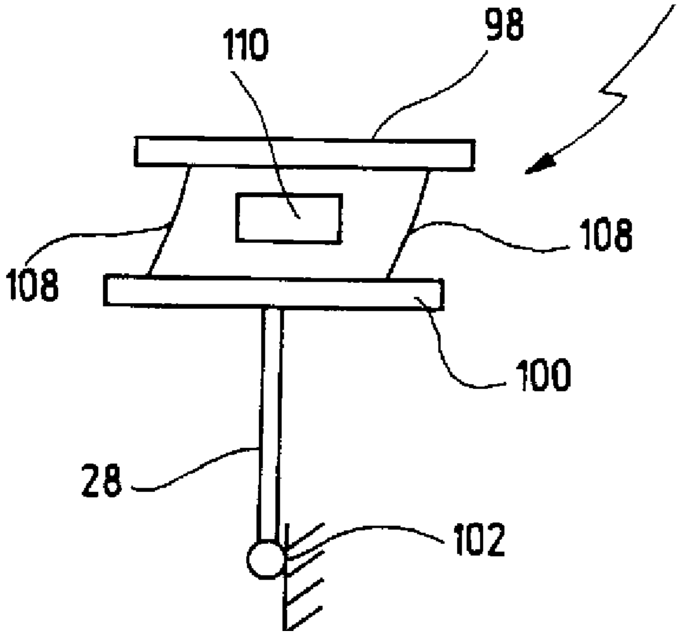
Practical example: a knife-edge

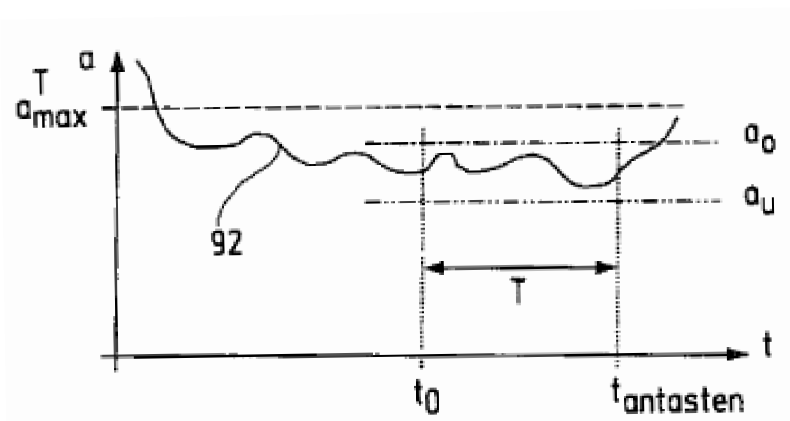


Checking stability of calibration

- Check certain qualifying parameters by re-calibrating (e.g. bending-parameters) by comparing the values over time
- For a known calibrated probetip the calibration-parameters can be checked in certain intervals

Checking stability/quality/repeatability of probes





DE 10 2004 038416 B4

- Check the acceleration in the probehead
- If the acceleration is too high give a warning or redo measurements

Check signals with acceleration sensor

FIG.18

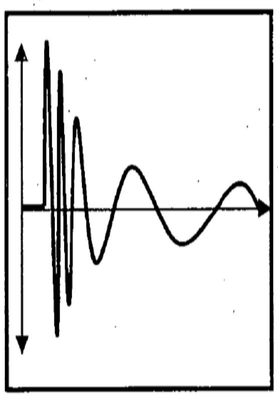


FIG.19

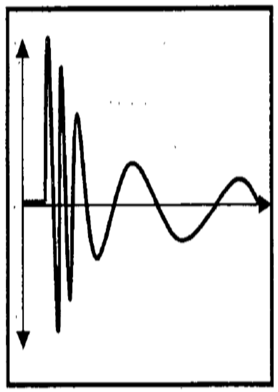


FIG.20

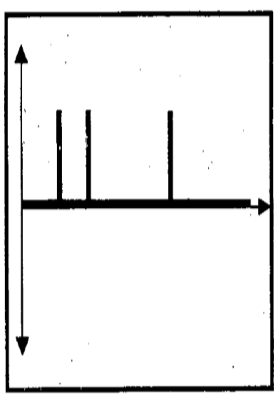


FIG.21

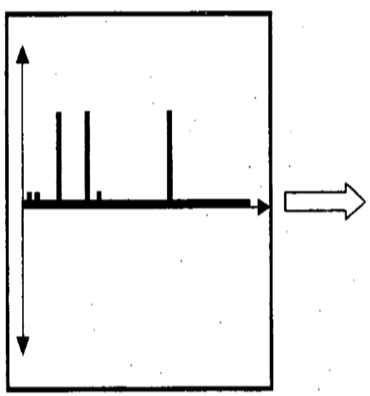
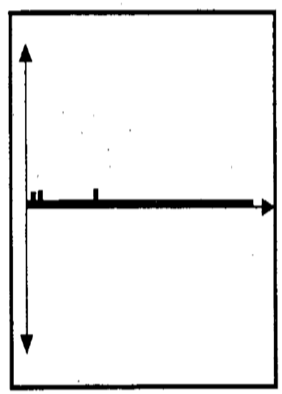


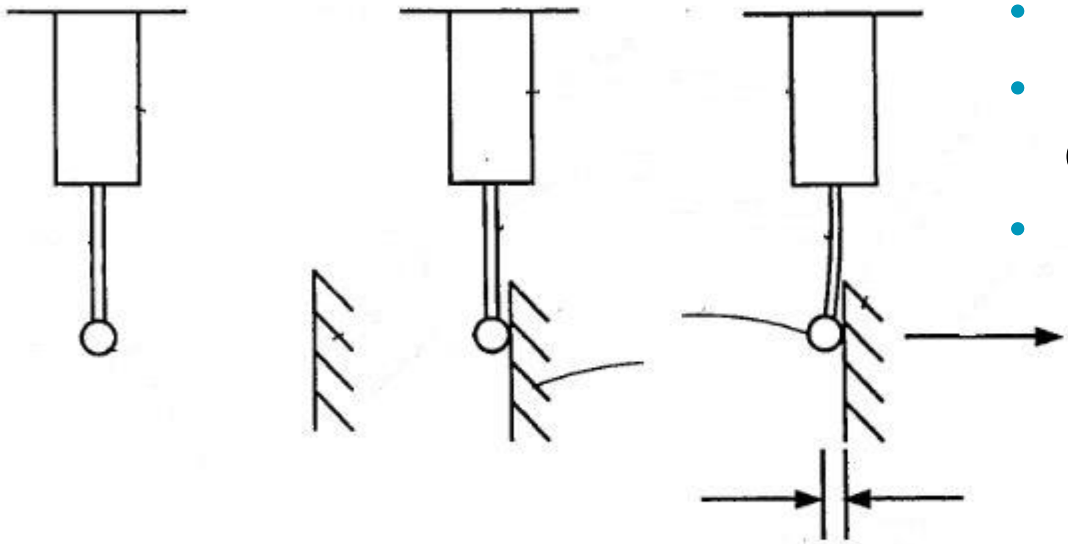
FIG.22



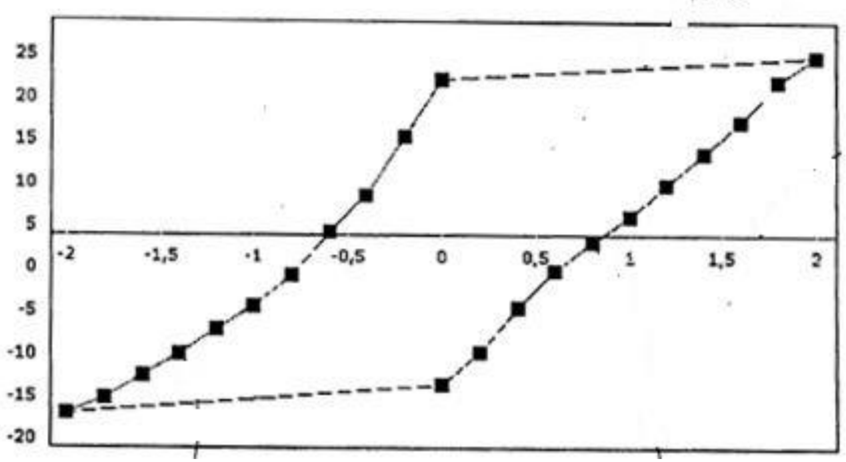
- Keep deflection signal and filter acceleration-effects

DE 10 2010018250 A1

Checking hysteresis (electrical and mechanical)



- Delay due to
- Filtering of electronic components
- Mechanical nonlinearity



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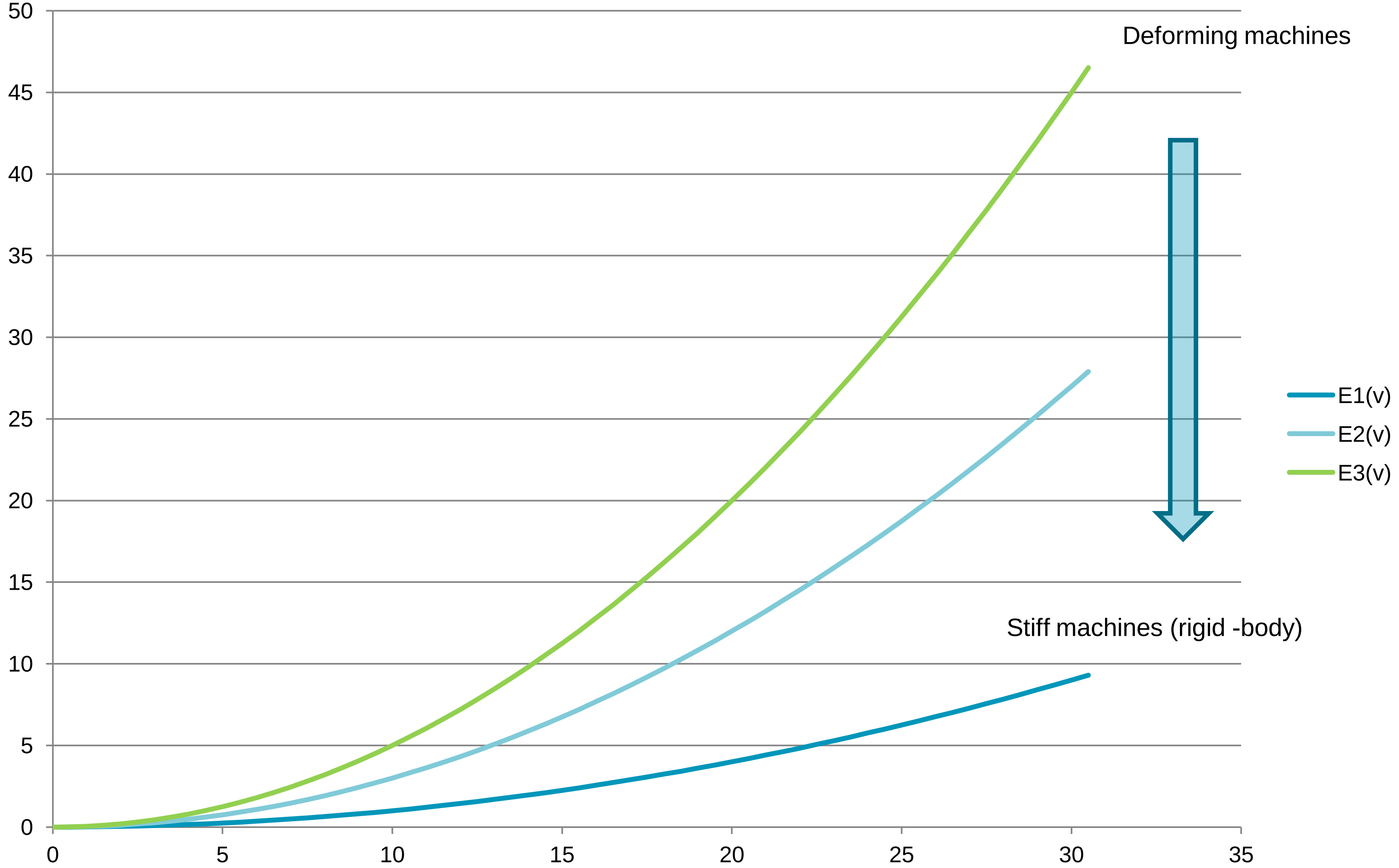
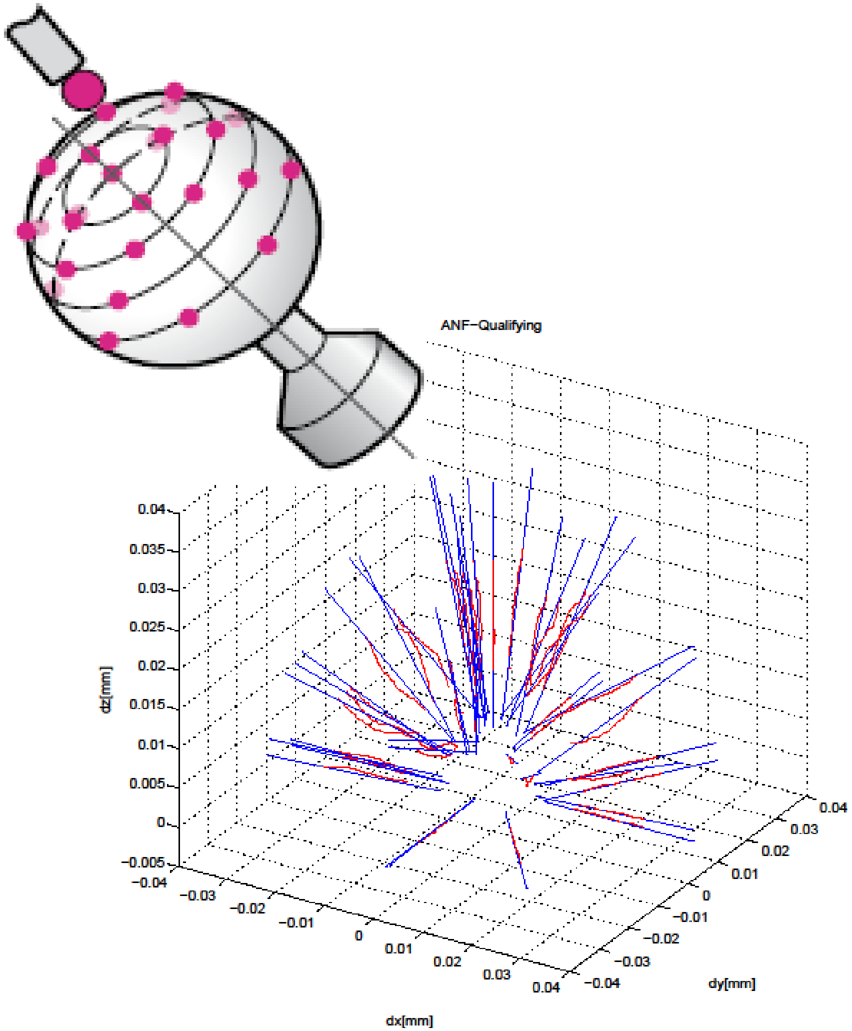
Compensate dynamic errors



HEXAGON METROLOGY

Checking stability/quality/repeatability of probes (ISO-Tests 10360-5)



MESSTECHNIK WETZLAR GMBH
Metrology Systems

Annahmeprüfung und Bestätigungsprüfung für Koordinatenmessgeräte (KMG)

I S O 1 0 3 6 0 - 5 : Antastabweichung P(FTU) / P(STU)

Kunde		VW Salzgitter	Prüfer	fwollmann		
Meßgerät		SXI	Prüfdatum	27-JAN-2015 / 17:22:28		
Seriennummer		103	Standort	Halle 1		
S/N Tastkopf		109	Bemerkung	lfps x390 y400		
MPE P(FTU) / P(STU) [µm]		1.90 / 0.00	Temperaturen während der Messung			
Parameter der Kugel	Durchmesser	24.9869	Temp. X-Achse	20.00	Kompensation	
	X-Mittelpunkt	-48.1	Temp. Y-Achse	20.00	Ja	
	Y-Mittelpunkt	-2.7	Temp. Z-Achse	20.00	Aut	
	Z-Mittelpunkt	120.8	Temp. Werkstück	24.26		
Quindos Version		Quindos7 - V 7.9.13331-Release-3	Firmware Version	8@17y		
ISO Programm Version		ISO 10360 - V10.14226 -HexPts	Dateiname	PTest_030		

PT NR.	ABW. [µ]	GRAFIK -TOL/2 +TOL/2
1	0.73	. *
2	-0.17	* .
3	0.60	. *
4	0.09	.*
5	0.08	.*
6	-0.44	* .
7	-0.67	* .
8	0.24	. *
9	0.09	.*
10	-0.47	* .
11	0.31	. *
12	0.04	.*
13	-0.21	* .

PT NR.	ABW. [µ]	GRAFIK -TOL/2 +TOL/2
14	0.07	.*
15	0.13	. *
16	0.13	. *
17	0.12	. *
18	-0.15	* .
19	-0.20	* .
20	0.50	. *
21	-0.49	* .
22	-0.46	* .
23	0.29	. *
24	0.27	. *
25	-0.41	* .

Zusammenfassung

Größte positive Abweichung : 0.73 µm bei Punktnummer 1
Größte negative Abweichung : -0.67 µm bei Punktnummer 7

Toleranz MPEp = 1.90 µm
Spanne der Abweichungen = 1.40 µm

Testergebnis: bestanden !

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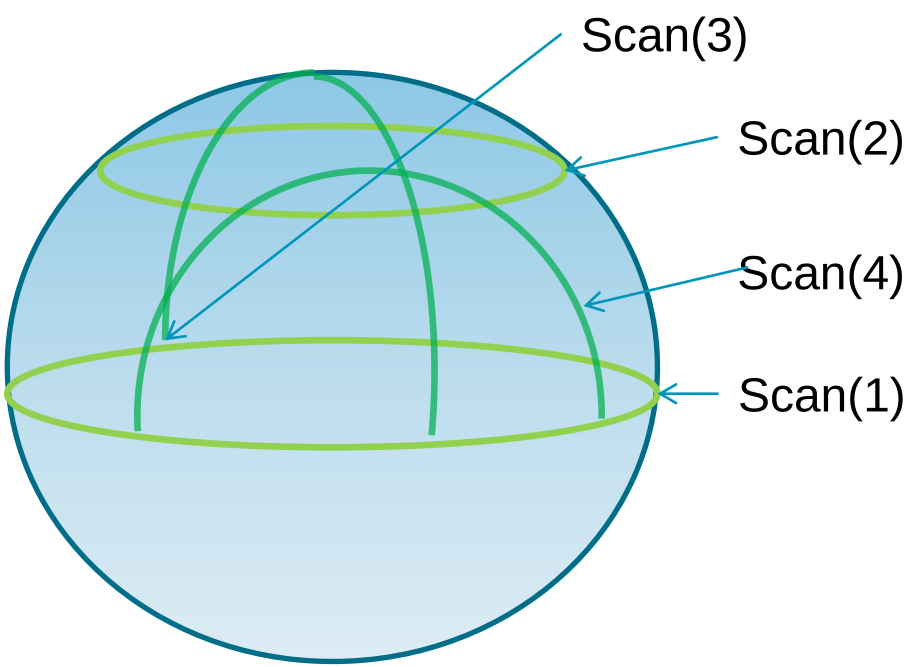
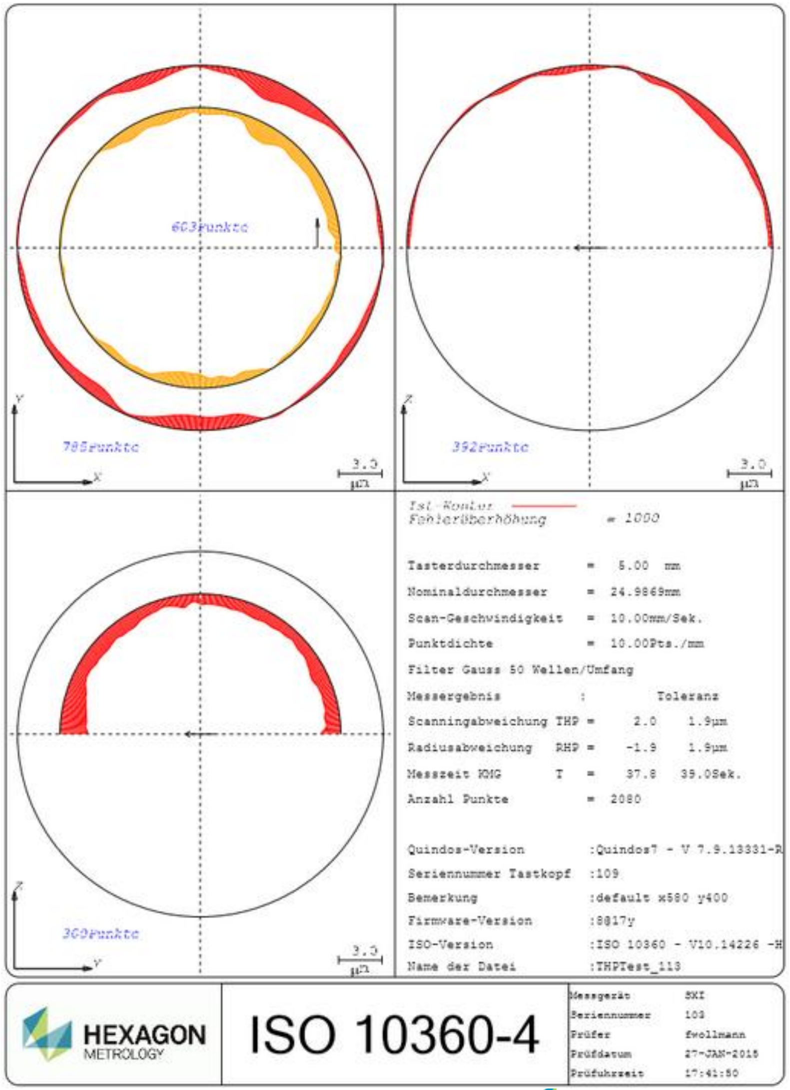
Checking stability/quality/repeatability of probes (ISO 10360-4)





HEXAGON METROLOGY

Concluding remarks

- The world of CMMs is quite rich and complicated and therefore still very interesting
- Studying patents can provide a broad knowledge-base of what‘s already achieved
- Reproducibility is most important for accuracy

HEXAGON
METROLOGY