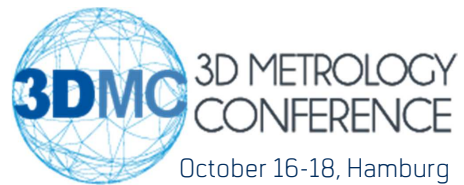




Integrated Measurement Systems for Machine Tools

Opportunities and Challenges



mit uns technisch überlegen

machine tool division

The 5th Dimension of Complete Machining

GEORG ultraturn MC



machine tool division



mit uns technisch überlegen

Integrated Measurement
Systems for Machine Tools

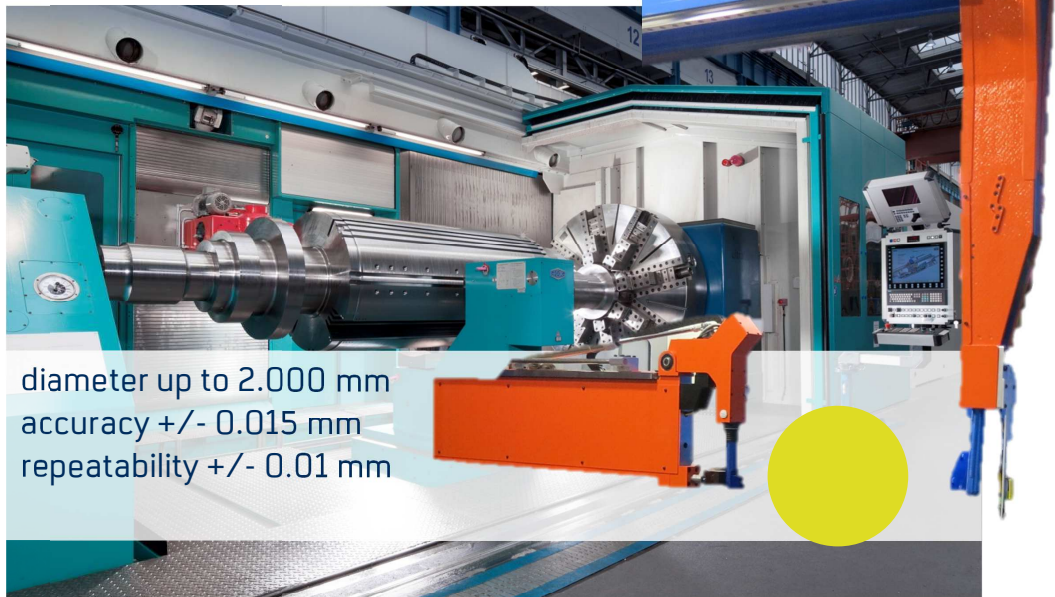
3

16.10.2018

Integrated Measurement Systems for Machine Tools

Measurement Task

> Measurement Task

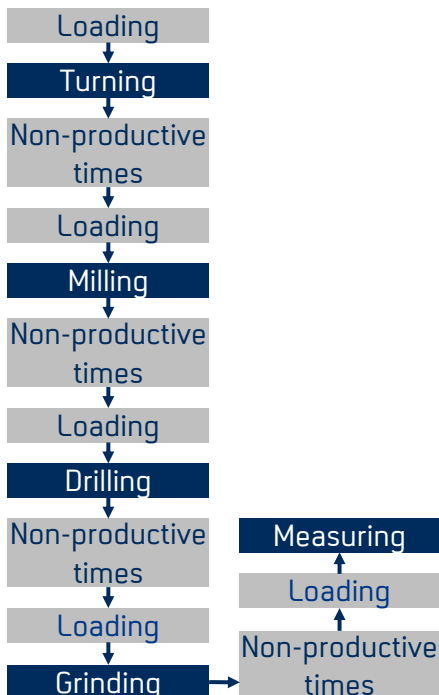


diameter up to 2.000 mm
accuracy +/- 0.015 mm
repeatability +/- 0.01 mm

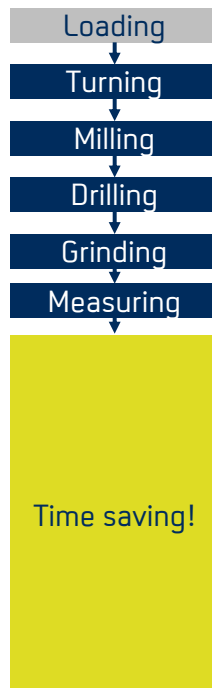
The 5th Dimension of Complete Machining

Opportunities: Increased Efficiency and Quality

Conventional machining



Complete Machining



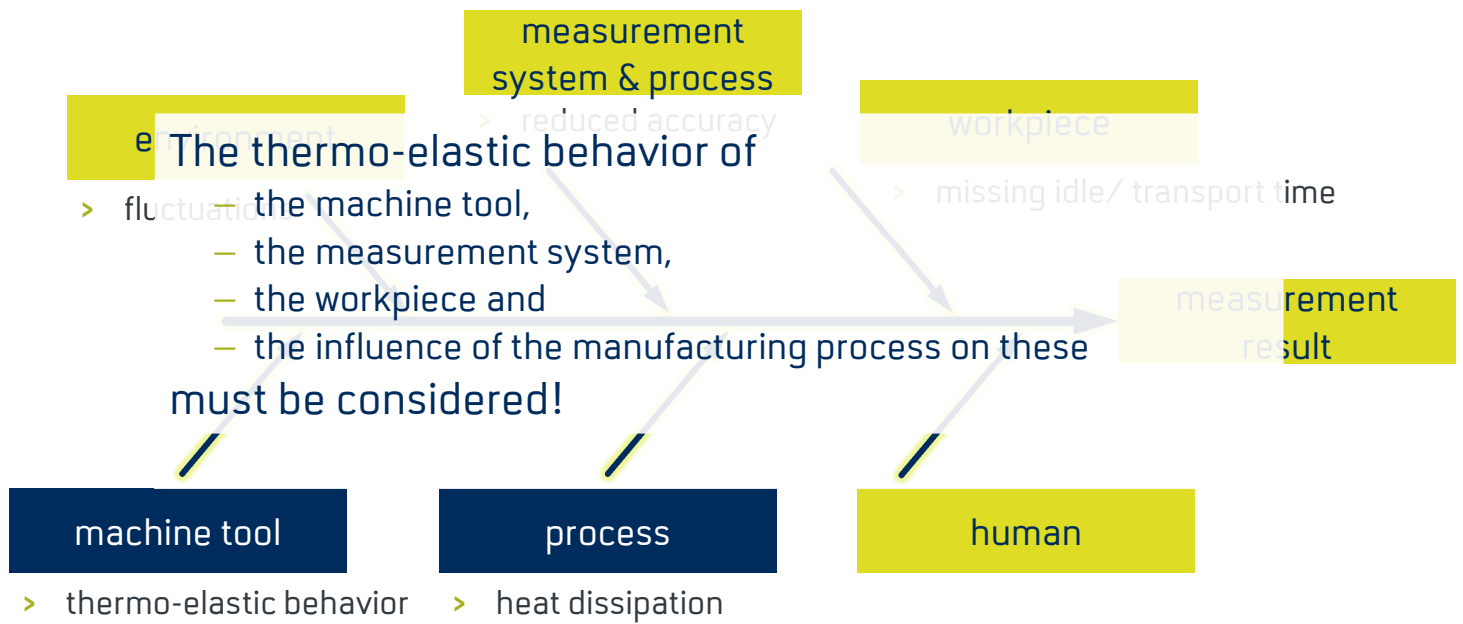
Advantages

- Less number of machines
- Less space needed
- Less employees
- Reduction of risk
- Higher productivity
- Improved workpiece accuracy
- Cycle time reduction for up to **40%**

Great Cost Savings

Challenges

Influences on the measurement process



Challenges

Optimal measuring conditions

> measuring room



source: WZL

> Conditions

- > well-defined
- > VDI/VDE 2627
- > temperature sensors (9)
- > constant
 - temperature and
 - humidity
- > even temperature distribution of
 - measurement system
 - environment
 - workpiece
- > clean environment

Challenges

Optimal measuring conditions

> shopfloor

- > Conditions
 - > unknown
 - > ~~VDI/VDE 2627~~
 - > no temperature sensors
 - > variation of
 - temperature and
 - humidity
 - > uneven temperature distribution of
 - measurement system
 - environment
 - workpiece
 - > dirt & dust



Challenges

Optimal measuring conditions

> measuring room



An average shopfloor can never compete with an high quality measuring room!

> shopfloor



- > $\Delta T \leq 0,8 \text{ K}/24 \text{ h}$ (class B)
- > $\Delta T \leq 0,3 \text{ K}/\text{m}$ (class B)

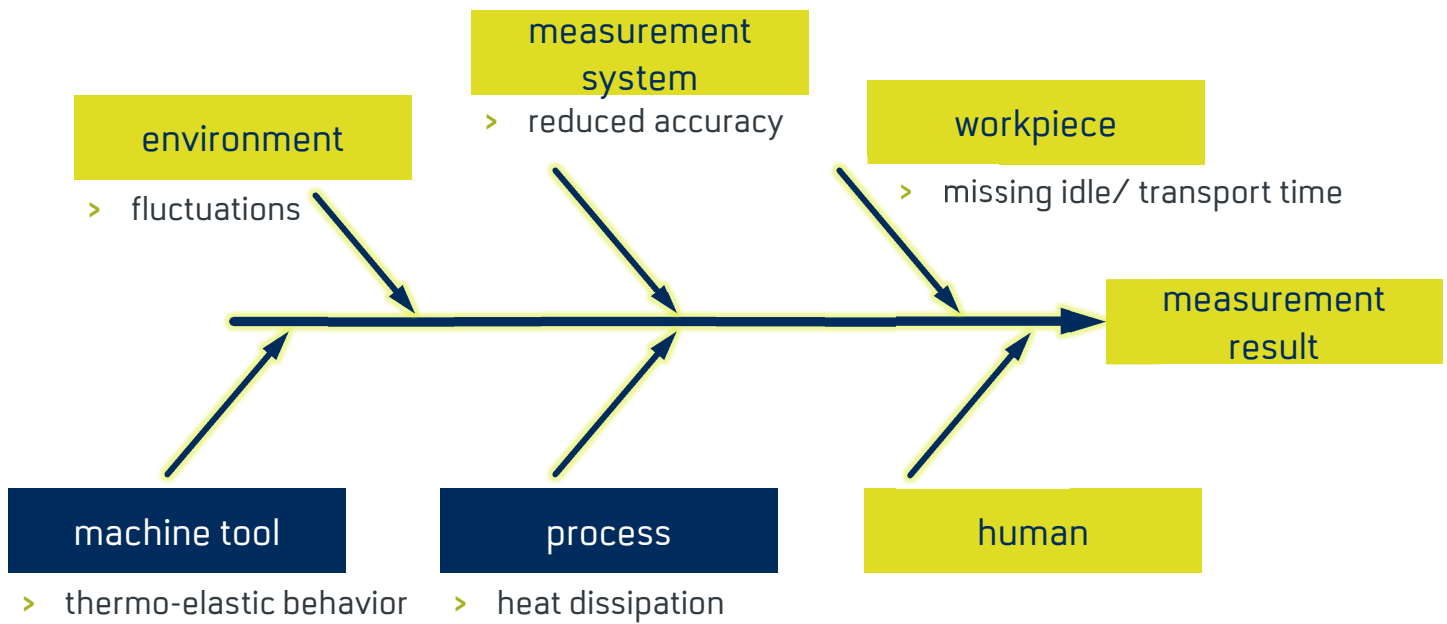
source: WZL

- > $\Delta T_{\text{typ}} \leq 5 \text{ K}/24 \text{ h}$
- > $\Delta T_{\text{typ}} \leq 0,3 - 2 \text{ K}/\text{m}$

Quelle: M. Wennemer: Methode zur messtechnischen Analyse und Charakterisierung volumetrischer thermo-elastischer Verlagerungen von Werkzeugmaschinen, Dissertation, RWTH Aachen, 2018, ISBN 978-3-86359-609-5

Challenges

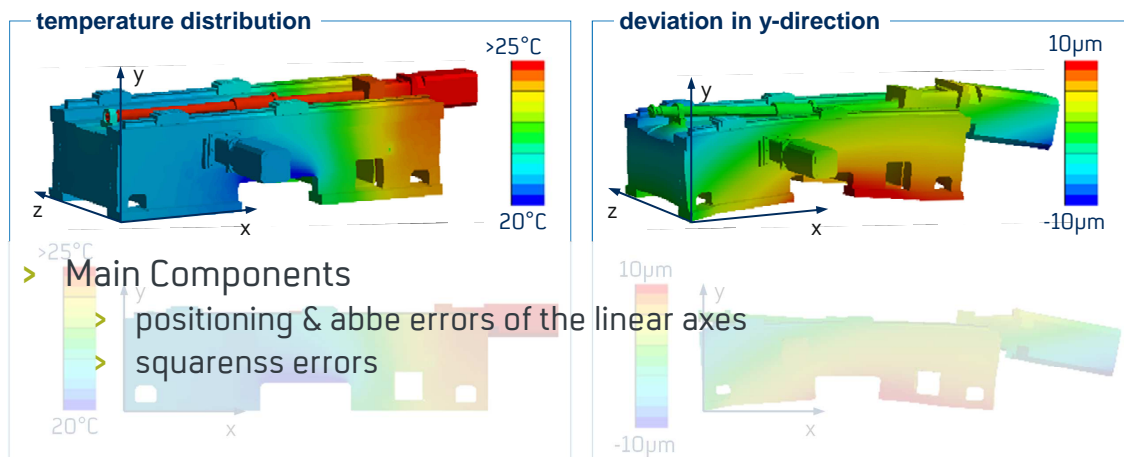
Influences on the measurement process



Challenges

Thermo-elastic behavior of machine tools

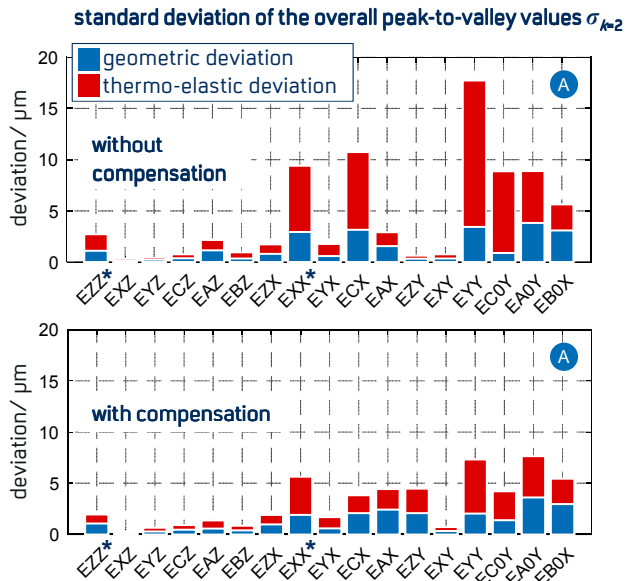
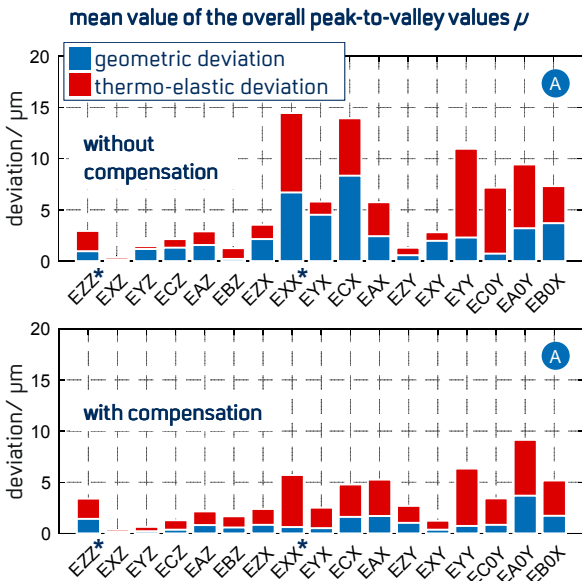
- > example of a small to medium size machine bed



The complex thermo-elastic behavior of machine tools can be reduced to some significant deviations!

Challenges

Thermo-elastic behavior of machine tools

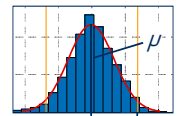


thermo-elastic load:

Single & combined movement of the x- and y-axis

machine tool A


31.10.2016 - 11.01.2017
n = 25 (no. of tests)



* error on scale height without Abbe error

Static geometric compensations only affects single thermo-elastic states!

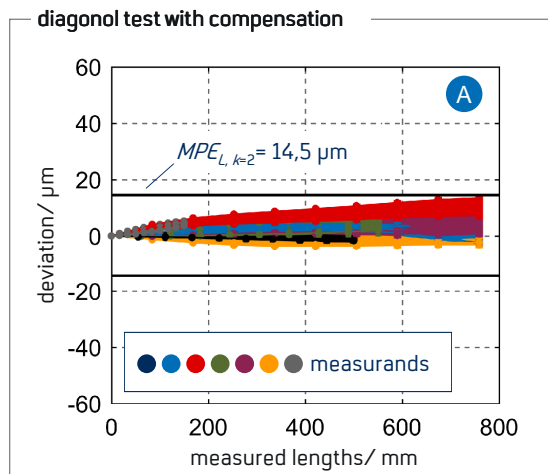
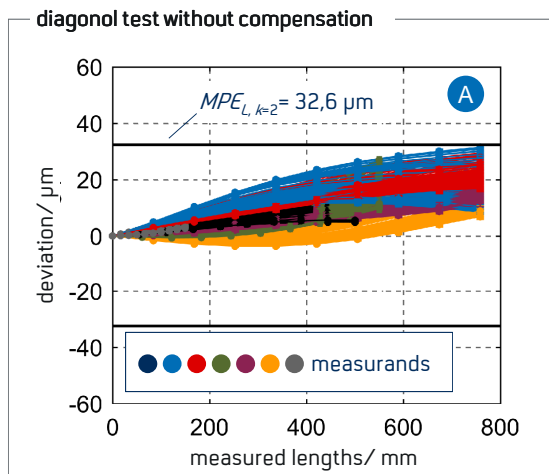
Quelle: M. Wennemer: Methode zur messtechnischen Analyse und Charakterisierung volumetrischer thermo-elastischer Verlagerungen von Werkzeugmaschinen, Dissertation, RWTH Aachen, 2018, ISBN 978-3-86359-609-5
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	16.10.2018	

Challenges


Thermo-elastic behavior of machine tools

> compensation results of a medium size machine tool



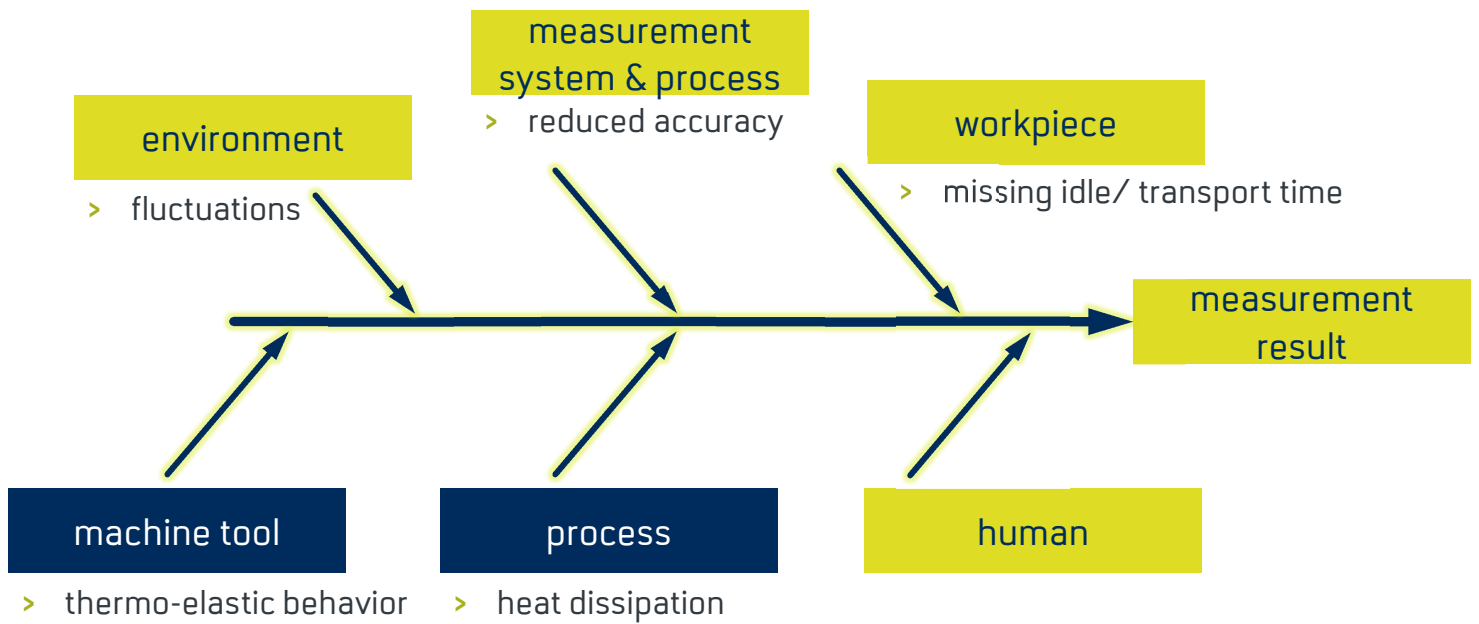
A significant compensation of thermo-elastic deviations based on control internal data is feasible!

Quelle: M. Wennemer: Methode zur messtechnischen Analyse und Charakterisierung volumetrischer thermo-elastischer Verlagerungen von Werkzeugmaschinen, Dissertation, RWTH Aachen, 2018, ISBN 978-3-86359-609-5
machine tool division

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	16.10.2018	

Challenges

Influences on the measurement process



Challenges

Thermo-elastic behavior of the workpiece

- > Influences on the workpiece



The thermo-elastic behavior of the workpiece is quite complex and hard to measure!

Challenges

Facing the challenge

> Interim conclusion

- > An average shopfloor can never compete with an high quality measuring room!
- > A machine tool is not a coordinate measuring machine!
- > The thermo-elastic behavior of
 - the machine tool,
 - the measurement system & process,
 - the manufacturing process on these must be considered!
- > Supervision of the machine tool deviations by additional measurement systems.
 - > Additional integrated measurement systems within the machine tool.
 - > e.g. mechanical isolated calliper
- > e.g. monitoring of the measuring task
- > related TCP deviations.
 - > Thermo-elastic deviations of machine tools can be significantly reduced by existing compensation methods!
- > Static geometric compensations only affects single thermo-elastic states!
- > The thermo-elastic behavior of the workpiece is quite complex and hard to measure!

Measurands taken by machine tools must be constantly supervised by a higher-level system!

Integrated Measurement Systems for Machine Tools

Measurement System

> Measurement System

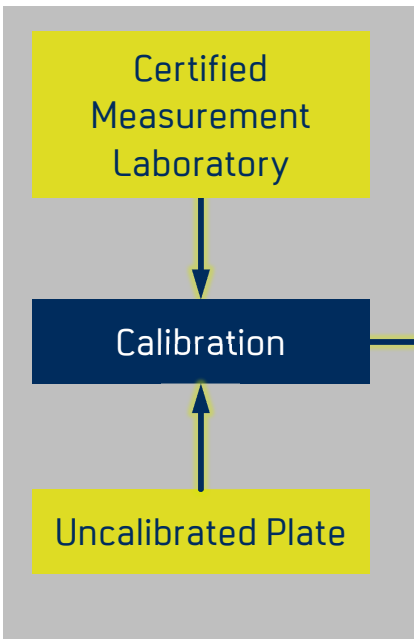
- > enclosure for static environmental conditions
- > additional integrated/ isolated measurement systems within the machine tool.
- > calibrated plate to compensate the thermo-elastic behavior.



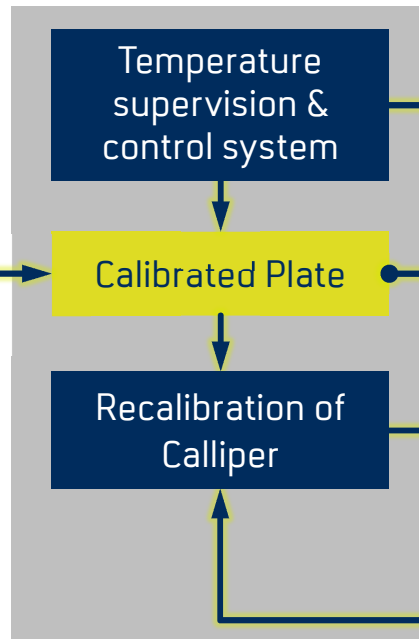
Integrated Measurement Systems for Machine Tools

Measurement Procedure

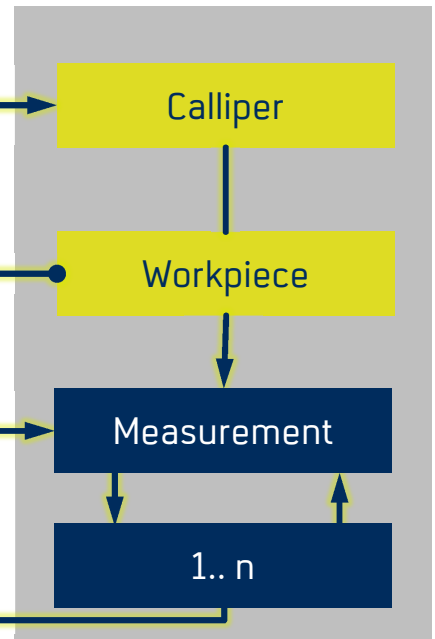
> Calibration



> Supervision & Control



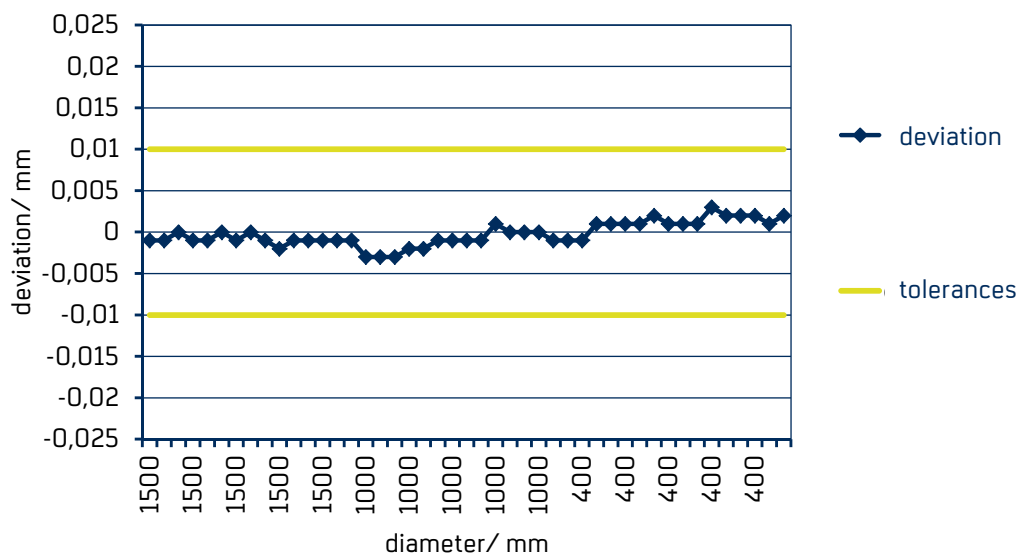
> Measurement



Integrated Measurement Systems for Machine Tools

Measurement example of the repeatability

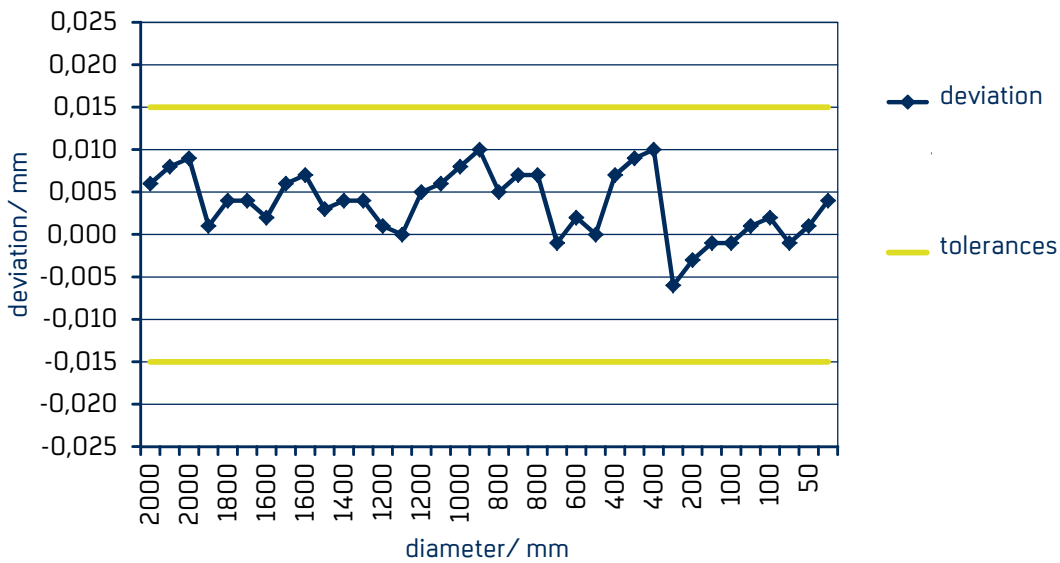
> Repeatability: $\pm 0.01 \text{ mm}_{k=2}$



Integrated Measurement Systems for Machine Tools

Measurement example of the accuracy

> Accuracy: $\pm 0.015 \text{ mm}_{k=2}$



Documentation

Measuring report

> Automatic generated measuring reports

Wellenbearbeitungs-Zentrum Ultraturm 4000MC		
Datum: 29.03.2015	Mess-Protokoll	
Uhrzeit: 14:16:36		
mit uns technisch überlegen		

Wellenbearbeitungs-Zentrum Ultraturm 4000MC											
Datum: 29.03.2015	Mess-Protokoll										
Uhrzeit: 14:16:36											
mit uns technisch überlegen											
Werkstück:	Messpunkt-Nr.:										
Auftrags-Nr.:	Fert.-Zustand:										
Zeichnung-Nr.:	Bearb.-Zustand:										
Zeichn.-Index:	Reserve										
Kennnummer:	Reserve										
Kreisform											
Solldurchmesser:	2200,000 mm										
Position (Z-Achse):	0,000 mm										
Messung:	Rundlauffehler (Exzentrizität):	0,9 µm bei: 118,9°									
Mittlerer Durchmesser:	2200,028 mm	Kreisformabweichung nach DIN ISO 1101:	5,1 µm								
Max. Durchmesser:	2200,032 mm	Max. positive Abweichung:	32,4 µm								
Min. Durchmesser:	2200,023 mm	Max. negative Abweichung:	23,0 µm								
Kreisformabweichung [µm]:											
0°	30°	60°	90°	120°	150°	180°	210°	240°	270°	300°	330°
16,7	17,2	18,5	17,1	16,7	16,4	16,4	16,7	18,2	17,5	17,0	15,2
■ Abweichung vom Solldurchmesser											

Messpunkt-Nr.:									
Fert.-Zustand:									
Bearb.-Zustand:									
Reserve									
Reserve									
e):		2200,000 mm							
		0,000 mm							
messer:		2200,028 mm							
:		2200,032 mm							
:		2200,023 mm							
Rundlauffehler (Exzentrizität):		0,9 µm bei: 118,9°							
Kreisformabweichung nach DIN ISO 1101:		5,1 µm							
Max. positive Abweichung:		32,4 µm							
Max. negative Abweichung:		23,0 µm							
µm [µm]:									
60°	90°	120°	150°	180°	210°	240°	270°	300°	330°
16,5	17,1	16,7	16,4	16,4	16,7	18,2	17,5	17,0	15,2
Abweichung vom Solldurchmesser									



Integrated Measurement Systems for Machine Tools

Conclusion

- > A machine tool is not a coordinate measuring machine!
- > Two ways facing the challenges:
 - > Supervision of the machine tool deviations by additional measurement systems.
 - > e.g. monitoring of the measuring task related TCP deviations.
 - > Additional integrated measurement systems within the machine tool.
 - > e.g. mechanical isolated calliper

Integrated measurement systems have an huge potential to improve efficiency and quality significantly!

Integrated Measurement Systems for Machine Tools

Facing the challenge



Industrial research group „Precision manufacturing of large parts“

Thank you for your attention!

Dr.-Ing. Dipl.-Wirt.-Ing

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Maschinenfabrik

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Email matthias.wennemer@georg.com

werkzeugmaschinen



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24

16.10.2018