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Test Piece for Visualization of Thermally Induced Deviations on Five-axis Machine Tools

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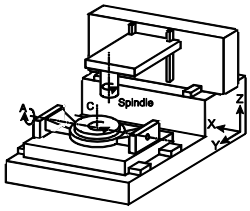
Introduction

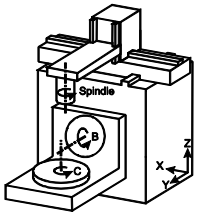
- Accuracy is significantly influenced by thermal deviations
- Methods to detect thermally induced errors on machine tools are basically complex measuring setups
- Development of a thermal test piece similar to a geometrical test piece
  - Easy setup
  - Simple analysis
  - The first attempt: Focus on X-, Y- and Z-errors

Introduction

- Testing the test piece on 2 different machine tools with a swiveling rotary table
  - Manufactured out of aluminium
  - Milling during the test cycle with a fine miller, infeed 0.1 mm



Machine Tool A/C

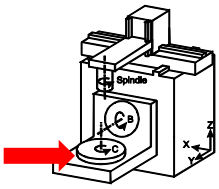


Machine Tool B/C

Test cycle

- 6 hours test cycle
- 3 hours warming up followed by 3 hours cooling down
- Thermal load induced by rotating the table (C-axis)
- Milling parts of the test piece in hourly intervals

Thermal load



Machine tool A/C

Influences on accuracy of test piece

- **Geometrical errors**
  - 52 geometric errors
  - E.g. straightness of axis motion

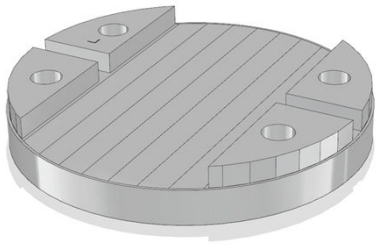
  machine tool B/C Y-axis 2 µm

  machine tool A/C X-axis 2 µm
- **Thermal influences**
  - Moving axis

    Δz up to 80 µm after 3 hours rotating the C-axis (B/C)
  - Chip flow
  - Ambient temperature

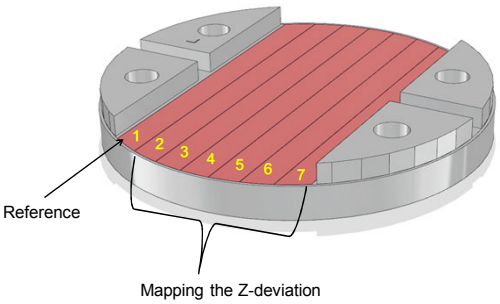
➡ Thermal deviations dominate the influences on accuracy

Thermal Test Piece

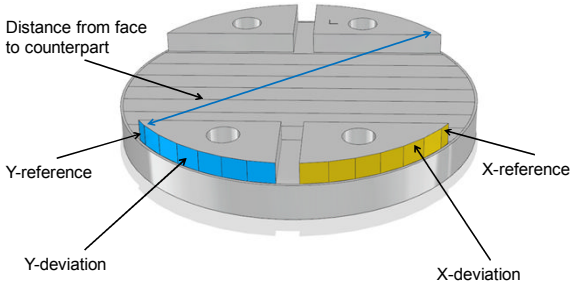


Diameter: 200 mm Height: 25 mm

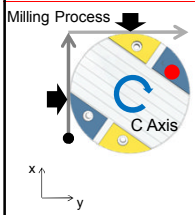
Thermal Test Piece, Z-deviation



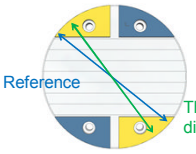
Thermal Test Piece, X- and Y-deviation



Thermal Test Piece, X- and Y-deviation



Reference	+ geometric deviation + positioning accuracy
Thermal influenced distance	+ geometric deviation + positioning accuracy + **thermal deviation**
Reference – Thermal influenced distance	+ repeatability of machine tool + **thermal deviation**

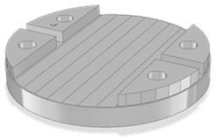


- Two milling positions of material removal
- Thermal deviation dominating

Manufacturing

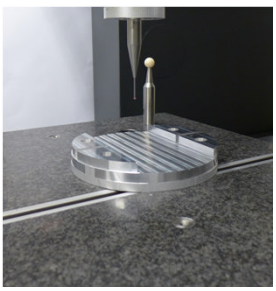
- Mounting the blank
- Diameter 200mm height 25mm

- Milled test piece before test cycle
- One half of the X-Y-faces is milled

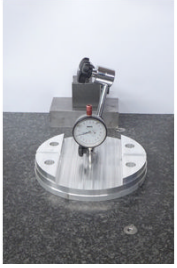


- Milled test piece after test cycle
- Ready to unmount

Measuring methods

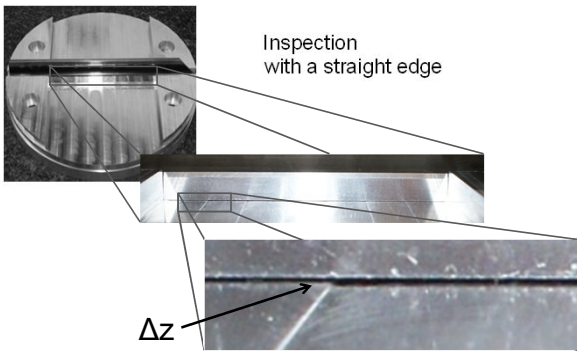


Measuring with a dial gauge

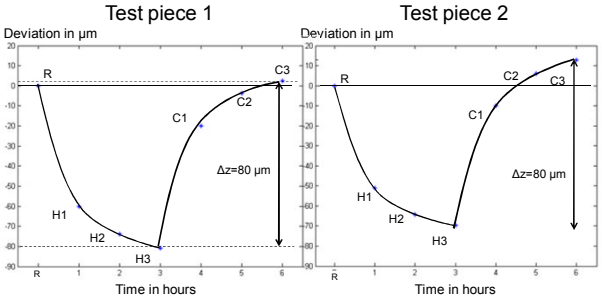


Test piece placed in a coordinate measuring machine

Qualitative inspection

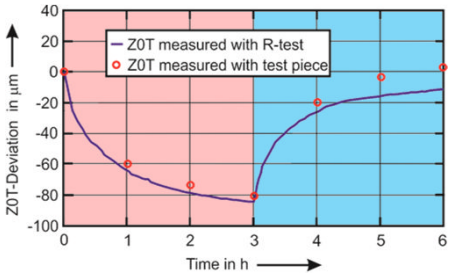


A/C , Z-deviation

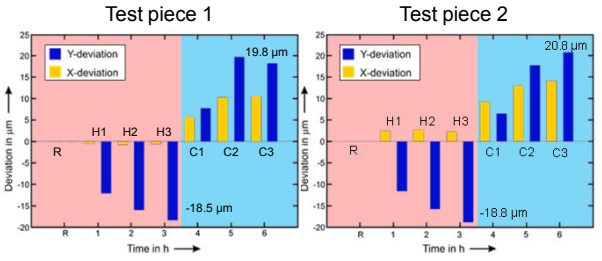


R = reference H = heat-up C = cool-down

A/C , Z-deviation
Comparison with other measuring data

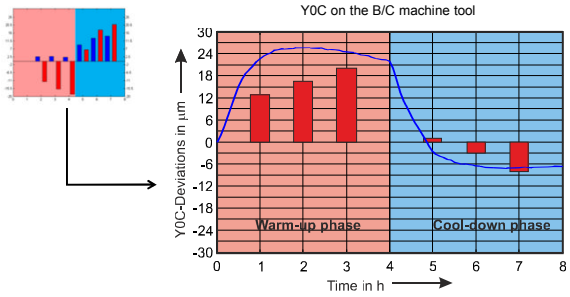


B/C, X- and Y-deviation



R = reference H = heat-up C = cool-down

B/C, X- and Y-deviation
Comparison with other measuring data



- Measuring data without any processes or cutting fluid

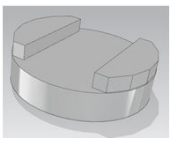
Conclusion

- Thermal deviations are reproducible and significant
- Easy setup and simple analysis of the test piece in comparison to regular measuring setups
- Sufficient data to check a machine tool or a thermal compensation

- Source of the deviations on the test piece not exactly identifiable
- No representation of A-, B- und C-deviations implemented

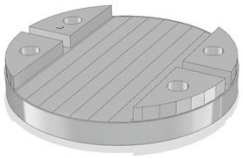
Outlook

- More faces for measuring (more measuring points)
- Better and more reference faces
- Implementing A-, B- and C-deviation
- Optimize the inspection with the straight edge
  Inspection also for X- and Y-deviation



Thank you all for listening!

Discussion



Movie

Influences on accuracy - Summary

	X		Y		Z	
Thermal influence on C-axis	B/C	A/C	B/C	A/C	B/C	A/C
	~0 µm	~10 µm	~24 µm	~0 µm	~28 µm	~80 µm
Some geometrical errors	2 µm	6 µm	2 µm	7 µm	2 µm	2 µm
Measurement uncertainty	1.5 µm / 1µm		1.5 µm / 1µm		0.6 µm / 1µm	

➡ Thermal deviations dominate the influences on accuracy

Thermal Test Piece – Finished surfaces for measuring