TRACEABLE IN-PROCESS DIMENSIONAL MEASUREMENT (IND62 TIM)

A ball-bar standard for monitoring performance of machine tools

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Project requirements

Issues in in-process quality control

- Production process needs quick information about quality – application of in-process measurements is increasing
- In-process measurements on machine tools are in most cases not traceable
- Harsh environmental conditions
- No proper traceable standards available
- Lack of calibration methods and procedures

Project requirements

Project solutions

- One-dimensional standard
- “Thermo-invariant” (stable length in harsh environmental conditions)
- Purpose of use: fast verification of the performance of a machine tool
- Machine tools to be verified: multi-axis milling centres

Concept

- Conceptual design: rod with two balls

- Modular construction: materialising different lengths
- “Negligible” thermal expansion: ≤ invar
- High durability: materials resistant to harsh environmental conditions and high probing forces

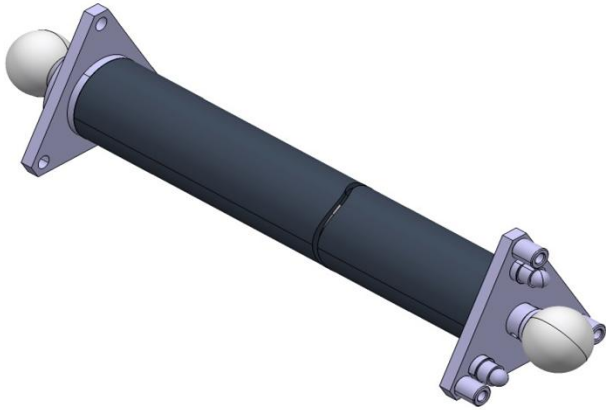
Concept

- Possible to assure traceability on the national level with existing equipment at acceptable uncertainty level (≈5 μm)
- Low mass: easy transporting and handling
- Low price

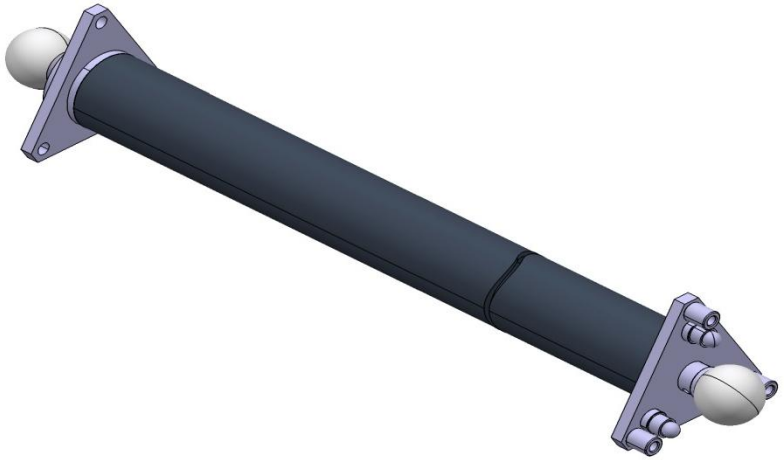
Design

Modular construction: 3 modules, 4 lengths

- Length 1: 500 mm (Module 1)

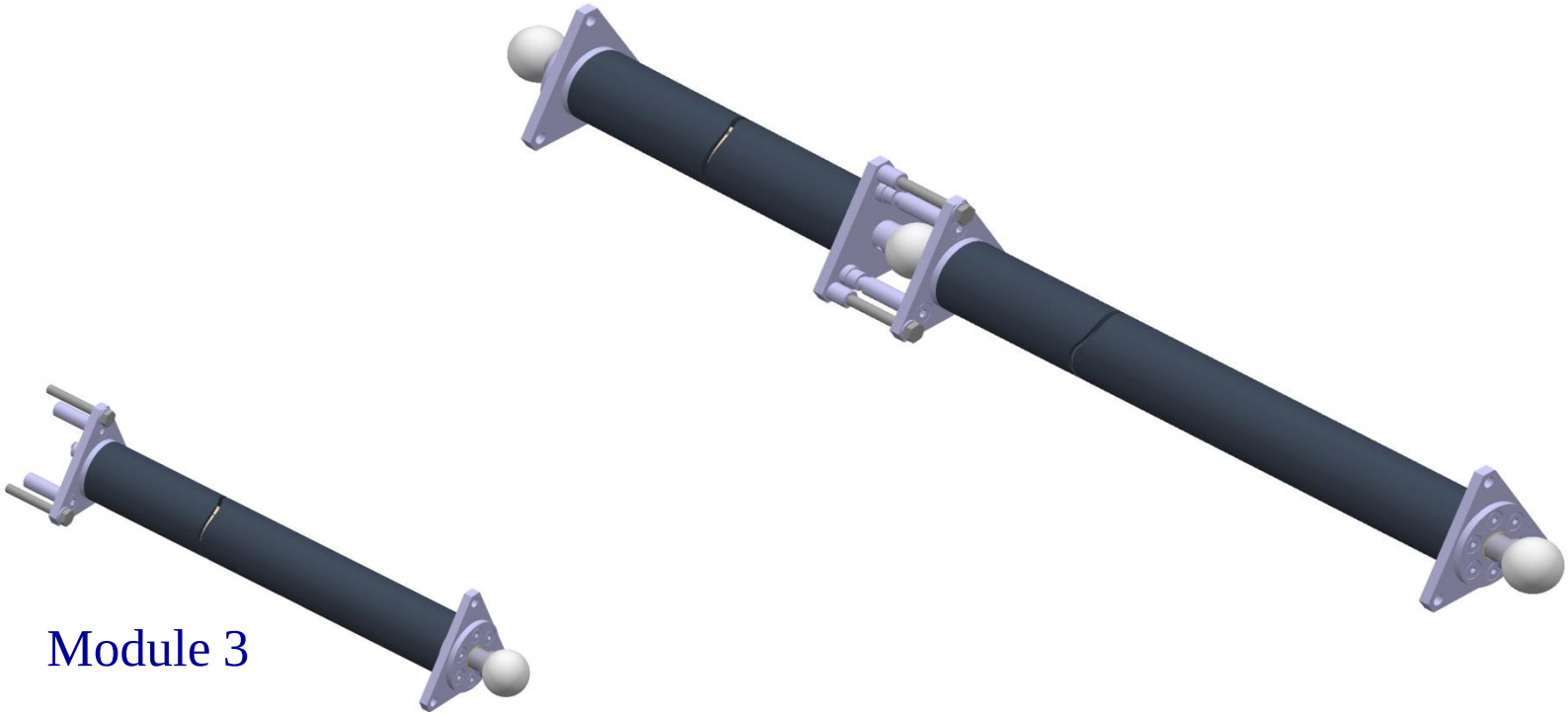


- Length 2: 1000 mm (Module 2)



Modular construction: 3 modules, 4 lengths

- Length 3: 1500 mm (Modules 1 and 3 assembled)



Module 3

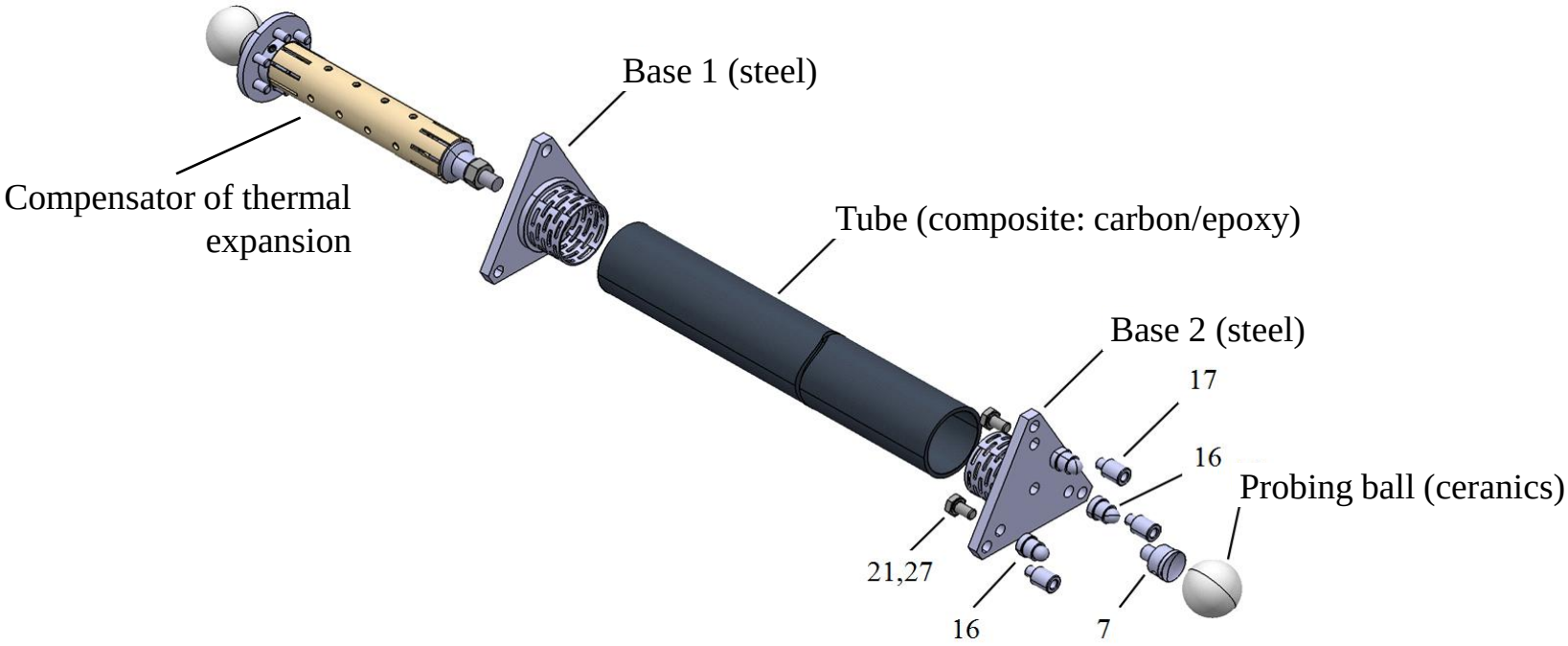
Design

Modular construction: 3 modules, 4 lengths

- Length 4: 2000 mm (Modules 2 and 3 assembled)

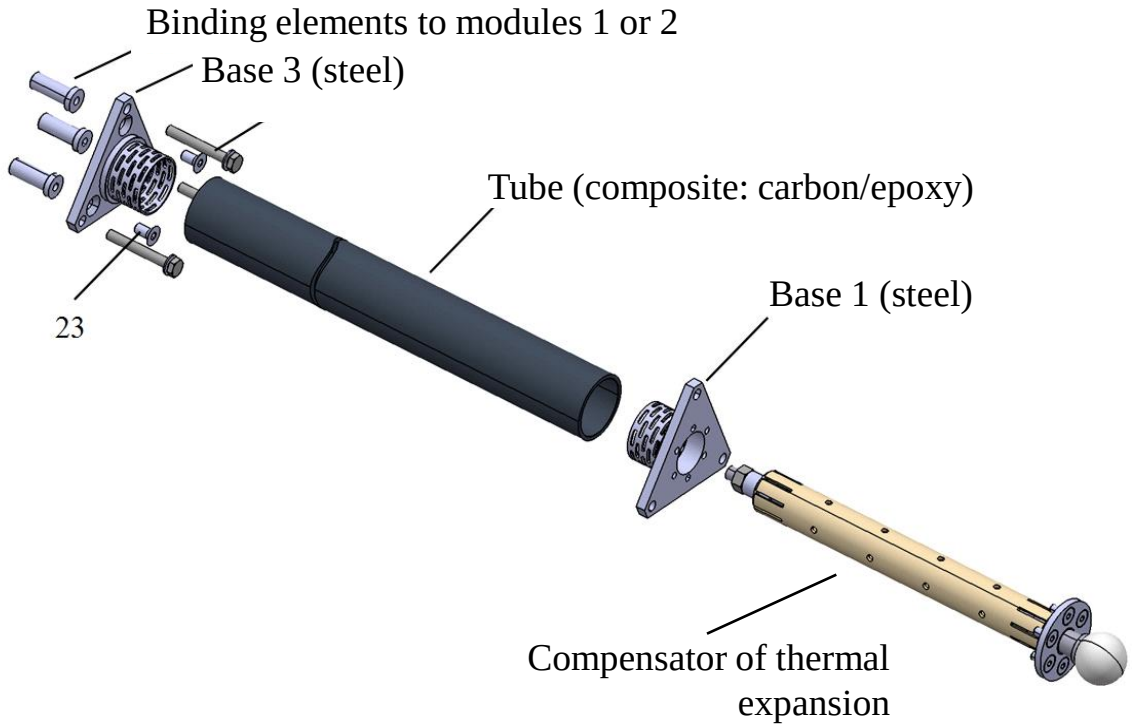
Design of modules

- Modules 1 and 2 (same design, different lengths)

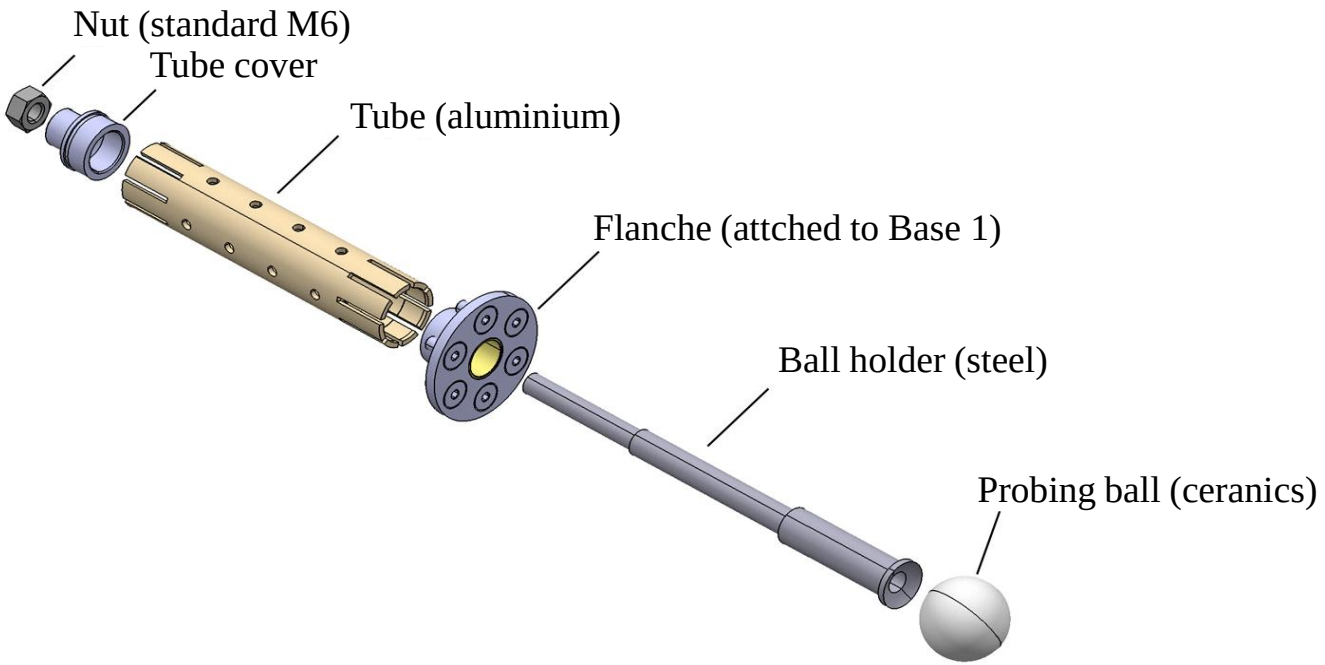


Design of modules

- Module 3

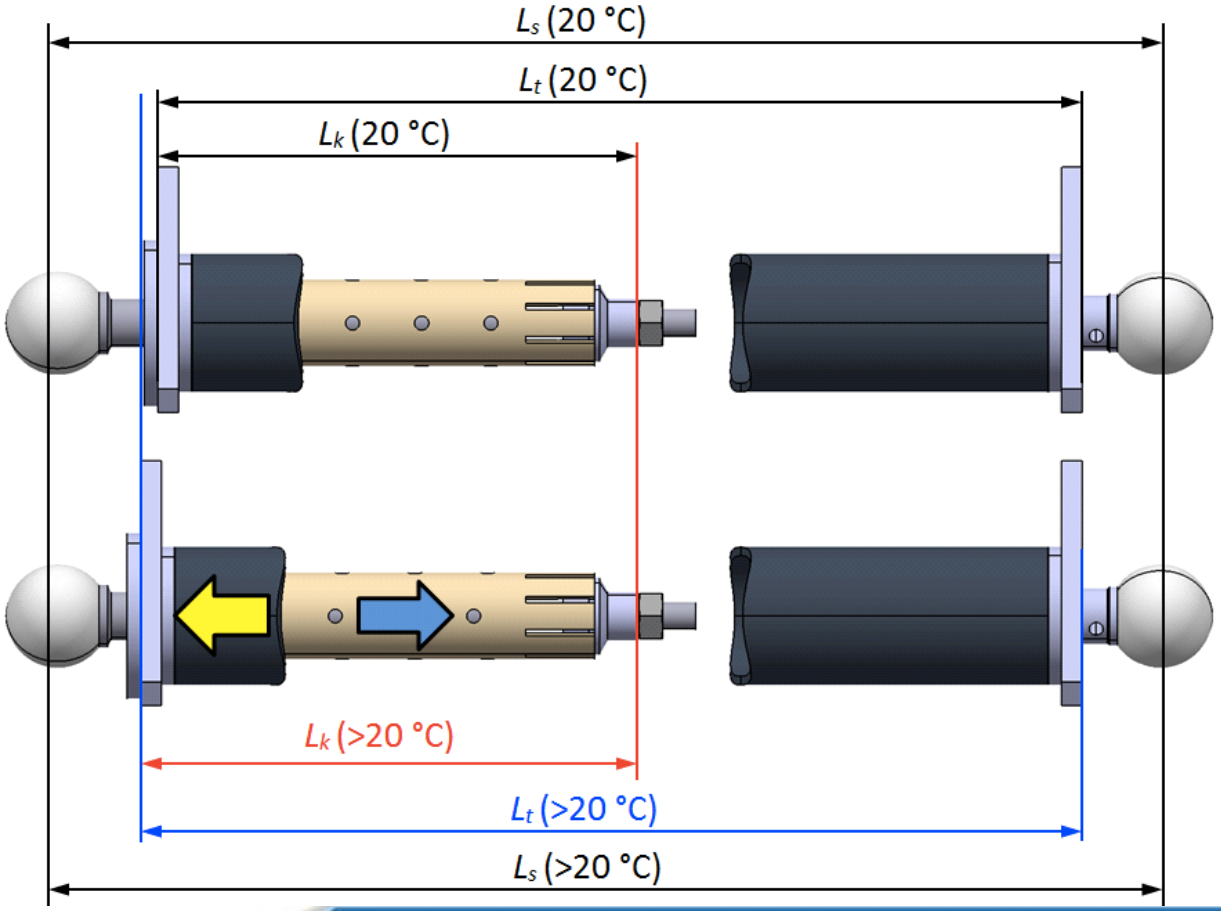


Design of the thermal expansion compensator



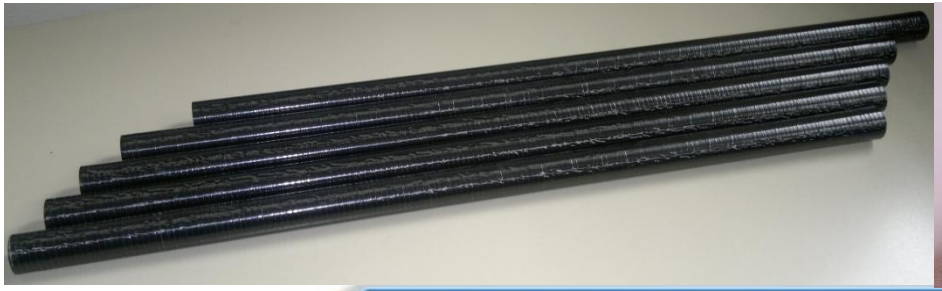
Design

Principle of the thermal expansion compensator



Main body – composite tube

- Special procedure:
  - cutting raw material in longitudinal and cross-direction
  - winding tube and thermo shrinking foil on a greased metal core
  - strengthening bond in autoclave
  - cutting on final length
- Producer: Veplas Velenje (unfunded partner)



Manufacturing

Ceramic balls

- Purchased

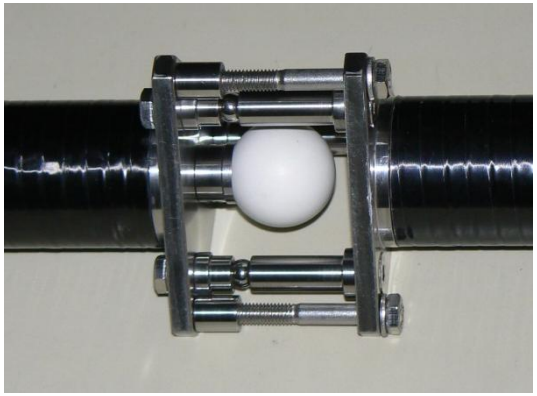
Steel parts

- Manufactured by using standard cutting procedures
- Producer: EMO Orodjarna Celje (unfunded partner)

Aluminium parts

- Manufactured by using standard cutting procedures
- Producer: Gorenje Orodjarna Velenje (unfunded partner)

Final products



Application

Field of application

- For fast performance verification of a machine tool
- Machine tools to be verified: multi-axis milling centres

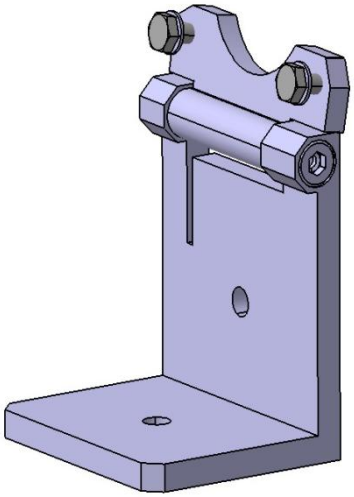
Procedure

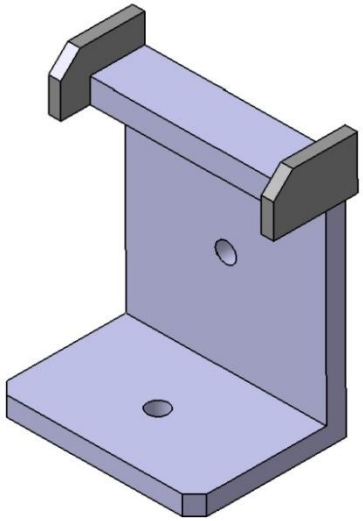
- Machine tool shall be equipped with a tactile probing system
- Distance between two ball centres shall be determined by the machine tool; the value is compared with the calibrated length
- Measurements are performed in different positions in the measuring volume (e. g. in axes x, y and z and in spatial diagonals)

Application

Fixing

- Fixing elements

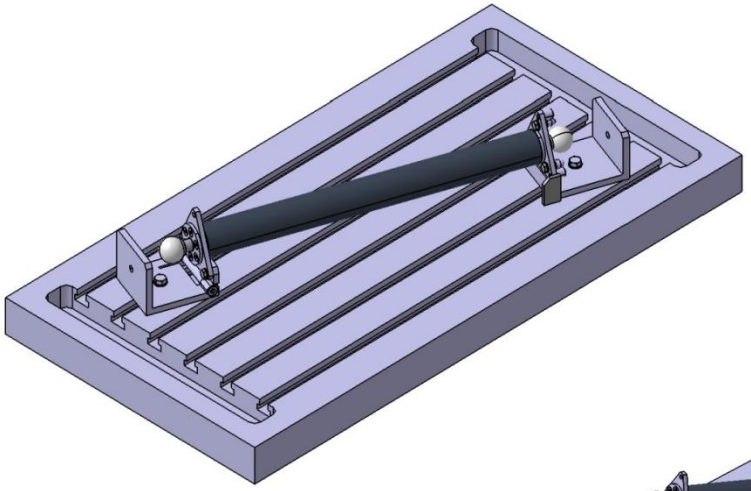


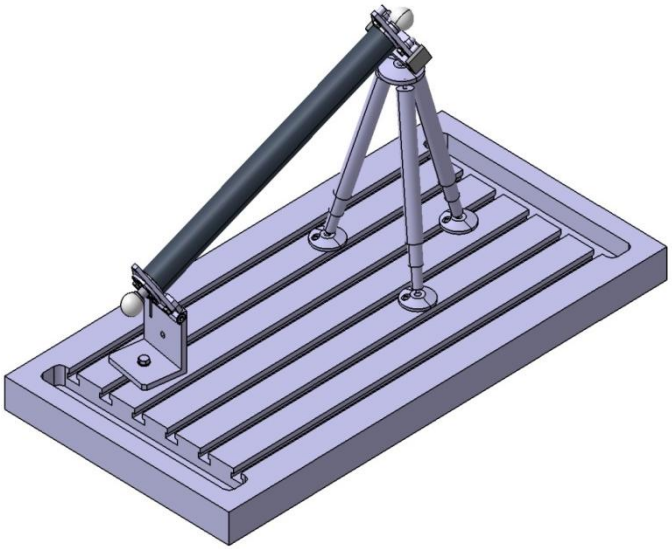


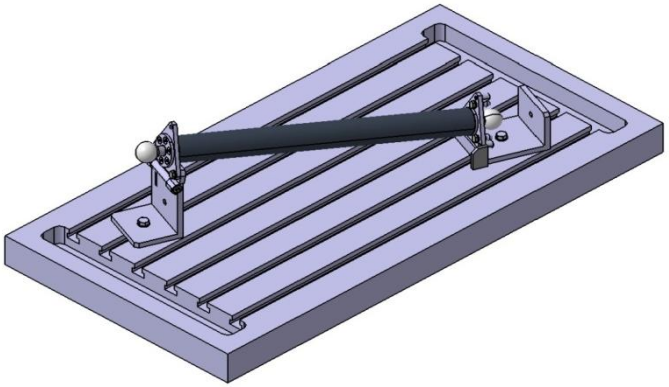
Application

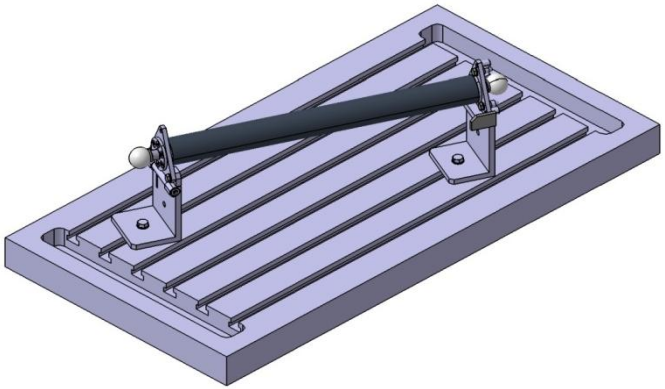
Fixing

- Fixing possibilities





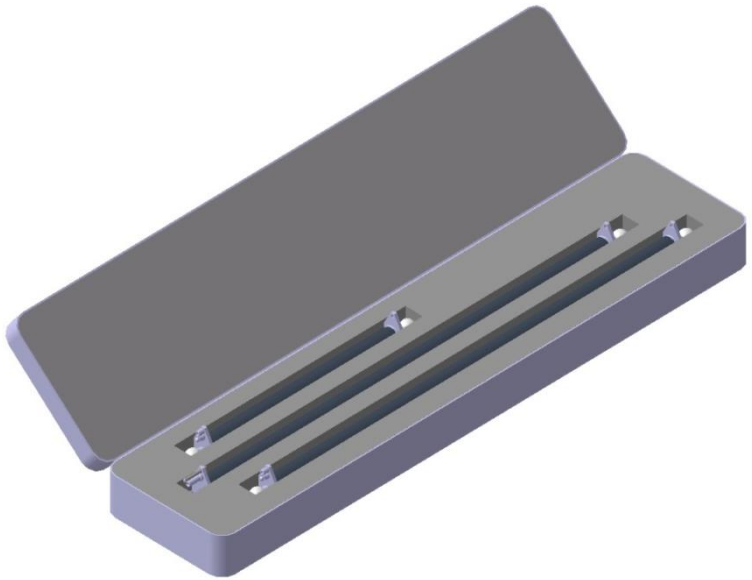




Application

Transportation

- All modules in 1 case



Traceability

Calibration procedure

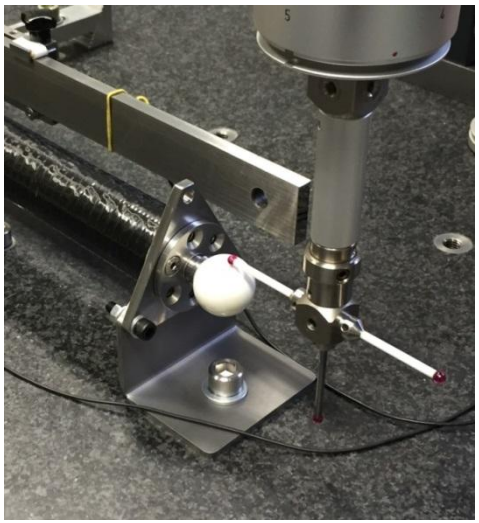
- Calibrated by using tactile CMM ZEISS UMC 850
- Modules calibrated separately by applying normal measurement procedure (probing balls in at least 20 points each, repeating measurements 5 times for each distance, calculating average distances and standard deviations)
- The ball distances on combined modules calculated by considering geometrical properties of joints between the modules
- Calibration certificate stating 4 distances between line centres (at nominal values 500 mm, 1000 mm, 1500 mm, and 2000 mm)

Measurement uncertainty: $U = 2{,}1\ \mu m + 3{,}3 \times 10^{-6} \times L$

Experimental verification

Verification of calculated thermal expansion

- Tests performed in the Laboratory for Production Measurement by using CMM Zeiss UMC 850 and steel gauge blocks
- Measured differences in length at different temperatures were compared with gauge blocks lengths (known thermal properties)



Experimental verification

Verification of calculated thermal expansion

- Results show no systematic correlation between the length and the temperature (considering the length measurement uncertainty)

	T °C	L_m mm	ΔL µm
Tn = 20 °C			
Ball bar standard	20,08	995,7499	
Gauge block	20,04	999,9913	
Tn = 22 °C			
Ball bar standard	22,23	995,7399	
Gauge block	22,21	1000,0027	2,2
Tn = 24 °C			
Ball bar standard	23,64	995,7377	
Gauge block	23,63	1000,0159	2,0
Tn = 26 °C			
Ball bar standard	25,84	995,7353	
Gauge block	25,84	1000,0373	2,1

Experimental verification

Measurements in industrial environment

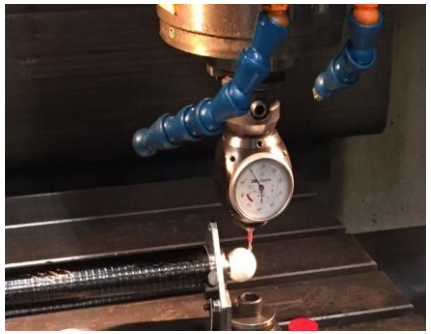
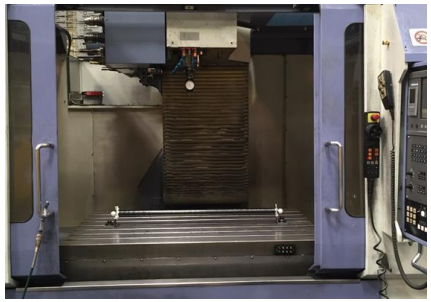
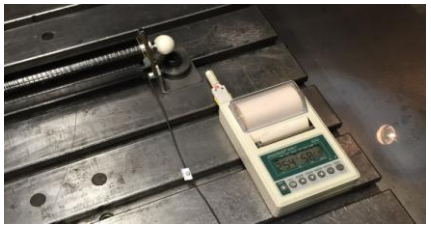
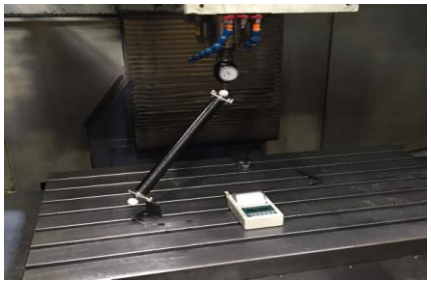
- Measurements were carried out on two 5-axes milling centres in EMO Orodjarna and Gorenje Orodjarna

Famup MC 120 - EMO Orodjarna

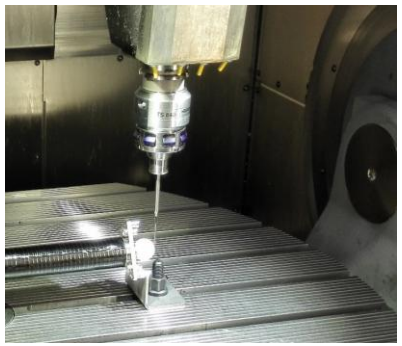
Hermle C50 - Gorenje Orodjarna

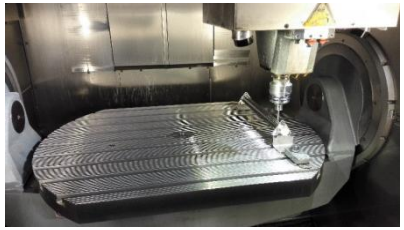
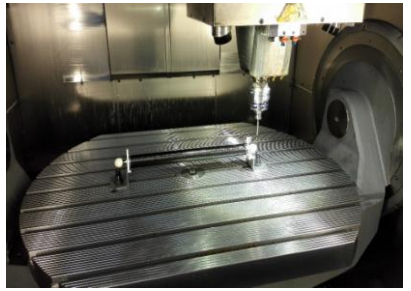
Experimental verification

Measurements in industrial environment

Famup MC 120 - EMO Orodjarna



Hermle C50 - Gorenje Orodjarna

Conclusion

- Purpose of use: fast verification of the performance of a machine tool in harsh environmental conditions
- Concept: simple modular construction, easy to use and to transport, low weight, no special maintenance necessary, negligible effects of environmental conditions, easy to calibrate
- The standard was produced and calibrated
- Thermal expansion properties were determined by experimental measurements
- Application in real conditions was tested in 2 production companies (unfunded partners in the project)

Conclusion

Thank you for attention