Characterization of large Machine Tool volumetric behaviour in workshop conditions

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OUTLINE

- IK4-TEKNIKER
- Background
- Objective of analysis
- Case studies
  - Absolute volumetric behaviour of Machine Tools in workshops
  - Variation of volumetric behaviour in a long time period
  - Analysis of RI compensation in misfit reduction
- Summary
- Conclusions
**WHO WE ARE**

**R&D Centre** (not-for-profit Private Foundation).

Applied research spanning 35 years.

**Mission:** To enhance the positioning and competitiveness of our clients through technology transfer.

Specialised in **Manufacturing**.

Founder members of the **IK4 Research Alliance**.
• **Some years ago…**
  - Modelisation of multilateration method
  - Users of several measuring devices (LT, levels, thermal sensors)
  - Development of sequential laser-based software for volumetric performance characterization of Machine-tools & CMM
  - Thermal drift measurements in Machine-tools
  - Development & validation of volumetric compensation models for MT

• **Nowadays…**
  - Uncertainty assessment of MT for in-process measurements
  - MT performance improvements due to measurements
**OBJECTIVE**

**SEQUENTIAL-MULTILATERATION METHOD**

**Measuring procedure:**
- Integration of several measuring devices
- Fully automatic acquisition
- Several stations
- Machine high-repeatability required

**Our goal:**
1. Reduction of misfit values range
2. Assessment of uncertainty budget
CASE STUDIES

1. **Absolute volumetric behaviour** of MT in workshops
2. **Variation of volumetric behaviour** in long time period
3. **Analysis of RI compensation** in misfit reduction
Absolute volumetric behaviour of MT in workshops
REALISATION

- **Scope**: understand the correlation between misfit histogram in relation with machine volume and thermal working conditions
- Measurements of MT and CMM in workshops & labs
- Analisys of misfit in the measurements (3σ)
- **Misfit**: deviation between measured distances and fitted ones

Wyler levels

Laser-Tracker Leica
RESULTS

- Misfit is around 20 µm for large range machines
- No linear relationship between misfit/vol. & misfit/Tº
- Several machine kinematics (column, bridge, gantry)
Variation of volumetric behaviour in a long time period
Variation of volumetric behaviour in a long time period

REALISATION

- **Scope**: analysis of variation of volumetric performance
- Simulation of measuring uncertainty in shopfloor availability
- Volumetric performance assessment in different thermal conditions (5x)
- Remote monitorization of the machine-tool ambiental conditions (air, surface)
- Definition of a common reference among measurements (same for all axis)
**MEASURING REQUIREMENTS**

- Measuring volume:
  - Axis X: 6000 mm
  - Axis Y: 3000 mm
  - Axis Z: 1500 mm
- Number of points: 270
- 12 dof model (3 cartesian axis)
  - Positioning
  - Straightness
  - Squareness
- 5 locations of measuring device
- Maximum uncertainty Z direction
Variation of volumetric behaviour in a long time period
MEASUREMENTS

Variation of volumetric behaviour in a long time period

12th of July

11st of September

22th of October

12th of December

13th of February
RESULTS

- Stable machine geometry (straightness, squareness) between 20°- 25°C
- Main variation due to $\Delta T$: positioning error
- Thermal expansion control: part & machine
- Common reference is critical to establish the range of variation
- The thermal expansion is different for each axis
- In short displacements the error is small (accurate differential displacements)

Variation of volumetric behaviour in a long time period
Analysis of RI compensation in misfit range reduction
REALISATION

- **Scope**: analysis of RI in misfit width histogram
- Use of refractometer (interferometry based wavelength-tracker) in volumetric measurement
- Time dependant three dimensional map of IR is built
- Synchronization of measurements
- Model considering time and height is estimated
- Compensation of RI for each distance measurement
**RESULTS**

- Little effect above misfit range
- Around few µm correction
- **Compensation**: Currently not worthy considering on volumetric error mapping

![Without-compensation](image1.png)

![Compensated](image2.png)
SUM-UP

• Measuring procedure improvements possible
• Machine modelisation enhancements
• Machine tool geometry is stable (gantry type)
• RI is not so critical in shopfloor measurement

Further measurements will show us the way……
REMAINING UNCERTAINTY SOURCES

- Lack of repeatability on the machine tool in a sequential multilateration process
- Long-term frequency stability of the laser
- Laser-beam steering mechanism imposed errors in the measured displacements
- Retroreflector induced errors

Further measurements

Real-time multilateration
+ MT complex models
+ Invariant volumetric performance
Eskerrik asko
Gracias
Thank you