

Advanced identification and control for thermal systems

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Advanced Identification and Control for Thermal Systems

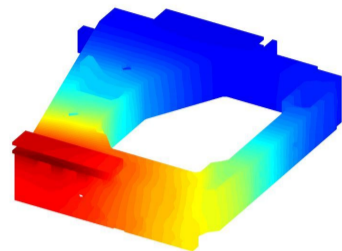
Enzo Evers
Bram de Jager
Tom Oomen
e.evers@tue.nl
Control Systems Technology
Dept. Mechanical Engineering



Thermal Deformations

Challenges:

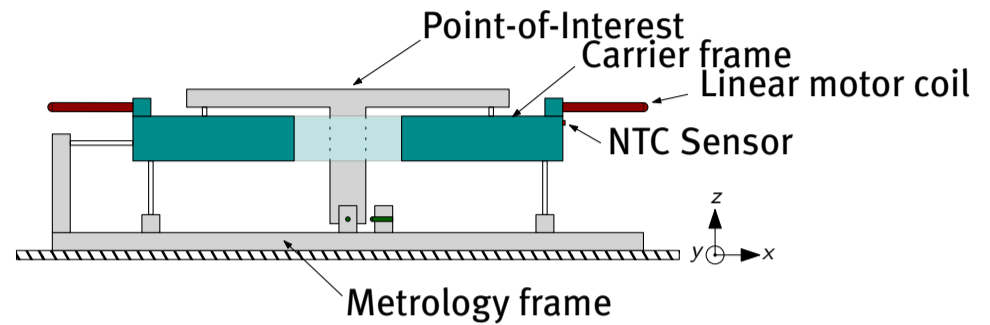
- Accuracy: Deformation induced by thermal gradients
- Thermal control less developed compared to mechanical [1]



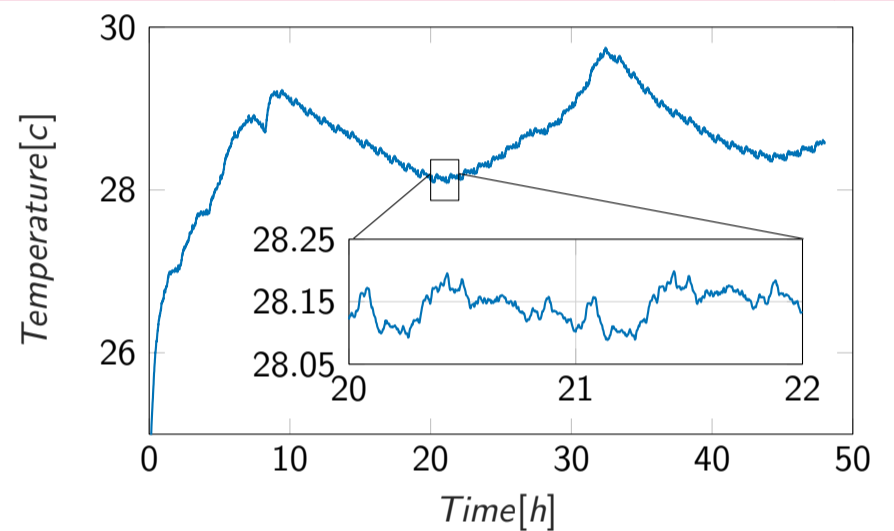
Experimental setup

Precision stage application (PSA)

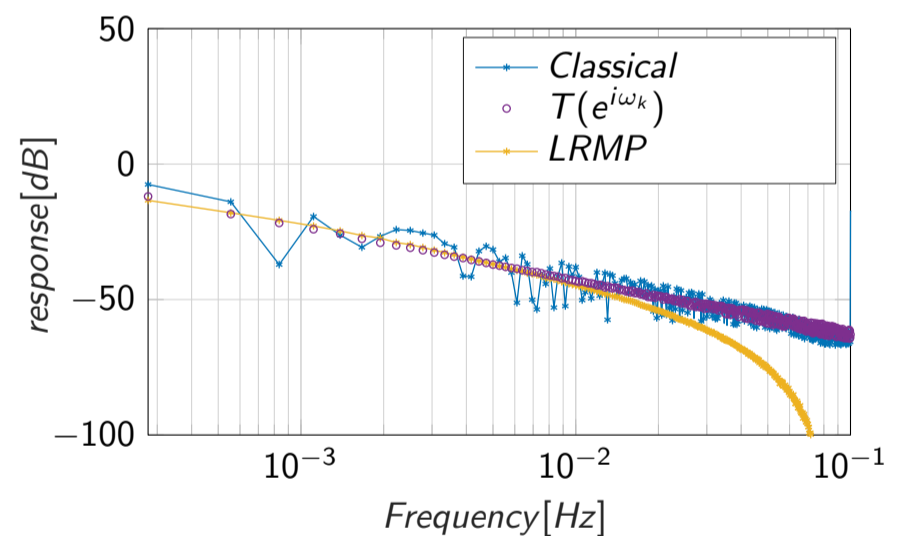
- Linear motor coil as heat source
- Multisine excitation with period of 1 hour



Experimental results



Strong transient response and environmental disturbance



Modelling for thermal control:

- Error compensation [2]
- Active control
- (Non-)parametric modelling

Next big step in FRF identification [3]

Key challenges in system identification:

$$Y(k) = G(e^{i\omega_k})U(k) + \underbrace{T(e^{i\omega_k})}_{\text{transient}} + V(k)$$

Transient dynamics

- Mechanical: $\mathcal{O}(10 \text{ s})$
- Thermal: $\mathcal{O}(10 \text{ min})$

Proposed approach:

Local Rational Method with Prescribed Poles (LRMP)

Local window around a DFT bin k such that locally

$$G(e^{i\omega_{k+r}}) = \sum_{b=1}^{Nb} \theta_{G_b} B_b(e^{i\omega_{k+r}})$$

$$T(e^{i\omega_{k+r}}) = \sum_{b=1}^{Nb} \theta_{T_b} B_b(e^{i\omega_{k+r}})$$

where $B_b(e^{i\omega_{k+r}})$ are (rational) basis functions

$$B_b(z) = \left(\frac{z\sqrt{1-|\zeta_n|^2}}{z-\zeta_n} \right) \prod_{k=0}^{n-1} \left(\frac{1-\bar{\zeta}_k z}{z-\zeta_k} \right)$$

where $\zeta = \{\zeta_0, \zeta_1, \dots, \zeta_p\}$ are the pre-specified poles for the all-pass functions.

FRF identification:

1. Classical: Spectral analysis, large transient error
2. Transient estimation and removal
3. LRMP: Improved FRF estimation

Future work:

- Error compensation and control [2]
- Inferential control [4]

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 [3] E. Evers, B. de Jager, and T. Oomen, "Improved Local Rational Method by incorporating system knowledge: with application to mechanical and thermal dynamical systems," in 18th IFAC Symposium on System Identification (SYSID 2018), Stockholm, Sweden, 2018.
 [4] J. Guo, "Positioning Performance Enhancement via Identification and Control of Thermal Dynamics: A MIMO Wafer Table Case Study," MSc Thesis, Eindhoven University of Technology, 2014.

