Advanced identification and control

Advanced Identification and Control: Thermodynamics in precision mechatronics

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Abstract for oral presentation

In modern times technological advancements and innovations are ubiquitous. To facilitate these developments requires tremendous effort in the high-tech manufacturing, life sciences and the medical industry. Keeping up with the increased demands on accuracy and throughput on the mechatronic systems requires complex systems-of-systems based designs and advanced control methods.

Impressive progress in advanced motion control of precision mechatronics has led to a situation where motion systems are capable of positioning up to the nano-meter scale. These precise movements are essential in several industrial applications, e.g., the manipulation of the sample in an electron microscope and the manufacturing of integrated circuits.

As a result of these advancements, the position errors are entirely compensated and thermal-induced deformations have relatively become more pronounced on the overall system performance. Therefore, the thermal dynamical aspects are no longer negligible and must be actively controlled.

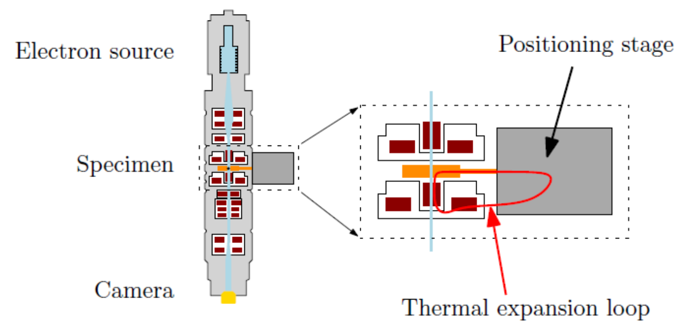

Figure 1 A general overview of a typical transmission electron microscope. The expansion loop represents the collective thermal expansion of different components in the mechanical positioning stage assembly. Dominant heat sources in the system are the coils that are used to shape the electron beam. [1]

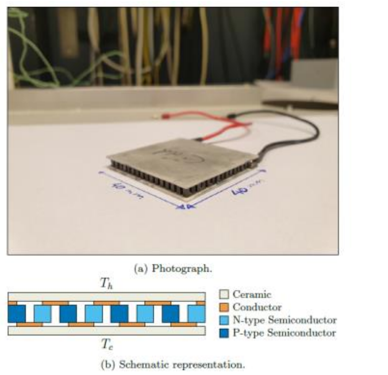

Figure 2 Photograph and schematic representation of a thermo-electric module. The semiconductor elements are contained between two ceramic plates. [2]

We present a selection of recent contributions on modelling and control of thermodynamical aspects in precision mechatronics. In particular: 1) A framework that achieves fast and accurate identification of thermal FRFs. It addresses several challenges that are typically faced when identifying a thermal FRF. Specifically, transients are addressed by using a local modelling approach. 2) A high-fidelity parametric model is obtained by constructing a lumped-mass parametric model and leveraging the improved FRF to calibrate the model parameters. This grey-box approach is shown to be successful in several industrial application case studies. 3) A novel actuator concept using thermo-electric elements is presented that can alleviate challenges associated with traditional heater based control. The overall result is a framework for the identification and control of thermodynamic aspects in precision mechatronic systems.

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[1] Evers, E., van Tuijl, N. A., Lamers, R., de Jager, A. G. & Oomen, T. A. E., Fast and Accurate Identification of Thermal Dynamics for Precision Motion Control: Exploiting Transient Data and Additional Disturbance Inputs. Oct 2020, In IFAC Mechatronics. 70, 8 p., 102401.

[2] Evers, E., Slenders, R., van Gils, R., & Oomen, T. A. E. (Accepted/In press). Temperature-Dependent Modeling of Thermoelectric Elements. In 21st IFAC World Congress, Berlin, Germany.