Advanced Identification and Control: Thermodynamics in precision mechatronics

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Abstract for Poster

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.

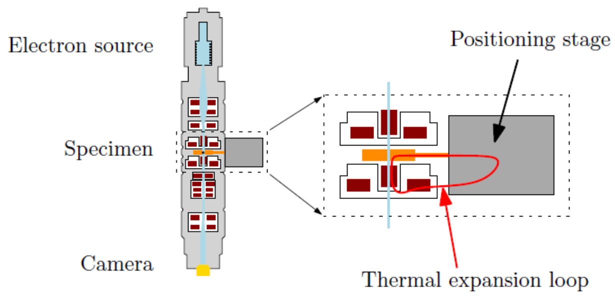

Figure 1 A general overview of a typical transmission electron microscope. The expansion loop represents the collective thermal expansion of different components in the mechanical positioning stage assembly [1].

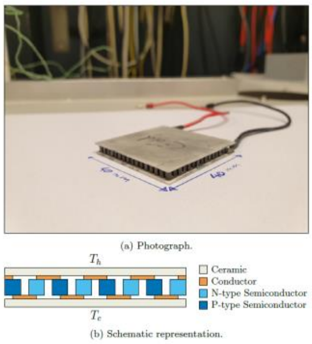

Figure 2 Photograph and schematic representation of a thermo-electric module. The semiconductor elements are contained between two plates [2].

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 systematic approach to high-fidelity parametric modelling 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 that can alleviate challenges associated with traditional heater based control.

The overall result is a collection of tools and techniques for the identification and control of thermodynamic aspects in precision mechatronic systems.

[1] E. Evers, N. van Tuijl, R. Lamers, B. de Jager and T. Oomen, "Fast and Accurate Identification of Thermal Dynamics for Precision Motion Control: Exploiting Transient Data and Additional Disturbance Inputs," *To appear*, 2020.

[2] E. Evers, R. Slenders, R. van Gils and T. Oomen, "Temperature-Dependent Modeling of Thermoelectric Elements," in *21th World Congress of the International Federation of Automatic Control*, Berlin, Germany, 2020.