Data-driven reduced-order modeling of thermo-mechanical models of machine tools

Q. Aumann[1], P. Benner[2,1], I. V. Gosea[2], J. Saak[2,1], and J. Vettermann[1]

[1] *Research Group Mathematics in Industry and Technology, University of Technology Chemnitz, Reichenhainer Str. 41, 09126 Chemnitz, Germany*
[2] *Max Planck Institute for Dynamics of Complex Technical Systems, Sandtorstr. 1, 39106 Magdeburg, Germany*

Thermo-mechanical finite element models predict the dynamic behavior of machine tool systems during the manufacturing process. Such models consist of interconnected substructures, which may or may not be moving relative to each other. The main quantity of interest is the displacement of the tool center point from its desired location due to mechanical deformation, which is mainly caused by the system's constantly changing thermal field. Resulting numerical models are typically very large, and methods to reduce the computational complexity are therefore required for their efficient application in design and control [4, 3].
Machine tool systems typically consist of multiple interconnected substructures which may exhibit different properties, for example local nonlinearities. Maintaining independent (reduced-order) models for the substructures enables a flexible design process, as new machine designs can efficiently be assembled by combining the substructures. However, such models often have a high number of inputs and outputs to correctly model their interconnections and couplings.
In this contribution, we use a data-driven model order reduction method based on the Loewner framework to obtain reduced-order models of thermo-mechanical numerical models of machine tools. The method computes a reduced-order model from transfer function measurements only and does not require direct access to the discretized models. The resulting reduced-order models are required to preserve stability, as they should be used for time domain analysis [2]. A particular challenge for an effective model order reduction are the high number of inputs and outputs of the subsystems [1]. In the considered case, the matrix-valued transfer function is not fully populated, i.e. certain combinations of input and output mappings produce zero outputs.

References

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