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Toward transient finite element simulation of thermal deformation of machine tools in real-time

Daniel Ruprecht[1], **Andreas Naumann**[2] **and Joerg Wensch**[3]

[1] School of Mechanical Engineering, University of Leeds, UK, d.ruprecht@leeds.ac.uk
[2] Institute for Scientific Computing, Technische Universität Dresden, Germany, andreas.naumann@tu-dresden.de
[3] Institute for Scientific Computing, Technische Universität Dresden, Germany, joerg.wensch@tu-dresden.de

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Transient Finite element models can accurately describe the spatial and temporal distribution of heat in machine tools as well as the resulting deformation from basic physical principles [1, 2]. Fundamentally, this allows to correct for displacements of the Tool Centre Point and enables high precision manufacturing. However, the computational cost of FE models and restriction to generic algorithms in commercial tools prevents their operational use since, for online error compensation, simulations have to run faster than real-time.

We will present an iterative multi-rate time stepping algorithm based on spectral deferred corrections, tailored for a machine tool with one axis of movement, consisting of a head stock moving on rails attached to a stand [3]. By using a bespoke algorithm and an efficient implementation in the DUNE finite element library [4], we are able to simulate heat flow and thermal deformations for the fully coupled problem faster than real-time. Simulations with a time discretisation error of around 3% are possible with a look-ahead factor of ten.

The talk will describe the algorithm and present results. Further possibilities to reduce runtimes for even larger look-ahead factors will be discussed.

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