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A HIGHER-ORDER FICTITIOUS DOMAIN METHOD FOR THE MODELING OF THERMOELASTIC DEFORMATIONS IN NC MILLING

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In this presentation, the combination of a higher-order fictitious domain method along with state-dependent mesh refinements is proposed for the modeling of thermo-mechanical deformations induced during NC-milling processes.

In the roughing process of the NC milling, a significant amount of heat is induced into a work piece due to the conversion of energy during the chip formation process. This results in global thermo-mechanical deformations that remain present in the subsequent finishing process and may consequently cause a strong deviation of the work piece surface from its designed shape after cooling down. Thus, critical manufacturing tolerances may be exceeded.

The aforementioned deformations are modeled by the standard equations of linear thermo-elasticity that are here discretized via the Crank Nicolson scheme in time and a higher-order fictitious domain method in space, see also [1, 2, 5]. The continuous (deformation dependent) material removal implied by NC milling processes causes a continuously changing domain of possibly complex geometry. To model that changing domain, state-dependent mesh refinements are pursued using interface representation algorithms such as the marching cubes algorithm along with corresponding volume meshes on an adaptively refined axis-parallel hexahedron mesh, see also [4, 5]. These meshes are utilized in the fictitious domain method using (coarse-scale) hexahedrons from the mesh refinement history for the definition of the higher-order Ansatz spaces and using any further refinement of these hexahedrons as sub-meshes. The latter allow for an appropriate definition of a characteristic function for the state-dependent domain of the milled work piece and may hence serve for quadrature purposes in the discretized equations of linear thermo-elasticity.

For the definition of the Ansatz spaces, standard higher-order tensor product finite element shape functions based upon integrated Legendre polynomials are multiplied with the state-dependent characteristic function for the domain. Possible multi-level hanging nodes and varying polynomial degrees in the chosen mesh for the Ansatz spaces are handled with so called connectivity matrices, see also [3].

Excellent applicability of the proposed approach for the modeling of complex NC milling processes is shown through the comparison of numerical results with measured data from actual physical experiments.

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