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HOMOGENIZATION OF THE CONTACT COUPLING EQUATIONS WITHIN AN ITERATIVE, STEADY-STATE ALGORITHM FOR THE NUMERICAL SIMULATION OF METAL FORMING PROCESSES

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The industrial hot forming processes can be described with a time-dependent thermo-mechanical multi-field problem $(\vec{v}, p, \sigma, \varepsilon)$, conventionally resolved numerically using the incremental methods. Considering that such processes are stationary in nature, one can take advantage of the physics to resolve the problem using the steady-state methods, and thus speed up the computation by 10-50 times. These techniques have been used in the past [1][2] but only for simple configurations and/or with structured meshes, whereas, the modern-day problems are in the framework of complex configurations, unstructured meshes and parallel computing. The steady-state methods eliminate time dependency from the equations, but introduce additional unknowns into the problem, the steady-state shape and the contact surface $(\vec{x}, \Gamma_c)$, which can be computed by introducing a surface correction equation $\vec{v}.\vec{n}(\vec{x}) = 0$. The mechanical problem and the surface correction are strongly coupled through the unknown contact surface Γ_c. For the steady-state resolution, Ripert et al [3] proposed a staggered, two stepped, fixed point iterative algorithm, involving the computation of: (1) flow field from the thermo-mechanical equations on a prescribed domain shape, and (2) steady-state shape for an assumed velocity field. The contact constraints, described with the velocity $\vec{v}.\vec{n}^{tool} \leq 0$ in and the material impenetrability $\delta(\vec{x}) \geq 0$ in two steps respectively, are applied in the penalty form on the contact surface Γ_c, which is firstly predicted in the step (1) s.t. the contact stress $\lambda < 0$, and later corrected in step (2) s.t. the pseudo-contact stress $\mu < \varepsilon$. Here λ, μ are the Lagrangian multipliers for the two respective contact constraints, and ε is a small positive number. The resulting contact equations are non-homogeneously described, i.e., it is described in the nodal form in the former, and in the weighted residual form in the latter, which becomes critical to the convergence of certain problems. Thus, the notion of nodal collocation is invoked in the surface correction problem to homogenize the contact equations. The new contact coupling is tested with certain hot rolling test cases and it is found that the new iterative algorithm with the homogenized contact equations is more robust.

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