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Parallel domain decomposition preconditioners for Isogeometric discretizations arising in impact problems at high strain rates

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Shear bands are one of the most fascinating instabilities in metals that occur under high strain rates. They describe narrow regions, on the order of micron scales, where plastic deformations and significant heating is localized that eventually leads to fracture nucleation and failure of the component.

In this work shear bands are described by a set of four strongly coupled thermo-mechanical equations discretized by a mixed finite element formulation. A thermo-viscoplastic flow rule is used to model the inelastic constitutive law and finite thermal conductivity is prescribed which gives rise to an inherent physical length scale, governed by competition of shear heating and thermal diffusion. The residual equations are solved monolithically by a Newton type method at every time step and has been shown to yield mesh insensitive result. The Jacobian of the system is sparse and has a non-symmetric block structure that varies with the different stages of shear bands formation.

The aim of this work is to develop fast converging Isogeometric elements for monolithic solution of shear bands and appropriate parallel and iterative solvers that are robust through all the deformation stages: homogeneous, onset of instability and stress collapse. To this end, we propose irreducible and hybrid NURBS quadrilateral elements that are stable and locking free and lead to high rates of convergence. To solve the resulting linearized systems, a novel Schur based domain-decomposition preconditioners are proposed based on constitutive/conservation laws splitting. The elements and solvers are implemented in parallel and shows excellent scaling performance compared to standard solvers.

Keywords: Shear bands, NURBS, Preconditioner, Schur complement, Domain decomposition, Additive Schwarz method