Robust block preconditioners for efficient monolithic solution of shear bands

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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 nonsymmetric block structure that varies with the different stages of shear bands formation.

The aim of the current work is to develop robust preconsidioners to GMRES in order to solve the resulting Jacobian systems efficiently. The main idea is to design schur complements tailored to the specific block structure of the system and that account for the varying stages of shear bands. We develop multipurpose preconditioners that apply to standard irreducible discretizations as well as our recent work on isogeometric discretizations of shear bands.

The proposed preconditioners are tested on a couple of benchmark examples and compared to standard state of the art solvers such as GMRES/ilu and GMRES/mutligrid methods. Nonlinear and linear iterations counts as well as CPU times are reported and it is shown that the proposed preconditioners are robust, efficient and outperform traditional state of the art solvers.