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GEOMETRIC MULTIGRID FOR MHD SIMULATIONS WITH NEDELEC FINITE ELEMENTS ON TETRAHEDRAL GRIDS

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The Magneto-HydroDynamic (MHD) model is used extensively to simulate macroscopic plasma dynamics in Magnetic Confinement Fusion (MCF) devices. In these simulations, the span of time scales from fast wave dynamics to the desired evolution of equilibrium due to transport processes is large, resulting in stiff linear systems for implicit time advance. Many existing codes leverage toroidal symmetry, a common feature of many MCF devices, to develop efficient preconditioners for the linearized system. Recent interest in 3D effects in symmetric MCF devices and experiments with non-symmetric boundaries has renewed interest in improved geometric flexibility within numerical tools.

The PSI-TET code is a 3D non-linear extended MHD code based on a high order finite element method using unstructured tetrahedral grids, allowing arbitrary geometry to be captured easily. A mixed FE basis is used with a Nedelec vector basis set used to represent magnetic flux and scalar Lagrange elements used for each component of the plasma velocity. This talk discusses the application of geometric multigrid to preconditioning both equilibrium and time dependent MHD solves in PSI-TET. For equilibrium solves, the relevant linear systems are symmetric so a multigrid-preconditioned CG with Jacobi smoothers is used. The linearized systems produced for time dependent solves are not symmetric so a multigrid-preconditioner GMRES method is employed, with block-preconditioned smoothers. We discuss the implementation and performance of these methods in comparison to single level preconditioners for benchmark and experimental validation simulations. We also present implementation considerations for constructing multigrid levels from both h and p refinement of a base mesh while maintaining consistency CAD geometry. Work supported by DOE.