Block Preconditioners for Resistive MHD in Vector Potential Form

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ABSTRACT

In this talk, we consider block preconditioning strategies for linear systems arising from discretizations of the resistive magnetohydrodynamics (MHD) equations. In particular, we focus on fully implicit discretizations of 3D incompressible visco-resistive MHD. The dynamics of this system arise from a coupling of the Navier-Stokes equations and the Maxwell equations and can be characterized by a wide range of interacting length- and time-scales. The resulting linear systems are particularly difficult to solve when coupling between the electromagnetics and hydrodynamics is strong. Preconditioners for the fully coupled MHD system should both approximate the component physical systems and account for the coupling between them to be effective over a broad range of physical parameters. By considering block preconditioners, we segregate the Navier-Stokes system from the Maxwell system, and the effects of coupling can be captured in block factorizations.

We focus on formulations of the Maxwell equations in which the degrees of freedom are a vector potential A (where B = curl A) and a scalar potential φ. These unknowns can be related by a number of gauges that determine the structure of the 2×2 electromagnetics block. We consider stable discretizations of the Maxwell equations using curl-conforming edge elements for A and nodal elements for φ. We use existing solver technology to develop approximations for this subsystem given different choices of gauge. Many effective preconditioning strategies have been developed for the discretized Navier-Stokes equations. By modifying such strategies in tandem with the block factorizations, we propose new block preconditioners for the full 4×4 MHD system. The parallel performance of these preconditioners is demonstrated by presenting scaling results over a range of physical problems and parameters.