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Preconditioners for Mixed Finite Element Discretizations of Incompressible MHD Equations

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We consider preconditioning techniques for a mixed finite element discretization of an incompressible magnetohydrodynamics (MHD) problem. We use Taylor-Hood elements for the fluid variables and a mixed Nedelec pair for the magnetic unknowns. Upon discretization and linearization, a 4-by-4 nonsymmetric block-structured linear system needs to be (repeatedly) solved. One of the principal challenges is the presence of a skew-symmetric term that couples the fluid velocity with the magnetic field. Our proposed preconditioner exploits the block structure of the underlying linear system, utilizing and combining effective solvers for the mixed Maxwell and Navier-Stokes subproblems. The preconditioner is based on dual and primal Schur complement sparse approximations. We perform spectral analysis for an ideal version of the preconditioner, and develop and test a practical version of it. Large scale numerical results for linear systems of dimensions up to ten million demonstrate the effectiveness and scalability of our approach.