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Towards Robust Numerical Solvers for Nuclear Fusion Simulations Using JOREK: A Numerical Analysis Perspective

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One of the most well-established codes for modeling non-linear Magnetohydrodynamics (MHD) for tokamak reactors is JOREK, which solves these equations with a Bézier surface based finite element method. This code produces a highly sparse but also very large linear system. The main solver behind the code uses either GMRES or Bi-CGSTAB with a physics-based preconditioner, but even with the preconditioner there are issues with memory and computation costs and the solver doesn't always converge well. This work contains the first thorough study of the mathematical properties of the underlying linear system. It enables us to diagnose and pinpoint the cause of hampered convergence. In particular, analyzing the spectral properties of the matrix and the preconditioned system with numerical linear algebra techniques, will open the door to research and investigate more performant solver strategies, such as projection methods.

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