Algorithmic aspects and performance of AMG-based preconditioning for an implicit FE VMS resistive MHD model

Paul Lin*, John N. Shadid†, Edward G. Phillips†, Jonathan J. Hu†, Paul Tsuji‡, Eric C. Cyr†, Roger P. Pawlowski† and David Sondak#

*,† Sandia National Laboratories
P.O. Box 5800 MS 1320
Albuquerque, NM 87185-1320 USA
e-mail: ptlin@sandia.gov

‡ Lawrence Livermore National Laboratory
7000 East Ave., Livermore CA 94550 USA

University of Texas
Austin, Texas 78712 USA

ABSTRACT

Resistive magnetohydrodynamics (MHD) models describe important natural phenomena and technological applications such as magnetically confined fusion energy and pulsed fusion reactors. Accurate numerical simulations require high resolution. Fully-coupled implicit Newton-Krylov approaches can be advantageous because of their robustness for complex multiphysics problems. However, they require the scalable solution of very large sparse linear systems. Multilevel/multigrid-based methods offer one potential approach for obtaining scalable solutions. We examine the performance of a fully-coupled algebraic multigrid (AMG) [1-5] as well as a block (with AMG applied to the sub-blocks) preconditioned Newton-Krylov solution approach for a finite element variational multiscale turbulence model on unstructured meshes for incompressible MHD. The smoothers can have a large impact on the performance and robustness of a multigrid preconditioner. We present scaling results for resistive MHD test cases, including results for over 500,000 cores on an IBM Blue Gene/Q platform.

REFERENCES

[1] A. Prokopenko, J. Hu, T. Wiesner, C. Siefert, R. Tuminaro, "Muelu user's guide 1.0," Techical Report SAND2014-18874, Sandia National Laboratories (2014)

[2] P. Lin, J. Shadid, R. Tuminaro, M. Sala, G. Hennigan and R. Pawlowski, "A parallel fully coupled algebraic multilevel preconditioner applied to multiphysics PDE applications: drift-diffusion, flow/transport/reaction, resistive MHD," International Journal Numerical Methods in Fluids, Vol. 64, Issue 10-12, pp. 1148-1179, (2010)

[3] J. Shadid, R. Pawlowski, J. Banks, L. Chacon, P. Lin and R. Tuminaro, "Towards a Scalable Fully-Implicit Fully-coupled Resistive MHD Formulation with Stabilized FE Methods" Journal of Computational Physics, Vol. 229, 20, pp. 7649-7671, (2010)

[4] J. Shadid, R. Pawlowski, E. Cyr, R. Tuminaro, P. Weber and L. Chacon, "Scalable Implicit Incompressible Resistive MHD with Stabilized FE and Fully-coupled Newton-Krylov-AMG," Comput. Methods Appl. Mech. Engrg., Vol. 304, pp. 1-25, (2016)

[5] D. Sondak, J. N. Shadid, A. A. Oberai, R. P. Pawlowski, E. C. Cyr, and T.M. Smith, "A new class of finite element variational multiscale turbulence models for incompressible magnetohydrodynamics," Journal of Computational Physics, Vol. 295, pp. 596-616, (2015)