Ongoing efforts towards scalable open-source liquid-metal MHD simulation for fusion multiphysics

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Detailed, predictive modelling using multiphysics simulation approaches is key to accelerating the development of commercially viable magnetic confinement fusion power plant designs. To accurately model large and complex fusion problems in high fidelity requires highly scalable simulation codes, coupled together to capture emergent physics. A significant component of this multiphysics problem is that of coolant and breeder flows, which in the case of liquid metals are dominated by magnetohydrodynamic (MHD) effects due to the interaction between the conducting fluid and the strong magnetic fields required for plasma confinement. In [1] we presented initial steps in exploring open-source liquid-metal MHD solvers, conducting scaling analysis and validation of two finite volume OpenFOAM MHD solvers and an initial implementation of finite element incompressible inductionless MHD in the Proteus application, built on the MOOSE framework. We now present an overview of ongoing efforts building on this, approaching a suite of liquid-metal MHD solvers intended to target requirements on a range of timescales, including advanced OpenFOAM MHD solvers developed by Blishchik et al. [2] and Fico et al. [3], and new finite element solvers in MOOSE and MFEM based on the inductionless, charge-conservative formulation derived by Li et al. [4] and demonstrated by Urgorri et al. [5]. Finally, work is ongoing to investigate and expand on the recently developed fully-inductive incompressible MHD implementation [6] in the spectral-element computational fluid dynamics code NekRS. Together these tools aim to provide the range of capability required for practical advances in liquid-metal MHD modelling, from short-term engineering applications to long-term high fidelity exascale multiphysics simulation.

References

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