ALMA toolkit for simulation of magnetohydrodynamic duct flows

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We introduce a magnetohydrodynamic (MHD) model built on the ALMA framework to simulate MHD duct flows and other benchmark problems associated with liquid metal blanket applications. These problems span across the laminar and turbulent regimes, spatially varying magnetic fields and wall conductivity values ranging from zero (insulating walls) to infinity (conducting walls). ALMA (Anti-symmetric, Large-moment, Accelerated) is a flexible and scalable toolkit based on 2008 Fortran standard, the Message-Passing Interface (MPI), OpenMP for shared memory computation on CPUs and OpenACC for GPU acceleration [1]. It exploits the anti-symmetric representation of standard fluid models to achieve fast performance with rigorous conservation at extreme scales. The anti-symmetric representation of the MHD equations enable inherent conservation of quadratic invariants (mass, momentum and energy). The benchmark problems are chosen from Smolentsev [2]. Firstly, the laminar flow of a conducting liquid in a rectangular duct subject to uniform transverse magnetic field is considered. Insulating walls and walls of finite conductance are chosen and the flow profile is validated for a range of Hartmann numbers (varying from 500 to 15000). Secondly, the liquid metal flow in square duct subject to a spatially varying magnetic field is simulated. Thirdly, the behaviour of a liquid metal flow in a high aspect ratio duct is analysed. The parameters are chosen such that the fluid behaviour lies in the turbulent regime. The results from these benchmark cases are compared against existing analytical and experimental studies in the literature to demonstrate the robustness of the model.

References

[1] F. D. Halpern and co-authors, Simulations of plasmas and fluids using anti-symmetric models, J. Comp. Phys., 445, 110631 (2021).

[2] Smolentsev and co-authors, An approach to verification and validation of MHD codes for fusion applications, Fusion Eng. des., 65–72 (2015).