A highly portable heterogeneous implementation of symmetry-preserving methods for magnetohydrodynamics

J.A. Hopman[1], F.X. Trias[1] and J. Rigola[1]

[1] *Heat and Mass Transfer Technological Center, Technical University of Catalonia, ESEIAAT, c/Colom 11, 08222 Terrassa, Spain, jannes.hopman@upc.edu*

MHD flows at high Hartmann numbers (Ha) require conservative discretisation schemes to accurately calculate the delicate balance between pressure gradient and opposing Lorentz force. The importance of conserving physical properties increases when capturing small-scale motions in turbulent and transitional regimes. In this work, a symmetry-preserving discretisation of the continuous operators in the Navier-Stokes equations is used to warrant this conservation [1]. The collocated grid arrangement of Ni et al. [2] is used as a basis, so that extension to complex geometries is possible.

To handle the high mesh requirements of MHD flows at high Ha, the method is implemented in HPC^2, a fully portable algebra-dominant framework for heterogeneous computing [3]. This framework relies on a reduced set of algebraic kernels necessary for calculating the MHD flow. Combined with multilevel parallelization, this framework provides high portability to different architectures such as multicore CPUs and GPUs, allowing for large-scale computations.

Finally, symmetries in the geometry of reactors are exploited to diagonalise and split the Laplacian matrix into highly-similar blocks [4]. Splitting both Poisson equations reduces the memory footprint of the Laplacian matrix and increases the arithmetic intensity from a sparse matrix-vector product, to a sparse matrix-matrix product, reducing computational cost.

References

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