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Jacobian-Free Newton-Krylov Discontinuous Galerkin (JFNK-DG) Method and Its Physics-Based Preconditioning for All-Speed Flows
HYEONGKAE PARK, ROBERT NOURGALIEV, DANA KNOLL, Idaho National Laboratory — The Discontinuous Galerkin (DG) method for compressible fluid flows is incorporated into the Jacobian-Free Newton-Krylov (JFNK) framework. Advantages of combining the DG with the JFNK are two-fold: *a*) enabling *robust and efficient high-order-accurate modeling of all-speed flows on unstructured grids*, opening the possibility for high-fidelity simulation of nuclear-power-industry-relevant flows; and *b*) ability to *tightly, robustly and high-order-accurately couple with other relevant physics* (neutronics, thermal-structural response of solids, etc.). In the present study, we focus on the physics-based preconditioning (PBP) of the Krylov method (GMRES), used as the linear solver in our implicit higher-order-accurate Runge-Kutta (ESDIRK) time discretization scheme; exploiting the compactness of the spatial discretization of the DG family. In particular, we utilize the *Implicit Continuous-fluid Eulerian (ICE) method* and investigate its efficacy as the PBP within the JFNK-DG method. Using the eigenvalue analysis, it is found that the ICE collapses the complex components of the all eigenvalues of the Jacobian matrix (associated with pressure waves) onto the real axis, and thereby enabling at least an order of magnitude faster simulations in nearly-incompressible/weakly-compressible regimes with a significant storage saving.

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