An Efficient hp-Adaptive Approach for Compressible Two-Phase Flows using the Level-Set Ghost Fluid Method

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ABSTRACT

We present an efficient hp-adaptive discretization for sharp interface simulations of compressible two-phase flows using the level-set ghost fluid method. The discretization employs a high order p-adaptive Discontinuous Galerkin (DG) scheme in regions of high regularity, whereas discontinuities are captured by a more robust Finite Volume (FV) scheme on an element-local sub-grid. The h-refinement strategy effectively carries over the subscale resolution capability of the DG scheme to shocks and the phase interface, while preserving an essentially non-oscillatory behavior of the solution. The p-refinement and the FV-limiting are controlled by a common indicator that evaluates the modal decay of the solution polynomials. The resulting adaptive hybrid DG/FV operator is used for the governing equations of both, the fluid flow and the level-set transport.
However, the hp-adaptive discretization, together with solving the computationally expensive level-set equations only in the vicinity of the phase interface, causes pronounced variations in the element costs throughout the domain. In parallel computations, these variations imply a significant workload imbalance among the processor units. To ensure parallel scalability, the proposed discretization thus needs to be complemented by a dynamic load balancing (DLB) approach. We introduce a DLB scheme that determines the current workload distribution accurately through element-local walltime measurements and repartitions the elements efficiently along a space-filling curve.
We provide strong scaling results to underline the parallel efficiency of the presented hp-adaptive sharp interface framework. Moreover, complex benchmark problems demonstrate that it handles efficiently and accurately the inherent multiscale physics of compressible two-phase flows.

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