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PROCEEDINGS

From the Hybrid Lattice Boltzmann Model for Compressible Flows to a Unified Finite Volume solver

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ABSTRACT
The hybrid lattice Boltzmann model [1] for compressible flows uses the lattice Boltzmann method (LBM) to simulate the flow field and the finite volume scheme for the energy field. It inherits the good numerical stability and low dissipation [2] of LBM and avoids the complexity of solving all governing equations within the LBM framework. However, it still faces three issues. First, for compressible flows, the equilibrium distribution functions must exactly recover third-order moments, but it cannot be achieved for the simple DmQn (m dimensions and n discrete phase velocities) models involving only neighboring nodes [3], like D2Q9, D3Q15, D3Q19, and D3Q27 models. Correction terms have to be introduced and carefully discretized to maintain numerical stability. Second, for irregular boundary treatment with interpolation, mass leakage [4] occurs and complicated modifications are needed. Third, due to the dependency of LBM on uniform mesh, the hybrid solver is based on uniform meshes as well, which requires much finer meshes to approximate curved boundaries and thus decreases efficiency. To address these issues, the present paper reconstructs an ideal LBM model for compressible Navier-Stokes equations as time-discretized moment equations with physically consistent dissipation terms. Consequently, both flow and energy fields are solved by the finite volume scheme. Compared with the hybrid LBM model for compressible flows, the reconstructed model maintains mass conservation, avoids correction terms, and can be applied to nonuniform meshes naturally. Simultaneously, the good numerical stability and low-dissipation characteristic at a small viscosity of LBM can be retained to a large degree by using appropriate numerical schemes.

KEYWORDS
Hybrid lattice Boltzmann model; compressible flow; finite volume solver; numerical stability

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