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Extension of lattice Boltzmann flux solver for simulation of 3D viscous compressible flows. (English) Zbl 1443.65170

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Summary: The lattice Boltzmann flux solver (LBFS), which was presented by Shu and his coworkers [*L. M. Yang* et al., Comput. Fluids 79, 190–199 (2013; Zbl 1284.76313); *C. Z. Ji* et al., Mod. Phys. Lett. B 23, No. 3, 313–316 (2009; Zbl 1419.76520); *C. Shu* et al., "Lattice Boltzmann flux solver: an efficient approach for numerical simulation of fluid flows", Trans. Nanjing Univ. Aeronaut. Astronaut. 31, No. 1, 1–15 (2014)] for simulation of inviscid compressible flows, is extended to simulate 3D viscous compressible flows in this work. In the solver, the inviscid flux at the cell interface is evaluated by local reconstruction of one-dimensional lattice Boltzmann solution through the application of non-free parameter D1Q4 model to the Riemann problem, while the viscous flux is evaluated by conventional smooth function approximation. In the existing LBFS [Yang et al., loc. cit.; Ji et al., loc. cit.; Shu et al., loc. cit.], the distribution functions at the cell interface streamed from neighboring points are directly used to compute the inviscid flux, which contains superabundant numerical dissipation for simulation of viscous flows. In the present work, we start from the Chapman-Enskog analysis [*Z. Guo* and *C. Shu*, Lattice Boltzmann method and its applications in engineering. Hackensack, NJ: World Scientific (2013; Zbl 1278.76001)] and consider both the equilibrium part and non-equilibrium part of the distribution function at the cell interface. It is well known that the inviscid flux can be fully determined by the equilibrium part and the non-equilibrium part can be viewed as numerical dissipation for the calculation of inviscid flux. The drawback of the existing LBFS is removed by introducing a switch function which ranges from 0 to 1 in order to control the numerical dissipation. In the smooth region such as in boundary layer, the switch function takes a value close to zero, while around the strong shock wave, it tends to one. Through test cases with complex geometry, it has been demonstrated that the present solver can work very well for simulation of 3D viscous compressible flows.

MSC:

65M08 Finite volume methods for initial value and initial-boundary value problems involving PDEs
76M28 Particle methods and lattice-gas methods
76N06 Compressible Navier-Stokes equations

Keywords:

non-free parameter D1Q4 model; lattice Boltzmann flux solver; 3D viscous compressible flows; finite volume method

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