The Hong Kong University of Science and Technology

Department of Mathematics

MPhil THESIS EXAMINATION

Numerical Validation of the Unified Gas-Kinetic Wave-Particle Method

By

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ABSTRACT

In recent years, the unified gas-kinetic wave-particle (UGKWP) method has been developed to simulate non-equilibrium and multi-scale flows. In the UGKWP method, the analytical flux (wave) and free streaming particle are coupled kinetically, which depends on the local state. The particle dominates the simulation at the rarefied flow limit, and its computational efficiency is equal to stochastic particle methods. At the continuum flow limit, wave dominates the simulation, and the computational efficiency approaches to Navier–Stokes (NS) solvers. Due to the adaptive coupling of wave and particle, the method can simulate multi-scale flows with efficiency and accuracy. Although the UGKWP method adopts stochastic particles, it has no limits on the time step and mesh size as other stochastic particle methods require since it is based on the implicit integrated solution of the Boltzmann equation, which has considered the cumulative effect of particle collisions. So, the UGKWP method can allow a much larger time step and mesh size at the continuum flow limit than other stochastic particle methods. In this thesis, the performance of the UGKWP method will be extensively tested via various numerical cases, from free molecular flows to continuum flows. The numerical tests include sod shock tube test, hyper-speed flow around a circular cylinder and a cube, laminar boundary layer, and lid-driven cavity. The results suggest that the UGKWP method can capture the essential flow structure for all Knudsen regimes and has much higher efficiency than the unified gas-kinetic scheme (UGKS).

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