

PROCEEDINGS

A Gas Kinetic Flux Solver Based on Grad's Distribution Function: Extending Applicability from Continuum Regime to Transition Regime

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ABSTRACT

Conventional gas kinetic flux solvers (GKFS) based on the first-order Chapman–Enskog expansion are inherently limited to the Navier–Stokes (NS) level and fail to accurately capture non-equilibrium effects in flows beyond the continuum regime. To overcome the limitation, this paper presents a family of gas kinetic flux solvers that incorporate Grad's moment method to extend the applicability of the conventional GKFS framework. By reconstructing the initial gas distribution function using high-order truncated Hermite polynomial expansions, ranging from Grad's 13-moment (G13) and 26-moment (G26) to 45-moment (G45) system, the proposed schemes construct numerical fluxes directly from the local solution of the Boltzmann equation without relying on the linearized NS constitutive relations. A key feature of these methods is that high-order moments are determined through moment relationships and iterative procedures, thereby avoiding the need to solve complex partial differential equations. The resulting solvers retain the efficiency of finite volume discretization while capturing rarefaction effects. Benchmark test cases covering continuum, slip, and transition regimes demonstrate that the proposed Grad's distribution function-based solvers not only recover accurate NS solutions in the continuum limit but also significantly improve predictions of non-equilibrium phenomena in the transition regime.

KEYWORDS

Gas kinetic flux solver; Grad's distribution function; Boltzmann equation; moment method; continuum regime to transition regime

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