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LATTICE BOLTZMANN STUDY OF RAREFIED FLOWS

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KEY WORDS

Half-range Gauss-Hermite quadrature, Rarefied gases, Couette flow, Lid-driven cavity.

ABSTRACT

In the rarefied regime, gas flows can be described using the Boltzmann equation. In order to correctly describe the interaction between the fluid constituents and the domain boundaries, kinetic boundary conditions (i.e., diffuse reflection) must be implemented. In the vicinity of a diffuse-reflecting boundary, the Boltzmann distribution function develops a discontinuity which can be successfully modeled by projecting the distribution function onto the space of half-range Hermite polynomials. This idea can be transferred to the numerical realm by considering lattice Boltzmann (LB) models constructed with respect to half-range Gauss-Hermite quadratures [1]. In this talk, we will present recent results obtained using our family of LB models having half-range capabilities.

Couette flow

The Couette flow between parallel plates has been a long-standing benchmark test for rarefied gas analysys. In our recent study [1], we have validated our LB models against results available in the literature. Fig 1(a) shows the excellent agreement between our simulation results for the slip velocity [1] and the benchmark data reported in Refs. [2,3].

To demonstrate the applicability of our LB models based on half-range quadratures to flows in non-Cartesian geometries with curved boundaries, we have considered the analysis of the circular Couette flow between two coaxial cylinders. Fig 1(b) validate our results for the velocity profile from the near-continuum (Navier-Stokes) regime up to the free-streaming regime by comparison with the discrete velocity model (DVM) simulations of Ref. [4].

Lid-driven cavity flow

Our final application comprises the lid-driven cavity bounded by two coaxial cylinders and two radially placed walls. Fig. 2 shows the streamlines for a cavity with an opening $\Delta\varphi = \pi$, where the flow is driven by the inner cylinder which rotates counter-clockwise at angular velocity $\Omega = 1$.

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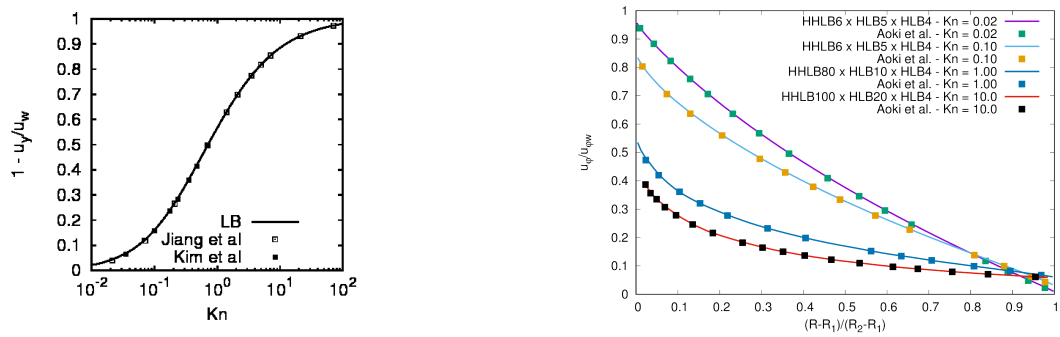

(a) **(b)**

Figure 1: **(a)** Relative slip velocity in Couette flow between parallel plates [1], validated against results from Refs. [2,3]. **(b)** Tangential velocity profile in the Couette flow between coaxial cylinders, validated against the results reported in Ref. [4].

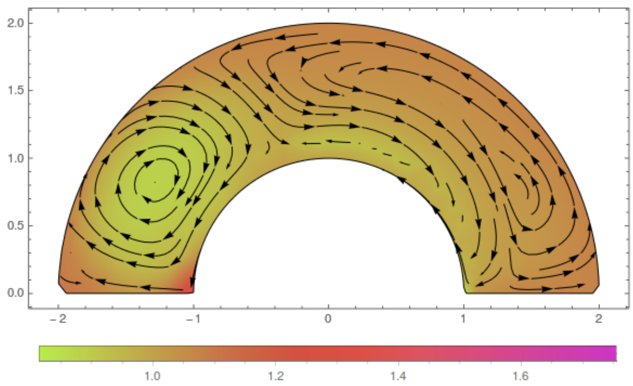

Figure 2: Velocity streamlines in a cylindrical cavity driven by the rotation of the inner cylinder.

Conclusion

Employing the half-range Gauss-Hermite quadrature enables our models to accurately recover the solution of the Boltzmann-BGK equation even for high Mach number compressible flows. These models can be applied for the simulation of flows of all degrees of rarefaction.

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