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A Second-order Slip Model for Early-transition-regime Flows

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We present a second-order slip model which extends the Navier–Stokes description of small-scale gaseous flows to second order in the Knudsen number. The model is based on the hard-sphere approximation and accounts for the effect of the Knudsen layers close to the walls which become important as the Knudsen number increases. We validate this model by comparing its predictions to direct Monte Carlo (DSMC) solutions of the Boltzmann equation for three different flows, namely, steady pressure-driven flow, unsteady impulsive-start flow and oscillatory shear flow. In all three cases, excellent agreement is found between the DSMC solutions and the model results up to Knudsen numbers of 0.4 for both the velocity and the stress fields. The agreement continues to be satisfactory beyond this Knudsen number. Given the prohibitive cost associated with solving the Boltzmann equation, especially in higher dimensions, this model should prove to be of great use for modeling isothermal small-scale flows.

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