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Modeling fluid flows in micro devices: the challenge of Knudsen-layer behavior NISHANTH DONGARI, YONGHAO ZHANG, JASON REESE, Department of Mechanical and Aerospace Engineering, University of Strathclyde, Glasgow G1 1XJ, UK, MULTISCALE FLOWS RESEARCH GROUP TEAM — Microscale gas flows often display non-standard fluid behavior and near a solid bounding surface. This leads to the formation of a Knudsen layer (KL): a local non-equilibrium region of thickness of few mean free paths (MFP) from the surface. Linear constitutive relations for shear stress and heat flux are no longer necessarily valid in the KL. To account this, we investigate a power-law (PL) form of the probability distribution function for free paths of rarefied gas molecules in arbitrary wall confinements. PL based geometry dependent MFP models are derived for complex geometry systems by taking into account the boundary limiting effects on the molecular free paths. Molecular dynamics numerical experiments are carried out to rigorously validate the PL model, under wide range of rarefaction conditions. As gas transport properties can be related to the MFP through kinetic theory, the Navier-Stokes-Fourier (N-S-F) constitutive relations are then modified in order to better capture the flow behavior in the KL. The new modeling technique tested for isothermal and non-isothermal gas flows in both planar and non-planar confinements. The results show that our approach greatly improves the near-wall accuracy of the N-S-F equations, well beyond the slip-flow regime.

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