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DECREASING STATISTICAL NOISE IN THERMAL CREEP FLOWS

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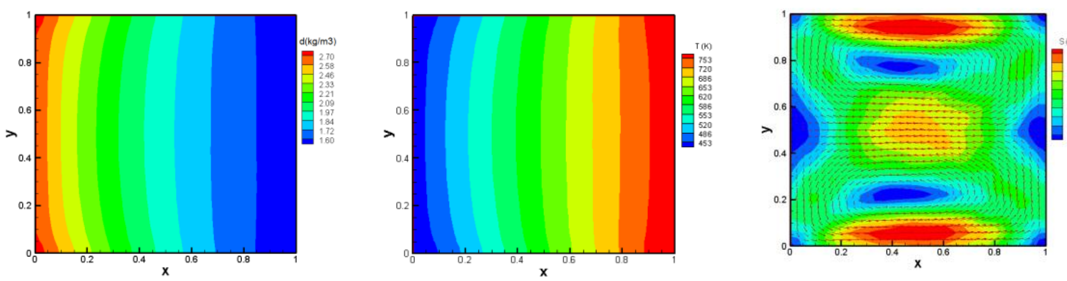
In this study a two-dimensional rarefied gas flow in a square cavity is investigated. This flow is induced by linear temperature gradients on both upper and lower walls. In rarefied gas conditions, the mean-free-path which is the average distance between consecutive molecule collisions is comparable with characteristic length scale of the flow geometry. Actually, the ratio of the mean-free-path and characteristic length is defined with a dimensionless Knudsen number (Kn). Shortly, Kn is a measure of the gas rarefaction. If Kn is lower than the 0.01, continuum based solvers are used to calculate the flow properties. But Kn is higher, because of the inadequate molecule collisions flow depart from the local equilibrium and conventional constitutive equations lose their validity. New non-linear constitutive equations are required. These new continuum based equations are called Burnett equations. But these equations are very difficult to solve because of the complicated boundary conditions and stability problems. Instead, particle methods are preferred in high Kn regimes. Direct simulation Monte Carlo is one of these methods (**Bird-1996**). This stochastic particle method is shown produce conformal results with the experimental studies. The first disadvantage of this method is the computational load in low Kn regimes. But new techniques are developed and the application range of the DSMC method continues extending into the lower Kn number regimes (**Bird-2006**). One other problem with the DSMC method is the slow convergence in the creeping flows, because of the statistical noise (**Chen-2005**). In Fig. 1, density, temperature and velocity contours developed in a square cavity are shown. Although the sampling numbers are same, it is very clear that, the noise in the velocity values is still very high.



(a) (b) (c)

Figure 1. Temperature gradient induced gas flow in a square cavity. (a) Density contours (b) Temperature contours (c) Velocity contours and vectors.

As a gas kinetic theory based method, all the macroscopic properties are calculated from the microscopic properties in DSMC method. The order of magnitude between molecular speeds of the gas molecules and flow velocities of the creeping flows is more than two. To calculate the slow flow velocities, the statistical noise in the DSMC method should be at least two orders of magnitude lower than the flow velocity. This requires tremendous number of sampling and computational load for the DSMC based solvers. In this work, a new approach to this problem is proposed. Additionally, other techniques taken from the literature are discussed.

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