Numerical Analysis of A Gas Flow In A Square Cavity Driven By Spanwise Lid Motion Based on Kinetic Theory: Behavior of The Gas Near A Sharp Corner

Masanari Hattori

Department of Aeronautics and Astronautics
Graduate School of Engineering
Kyoto University
Email: hattori.masanari.4r@kyoto-u.ac.jp

Abstract

A gas flow in a square cavity driven by a lid sliding in the direction of its line of contact with the cavity wall is considered. The steady behavior of the gas is numerically investigated based on the linearized Bhatnagar-Gross-Krook kinetic equation and the diffuse reflection boundary condition. When one applies the Stokes equation and the no-slip boundary condition to the system considered here, the flow velocity becomes multivalued at the corner between the lid and the cavity wall, and the shear stress diverges at the corner inversely proportionally to the distance from there, which is known as the so-called corner singularity. In the present work, the behavior of the gas near the corner is examined based on numerical results obtained from the kinetic theory. Although the range of the flow velocity value in the kinetic solution is limited due to the significant velocity slip near the corner, the flow velocity is, nevertheless, multivalued at the corner. The shear stress varies inversely proportionally to the distance from the corner up to the position that is a few tens of mean free paths away from there. The increase in the stress is suppressed at positions closer to the corner and its magnitude remains bounded.

Thus, the total forces acting on the lid and the side cavity walls are bounded as well. Due to the distinctive behavior of the stress near the corner, the resulting nondimensional total forces behave with an unconventional rate KnlnKn for small Knudsen numbers Kn.