DSMC simulations of Mach 10 hypersonic rarefied flow over a 2D cylinder

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Rarefied flows are generally categorised by lower fluid densities and larger molecular mean free-path to characteristic flow length ratios. General use of FVM solvers fail to predict flows correctly owing to break-down of the continuum characteristic of the original flow. Lagrangian methods such as molecular dynamics codes can in theory be used to predict these flows but are expensive for engineering applications. One exciting technique called Direct Simulation Monte Carlo or DSMC was introduced in early 60’s and pioneered by Prof. G.A. Bird. The first assumption is to reduce the number of particles in the simulation by introducing weighted simulation particle. Each simulated DSMC particle corresponds to fixed number of actual particles. This assumption greatly reduces the amount of computation. This technique uses Boltzmann Equation as base line, but de-couple the two important steps of particle movement and collision assuming that the time interval is very small. Particle movements are tracked based on newtonian motion theory whereas collisions are computed using statistical methods such as Monte Carlo. The bulk properties of the flow is calculated by integrating individual momentum of each particle. It has been observed that, this technique predict results comparable to limited experiment data for flows categorised as rarefied. DSMC simulations are used various fields such as re-entry flows, ionic thrusters, heat dissipation in micro-electronics and high-atmospheric low density flows.

In this study, DSMC simulation is introduced for a begineer by simulating a Mach 10 flow over a 2D cylinder within rarefied conditions of Knudsen number 0.25. The flow comprises of single species of monoatomic Argon. Important points from the study are capturing velocity slip and temperature jump over the cylinder wall. This will help in appreciating the non-equillibrium caused by lesser number of collisions near the wall which leads to such phenomenon. Simulations are carried on using dsmcFoam solver from OpenFoam Suite and grids are generated using Gmesh. This benchmark case is taken from a larger set of simulations simulated and discussed in the phD dissertation of Andrew J. Lofthouse[1].

[1]. NONEQUILIBRIUM HYPERSONIC AEROTHERMODYNAMICS USING THE DIRECT SIMULATION MONTE-CARLO AND NAVIER-STOKES MODELS by Andrew J. Lofthouse, phD thesis (Aerospace Engineering) in The University of Michigan,2008

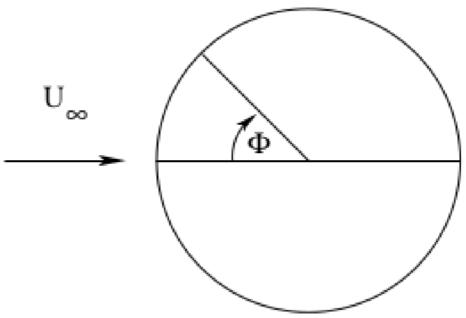

Fig. 1. 2D cylinder geometry definition

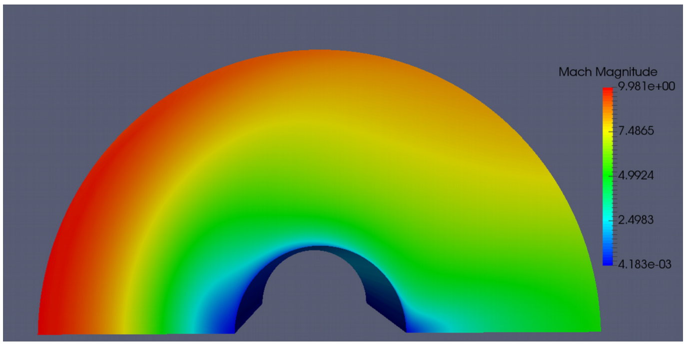

Fig. 2. 2D Mach contour