Three-dimensional discontinuous Galerkin method for the second-order Boltzmann-Curtiss constitutive model in continuum-rarefied gas flows

S. Singh[1], T. K. Mankodi[1], and R. S. Myong[1,2,a)]

[1] *School of Mechanical and Aerospace Engineering, Gyeongsang National University, Jinju, Gyeongnam 52828, South Korea*
[2] *Research Center for Aircraft Core Technology, Gyeongsang National University, Jinju, Gyeongnam 52828, South Korea*

[a)] Corresponding author: myong@gnu.ac.kr

The classical description based on the first-order Navier-Stokes-Fourier (NSF) constitutive laws has serious limitations in predicting the correct flow behavior of diatomic and polyatomic gases in thermal nonequilibrium. As a consequence, simple modification of transport coefficients in the classical NSF theory or introduction of the velocity-slip and temperature-jump boundary conditions cannot solve the current bottleneck of problems in the study of diatomic and polyatomic gas flows in non-equilibrium. In order to cope with these deficiencies, a non-classical theory based on the second-order Boltzmann–Curtiss constitutive relations for diatomic and polyatomic gases was developed by Myong [1, 2]. The second-order constitutive model has been successfully applied to some challenging problems of non-equilibrium gas flows where the NSF equations were found to be inappropriate [3, 4].

In this study, a multi-dimensional mixed-type discontinuous Galerkin (DG) method for the second-order Boltzmann-Curtiss constitutive model is presented for continuum-rarefied gas flow problems. The performance of the DG scheme is assessed by solving the supersonic gas flows past a 2D cylinder in continuum-rarefied regimes.

Fig. 1. Comparison of Mach contours for the Boltzmann-Curtiss based constitutive models.

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