Gas Dynamic Equations with Multiple Temperature

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The Bhatnagar-Gross-Krook (BGK) model approximates the collision term of the Boltzmann equation by a single relaxation process from non-equilibrium state to equilibrium one. From the BGK model, the Navier-Stokes, Burnett and Super-Burnett equations can be derived. However, the success of these derived macroscopic equations in the description of highly non-equilibrium flow is limited. In order to extend the validity of the BGK model to cope with complicated physical relaxation processes, we propose a generalized BGK (GBGK) model, where the gas distribution function settles to an equilibrium state through multiple particle collision processes. The GBGK model can be used to capture the transitional, rotational, and vibrational non-equilibrium flow phenomena.

Based on the GBGK model, the gas-kinetic schemes have been developed and have been successfully applied to the near continuum flow computations, such as the shock structure and non-equilibrium micro-flow computations. In this talk, we are going to present the corresponding new macroscopic governing equations from the GBGK model. In the new governing equations, the translational temperature becomes a tensor instead of the conventional scalar variable. At the same time, the Navier-Stokes constitutive relationship, such as the connection between stress and strain, is fully replaced by the temperature relaxation terms. These relaxation terms recover the Navier-Stokes relationship only in the limiting case as the temperature differences are very small, i.e., the so-called equilibrium limit.