A Computational Method for Eu's Generalized Hydrodynamic Equations of Rarefied and Microscale Gasdynamics

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Generalized hydrodynamic equations have been proposed by Eu (*Kinetic Theory and Irreversible Thermodynamics*, 1992) for modeling the motion of gases far removed from equilibrium. His generalized hydrodynamic equations are consistent with the laws of thermodynamics. In this paper, a computational method of solving Eu's generalized hydrodynamic equations is presented. It has been shown that the new equations are applicable to all Mach numbers and indeed satisfy the second law of thermodynamics at all Knudsen numbers and to every order of approximation. The computational method of the generalized hydrodynamic equations is based on the finite-volume formulation and is exactly the same as the compressible Navier–Stokes codes, except for an additional routine for calculating the shear stress and the heat flux from the given conserved variables and thermodynamic forces. To check its validity and potential for hydrodynamics applications, the method is tested for the structure of one-dimensional shock wave and for a two-dimensional flat plate flow problem. The numerical results show that the new computational model yields the shock solutions for Mach numbers tested, up to $M = 30$, and removes the singularity near the leading edge of a flat plate that is ill-defined in the case of the Navier–Stokes theory.

Key Words: rarefied and microscale gasdynamics; generalized hydrodynamic equations; finite-volume method.