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A generalized hydrodynamic computational model for rarefied and microscale diatomic gas flows

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Abstract

On the basis of Eu's generalized hydrodynamics, a computational model is developed for the numerical simulation of rarefied and microscale diatomic gas flows. The rotational nonequilibrium effect is taken into account by introducing excess normal stress associated with the bulk viscosity of the gas. The computational model for diatomic gases reduces to the model for monatomic gases in the limit of vanishing bulk viscosity. The thermodynamically consistent computational model is applied to the one-dimensional shock wave structure and the two-dimensional hypersonic rarefied flow around a blunt body in order to demonstrate its capability and validate the numerical results. The general properties of the constitutive equations are also presented through a simple analysis. The numerical results show that the new generalized hydrodynamic computational model yields the solutions in qualitative agreement with experimental data and DSMC results in the case of the problems studied.

AMS: 65M06; 76N15; 76K05

Keywords: Rarefied and microscale gas dynamics; Diatomic gases; Generalized hydrodynamic equations; Finite volume method

1. Introduction

The study of nonlinear gas transport in rarefied condition [23,39] and microscale flows associated with MEMS [19] has emerged as an interesting topic of significance in recent years. It has been largely motivated by the need for a theoretical tool to efficiently predict aerothermodynamic loads on vehicles operating in high altitude and by the growing interest in the development of theory for microscale devices in MEMS. In the case of MEMS, the initial emphasis on the development of efficient fabrication techniques for microscale devices is now shifting towards the understanding of fundamental physical phenomena in such devices, which is critical in predicting their performance and in providing information on the optimal space

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