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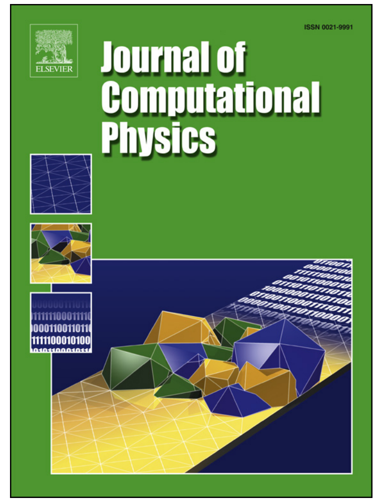

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A Simple Extension of Roe's Scheme for Real Gases

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Abstract

The purpose of this paper is to develop a highly accurate numerical algorithm to model real gas flows in local thermodynamic equilibrium (LTE). The Euler equations are solved using a finite volume method based on Roe's flux difference splitting scheme including real gas effects. A novel algorithm is proposed to calculate the Jacobian matrix which satisfies the flux difference splitting exactly in the average state for a general equation of state. This algorithm increases the robustness and accuracy of the method, especially around the contact discontinuities and shock waves where the gas properties jump appreciably. The results are compared with an exact solution of the Riemann problem for the shock tube which considers the real gas effects. In addition, the method is applied to a blunt cone to illustrate the capability of the proposed extension in solving two dimensional flows.

Keywords: Real gas, Roe's scheme, Local Thermodynamic Equilibrium (LTE), Riemann Problem, Exact solution

1. Introduction

The approximate Riemann solver introduced by Roe [1] has been extensively used to solve the Euler equations where the properties of the fluid are represented by the ideal equation of state. For high temperature and low density flows, this scheme loses its accuracy and in some cases may have no or nonphysical solutions. The most general way of treating high temperature gases requires accounting for both thermal and chemical nonequilibrium. The flux-splitting method of Roe has been extended to non-equilibrium real gases by [3] which is based on a thermodynamic model that includes the general thermal and chemical nonequilibrium flow of an arbitrary gas. However, introducing the assumption of local thermodynamic equilibrium (LTE) allows