Finite Volume Methods for Solving the Unsteady Euler Equations with Chemical Reactions

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Abstract

The flow around a space plane reentering the atmosphere is very often modelled by steady Euler flow with chemical reactions. Ground experiments made in shock tubes have to be modelled by unsteady chemical reacting Euler flow. Besides giving a short description of the overall scheme to simulate such a flow we shall focus on two particular aspects of this computation: 1) The chemical reactions induce an extremely thin, unphysical chemical boundary layer, which makes numerical computations of the two dimensional problem extremely difficult, if not impossible for todays computers. A modification of the Van Leer flux vector splitting is presented which is able to indicate the presence of this boundary layer. 2) Most todays numerical schemes are in a certain sense not truly two dimensional. A truly 2-dimensional scheme due to M. Fey will be presented.

1 Introduction

When solving unsteady Euler equations for hypersonic reactive flow one usually divides the task into two by applying operator splitting. This results in two separate problems, one is finding the solution of non reactive multidimensional Euler equations. Since no diffusion of species is assumed the other problem is finding locally, i. e. in each cell of the mesh, the solution of a small system of ordinary differential equations. The second problem is generally easy to solve since like system is small. e. g. less than 50 equations, in fact in the model described by Park [12] it consists after a proper reduction of 3 equations only. In Section 3 we shall rather describe a truly multidimensional scheme for the non reactive Euler equations. This scheme is not based on dimensional splitting. In principle it can be used for any space dimension and any type of grids,structured or unstructured. The basic idea behind this scheme is a decomposition of the fluxes according to physically motivated waves, a transport wave and a scalar- and a vector-valued spherical shaped wave. It turns out that the scheme is rather robust, i. e. no unphysical values occur even if strong shocks have to be computed. For two space dimensions a variant of the scheme has been used and it was seen to be computationally intensive. However a modification has been proposed in [7] which makes it faster than the standard Van Leer with dimensional splitting. In Section 4 we focus on the problem that a scheme to compute chemical reacting hypersonic Euler flow has to deal with an extremely this and unphysical chemical boundary layer. Besides reporting the phenomena a modification of the standard Van Leer flux vector splitting is proposed which at least gives an indication of the presence of the boundary layer. The problem of estimating the error due to the operator splitting is still open and will not be discussed in this paper.

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