Abstract

An attempt has been made to develop numerical methods for solving various problems associated with steady and unsteady flows past two-dimensional and three-dimensional configurations with special attention to the transonic speed range.

The transonic small perturbation (TSP) equation has been solved using a finite-difference relaxation technique which is formulated based on the time accurate approximate factorization algorithm. Modifications to the unsteady TSP formulation to include entropy and vorticity effects have been made. A computer code has been developed based on the modified TSP algorithm. This code is capable of predicting both two-dimensional and three-dimensional steady and unsteady flows with strong shockwaves quite accurately.

Transonic flow calculations have also been performed by solving the time dependent Euler equations. To solve these time dependent Euler equations various numerical schemes, using different spatial and temporal discretizations techniques and grids of different characteristics, have been taken up. All the schemes use a cell-centred finite volume approach. The following numerical schemes have been studied here to solve the Euler equations;

i) The Euler equations in integral form have been solved on structured grids using a cell-centered finite volume method along with an explicit multistage Runge-Kutta type integration scheme. Following Jameson *et al.* (1981), the central space discretization has been augmented with artificial dissipation terms. Computations have been performed for steady flows past various airfoils.

ii) With the goal of improving the accuracy of the solution to the Euler equations, a higher order upwind biased scheme has been studied using structured grids. The

driving algorithm is a cell-centered finite volume method based on the van Leer flux-vector splitting scheme. Both explicit and implicit time integration techniques have been used to advance the solution in time. The unsteady flow results have been obtained by employing a dynamic mesh algorithm for problems involving oscillating motion of airfoils and control surfaces.

iii) To analyze the flow past complex configurations like multi-element airfoils the above upwind biased scheme, used for structured grids, has been extended to accommodate unstructured triangular meshes. Only an implicit time integration scheme, which is computationally efficient for both steady and unsteady flow calculations, has been implemented in the present unstructured grid flow solver. A number of calculations have been performed for both steady and unsteady flow problems.

Computer codes using the above numerical schemes have been developed. These codes have been used to perform extensive numerical computations, involving various flow conditions, to assess the range of applicability of these schemes. Wherever possible computed results have been compared with experimental data and other numerical results available in the open literature. The agreement is satisfactory in most of the cases.

An attempt has also been made to evaluate the performance of the modified TSP code and the various Euler solvers, developed during the present study, for flow computation past airfoils when the free stream Mach number is supersonic. Again in most cases, satisfactory comparison has been obtained.

Keywords: - CFD; Transonic flow; Unsteady; Unstructured; Structured; Euler; TSP; Flux-Vector Splitting; Explicit; Implicit; Dynamic Mesh Algorithm.