Accurate Numerical Simulation Of Flow Fields

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Keywords: High-order compact schemes, convection-diffusion problems, Navier-Stokes equations equations.

Introduction

The research involves the application of a Hermitian fourth-order accurate compact finite difference scheme for solving two-dimensional transport problems. Two, 2-dimensional convection-diffusion problems with known analytical solutions as well as the incompressible 2D Navier-Stokes equations in vorticity-stream function form are considered as test cases. The time dependent forms of the governing equations are solved until the asymptotic steady-state solutions are obtained. Testing the convergence rate have shown that the scheme is fourth-order accurate. Comparison of the errors shows that the scheme is comparable with other high order schemes and far better than the standard second-order scheme.

Materials and Methods

The study is carried out through numerical solution of the finite difference versions of the problem equations considered. The governing partial differential equations are discretized by a Hermitian fourth order compact scheme. The convection-diffusion problems considered are solved by an explicit time integration procedure that produces tridiagonal matrix system of equations. The Navier-Stokes equations are solved by an ADI implicit time integration procedure that results in a block tridiagonal system of equations. A FORTRAN program that embodies the scheme is developed and used to solve these problems.

Results and Discussion

Numerical results are obtained for the convection-diffusion problems at different Reynolds numbers and compared with the analytical values. The convergence rate is tested by considering the absolute error resulted with different spatial step sizes. The tests have confirmed the fourth-order accuracy of the scheme. The stability of the scheme for the explicit time integration is studied by numerical experimentation and a stability criterion is obtained. The Navier-Stokes equations are solved for laminar flow in a two-dimensional square cavity. Results are obtained for Reynolds number 100. Numerical values of the vorticity and the stream function as well as the horizontal and vertical velocity components, obtained on a coarse grid are found to compare very well with the results of a standard second order scheme on a very fine grid. Results also compare favorably with other high order schemes.

Conclusions

A fourth-order compact finite difference scheme is successfully used to solve two-dimensional transport problems. The high-order accuracy of the scheme is confirmed. Numerical results obtained on coarse grids compare very well with results of a low-order scheme on very fine grids and with results of other high order schemes.

References

Mawlood, M. K., Asrar, W. and Basri, S., High-Order Compact Finite Difference Solution of Two-Dimensional Problems, Research Report No.UPM/FK/KAA/CFD/1/2001, University Putra Malaysia, 2001.

IRPA Project number: 02-04-0179