Transformation free (5,5)HOC discretization of transient Navier-Stokes/Boussinesq equations on nonuniform grids

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Abstract

In this work an implicit high order compact discretization of the Navier-Stokes (N-S) equations on nonuniform grid is presented. Subsequently the discretization is used to approximate Boussinesq equation. Contrary to earlier work on nonuniform grids this newly developed scheme is based on a comparatively smaller five point stencil and leads to an algebraic system of equations with constant coefficients. The scheme carries flow variable and its gradients as unknown, and is seen to report convergence of order four for linear flow problems even in nonuniform mesh. Temporally the scheme is second order accurate. Both primitive and vorticity-streamfunction formulations of the N-S equations have been tackled using the proposed formulation. Verification and validation studies are carried out. They help establish efficiency of the formulation in conjunction with both Dirichlet and Neumann boundary conditions. Simulation of interior and exterior flow problems near critical Hopf bifurcation points using comparatively lesser number of grid points document robustness of the scheme. Numerical solution obtained by solving Boussinesq equation for the problem of natural convection reveals wider applicability of the scheme involving heat transfer.

Keywords: Compact scheme, Navier-Stokes, Boussinesq, nonuniform grid, square cylinder, Hopf bifurcation