Parallel Solution of a Mixed Convection Problem

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ABSTRACT

Parallel implicit solution of the incompressible Navier-Stokes equations based on two fractional steps in time and Finite Element discretization in space is presented. The accuracy of the scheme is second order in both time and space domains. Large time step sizes, with CFL numbers much larger than unity, are taken. The Domain Decomposition Technique is implemented for parallel solution of the problem with matching and non-overlapping sub domains. The segragate solution to temperature field is obtained for the flow case where the forced convection is one order of magnitude higher than the free convection.

As is well known, explicit schemes impose severe restrictions on the time step size for analyzing complex viscous flow fields, which are resolved with sufficiently fine grids. To remedy this, implicit flow solvers are used in analyzing such flows. Accuracy of the scheme is also a major issue in the numerical study of complex flows. Naturally, the higher order accurate schemes allow one to resolve the flow field with less number of grid points. Resolving the flow field with less number of points gives a great advantage to implicit schemes since the size of the matrix to be inverted becomes small.

In this study a second order accurate implicit scheme for solution of full Navier-Stokes equations is developed and implemented. The space is discretized with brick elements while modified version of the two-step fractional method is used in time discretization of the momentum equation. At each time step, the momentum equation is solved only once to get the half time step velocity field. The pressure, on the other hand, is obtained via an auxiliary scalar potential which satisfies the Poisson's equation. For the parallel implicit solution of the matrix equations, modified version of the Domain Decomposition Method, [1,2], is utilized, and direct inversion in each domain is performed. Super linear speed ups were achieved, [3].

The implicit formulation for the momentum equation and the parallel implementation of the momentum, the pressure and the energy equation are given in [4]. The parallel solutions results obtained for the forced cooling of a room with chilled ceiling are given at the end.

The scheme here is made to run on SGI Origin 3000 utilized with 8 processors running Unix operating system. Public version of the Parallel Virtual Machine, PVM 3.3, is used as the communication library.
The flow in a room Reynolds numbers of 2000, based on 1m. length, inflow speed and the kinematic viscosity, is studied. The computational domain has the following dimensions: sides x=4m, y=2m(symmetry plane) and maximum height z=2.6m. The solution is advanced up to the dimensionless time level of 75, where the steady state is reached, with time step of 0.025. Computations are carried with the 6-domain partitioning grids with total number of 61x31x35 nodes. The following dimensionless numbers are employed. Re=2000, Pr =0.7, Gr/Re^2 = 0.01. The elapsed time per time step per grid point is 0.0002 seconds.

Velocity and temperature fields at the symmetry are presented in Figure 1 and in Figure 2. The time and spacewise variation of velocity and temperature fields indicate that the steady state cooling of the room can not be achieved under this flow conditions.

References

1. Gülçat, Ü. and Aslan, A.R., Accurate 3D Viscous Incompressible Flow Calculations with the FEM, International Journal for Numerical Methods in Fluids, Vol.. 25, (1997) 985-1001
2. Gülçat, Ü. and Üstoglu Ünal V., Accurate Implicit Solution of 3D Navier-Stokes Equations on Cluster of Workstations, Parallel CFD 2000 Conference, Trodheim, Norway, (2000), May ,
3. Gülçat, Ü. and Üstoglu Ünal V., Accurate Implicit Parallel Solution of 3D Navier-Stokes Equations, Parallel CFD 2002 Conference, Japan, (2002), May 20-22
4. Üstoğlu Ünal, V. and Gülçat, Ü., Parallel implicit solution of full Navier-Stokes equations, Lecture Notes In Computer Science, Vol. 2659, Springer-Verlag, (2003) 622-631.

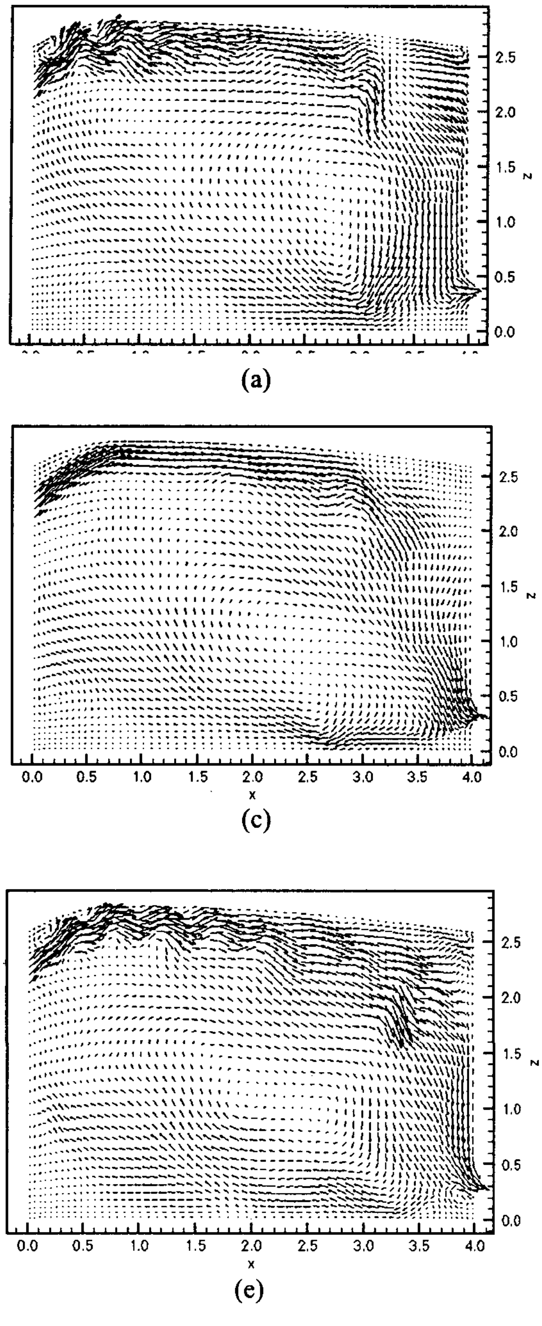
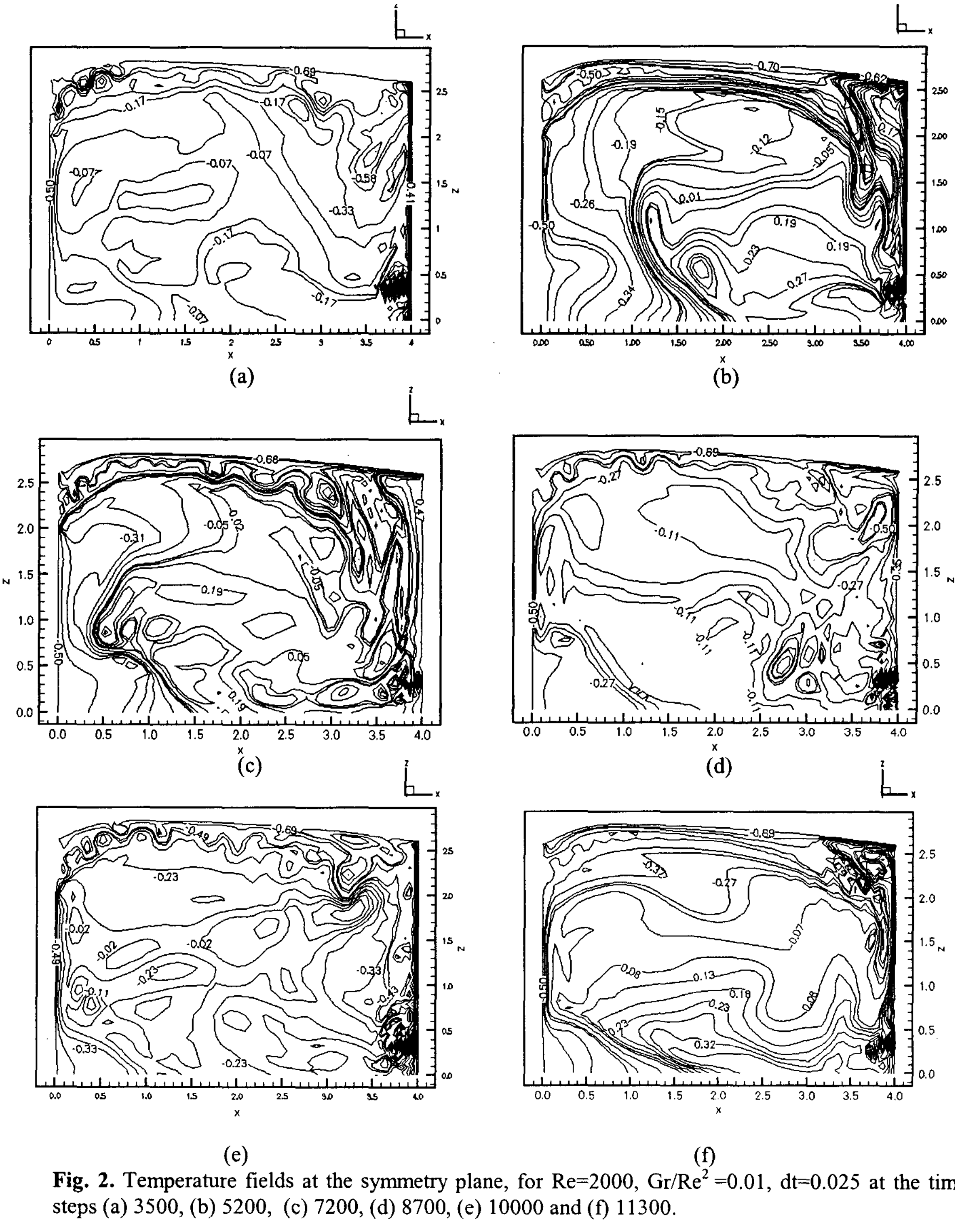


Fig. 1. Element Velocity Distributions at the symmetry plane, for Re=2000, Gr/Re^2=0.01, dt=0.025 at the time steps (a) 3500, (b) 5200, (c) 7200, (d) 8700, (e) 10000 and (f) 11300.



(a) (b) (c) (d) (e) (f)

Fig. 2. Temperature fields at the symmetry plane, for Re=2000, Gr/Re^2 =0.01, dt=0.025 at the time steps (a) 3500, (b) 5200, (c) 7200, (d) 8700, (e) 10000 and (f) 11300.