New preconditioner techniques for the steady and unsteady buoyancy driven flow problems

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Abstract

In this paper we study the performances of generalized minimal residual method (GMRES) preconditioned with geometric multigrid (GMG), applied to the both steady and unsteady buoyancy driven flow problems, discretized with finite element method. For the unsteady case, the second order Crank-Nicolson method is used for the temporal discretization. At each geometric multigrid level, we use Richardson iterative solvers preconditioned with different combinations of physics based and domain decomposition based preconditioners. Three different preconditioners are consdidered: incomplete LU decomposition (ILU), overlapping Vanka-type domain decomposition (ASM), physics based decomposition (FS). We also analyze the effect on the smoother of how the variables are ordered, and in particular whether the leading variables is the velocity (V) or the temperature (T), resulting in six classes of preconditioners: ILU_VPT, ILU_TVP, ASM_VTP, ASM_TVP, FS_VP-T and FS_T-VP. The eigenvalue analysis for the six preconditioners is conducted to study the rate of GMRES convergence under several Prandtl numbers. The numerical performances of nested combinations of the above preconditioners are compared. Numerical results show that the pair of FS_VP-T and FS_T-VP preconditioners works better than the other two pairs, and that the FS_T-VP preconditioner performs always the best in terms of the computational time for all the steady and unsteady cases.