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ACCELERATED CONVERGENCE OF THE NUMERICAL SIMULATION OF THE INCOMPRESSIBLE FLOW IN GENERAL CURVILINEAR CO-ORDINATES BY DISCRETIZATION ON THE DOUBLE STAGGERED GRIDS

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ABSTRACT

The convergence rate of a methodology for solving incompressible flow in general curvilinear co-ordinates is analyzed [1,2]. Double-staggered grids (DSG), each defined by the same boundaries as the physical domain are used for discretization. Both grids are MAC quadrilateral meshes with scalar variables (pressure, temperature, etc.) arranged at the center and the Cartesian velocity components at the middle of the sides of the mesh. The problem was checked against benchmark solutions of natural convection in a squeezed cavity, heat transfer in concentric horizontal cylindrical annuli and a hot cylinder in a duct. Poisson's pressure correction equations that arise from the SIMPLE-like procedure are solved by several methods: the successive overrelaxation (SOR), symmetric successive overrelaxation (SSOR), modified incomplete factorization preconditioner (MILU0), conjugate gradient (CG), conjugate gradient (CG) with preconditioners (CG-SSOR) and (CG-MILU). A genetic algorithm was developed to solve problems of numerical optimization of SIMPLE-like method calculation time, in a space of iteration numbers and relaxation parameters. The application provides a means of making an unbiased comparison between the double-staggered grids method and with widely used standard interpolation (SI) method. Furthermore, the convergence rate was demonstrated with the calculation of natural convection heat transfer in concentric horizontal cylindrical annuli. Calculation times when double staggered grids are used 5 to 10 times shorter those achieved by interpolation, the algorithm was tested with double precision on a Pentium 4 CPU 3GHz computer, Table 1. Results of the calculation of CG with MILU preconditioner are presented in Figure 1. With the double-staggered grids method calculation time slightly increases with increasing non-orthogonally of the grids whereas an interpolation method calls for very small iteration parameters that lead to unacceptable calculation times.

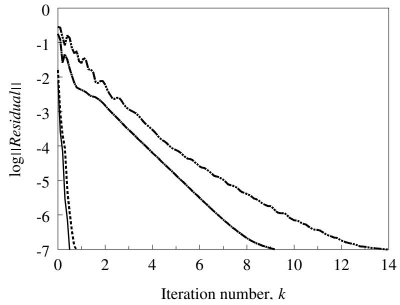

Figure 1: Convergence history of the SIMPLE method with the CG-MILU0 iteration process; - 64x32 cells, DSG; - - 128×64 cells, DSG; -·- 64×32 cells, SI; -··- 128×64 cells, SI.

Table 1: Computational results for natural convection in annuli. *In* is the number of iterations in the DSG method; *Ct(s)* is computing time (s); *Rin* is the relationship between the number of iterations in the SI method and that in the DSG method; *Rct* is a ratio between the computing time in the SI method and that in DSG method.

	$\|Residual\| \leq 10^{-4}$				$\|Residual\| \leq 10^{-7}$			
	In	*Ct(s)*	*Rin*	*Rct*	*In*	*Ct(s)*	*Rin*	*Rct*
				64×32 grid				
SOR	157	7	3.2	2.0	524	24	14.2	7.2
SSOR	159	7	6.2	3.4	400	18	17.0	9.1
MILU0	171	10	4.7	2.2	461	21	19.5	10.0
CG	222	14	4.0	2.3	479	31	13.2	5.1
CG-SSOR	167	8	5.9	3.0	462	22	11.7	5.8
CG-MILU0	177	8	4.1	2.5	556	31	16.6	7.3
				128×64 grid				
SOR	218	45	5.86	3.42	736	153	20.1	10.5
SSOR	214	44	5.83	2.89	883	167	15.9	8.6
MILU0	256	57	5.25	2.47	830	184	18.5	8.2
CG	265	95	7.18	3.32	1099	307	15.9	5.8
CG-SSOR	271	54	3.09	1.74	887	181	18.3	9.9
CG-MILU0	256	57	3.20	1.65	873	187	16.1	9.4

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