LARGE EDDY SIMULATION OF TURBULENT FLOWS ON MULTIPROCESSOR SYSTEMS

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Abstract The parallel algorithm for large eddy simulation of the three-dimensional Navier-Stokes equations was developed and implemented in the research. For a closure a modified Smagorinsky model is proposed.

The turbulent motion is the most common form of the motion of fluids, gases in nature and in many technical devices. Therefore, the main issue for the studies of turbulent flows is development or improvement of the known numerical methods allowing to make the most effective and accurate complex calculations of turbulence and their applications in the solving of major practical problems of turbulent flows [1, 2]. Nowadays numerical simulation with the use of parallel techniques on multiprocessor systems is the only method for the turbulence modeling.

In this research the effective parallel numerical algorithm for solving a three-dimensional problem of a moving cavity with large Reynolds numbers implemented on the multiprocessing system.

The three-dimensional test problem on the lid-driven cavity flow at Reynolds numbers up to 10000 is considered. The cavity lid (wall 6 in fig. 1) moves to the right with the constant speed of u=1. No slip boundary conditions have been employed on the remaining walls (walls 1, 2, 3, 4, 5 in fig. 1). To determine the turbulent characteristics it is necessary to numerically simulate the changes in all parameters at different Reynolds numbers.

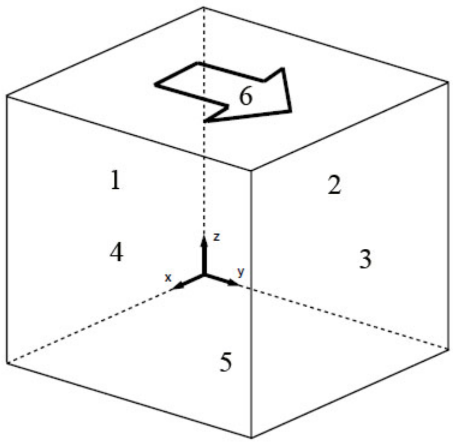

Figure 1. Computational domain

We propose a model of closure for the large eddy simulation on the basis of a modified standard Smagorinsky model [3]. The proposed model dynamically changes the value of Smagorinsky coefficient, which is not fixed, but is calculated at each specific time step.

For the solution of Navier - Stokes equation the splitting scheme on physical parameters which consists of three stages is used. At the first stage Navier - Stokes equation is solved without taking pressure into account. The compact scheme of the raised order of accuracy is used for approximation of convection and diffusion terms of equation. At the second stage Poisson equation is solved, received from the continuous equation taking velocity field of the first stage into consideration. The original algorithm of the solution is developed to solve the three-dimensional Poisson equation – spectral transformation in combination with matrix sweep. The received field of pressure at the third stage is used for recalculation of velocity field definition.

In the research by way of example of the numerical simulation of a three-dimensional lid-driven cavity flow problem, process aspects of the development of scalable parallel calculations with the use of MPI library are given. Parallel algorithm scalability and implementation evaluated by obtaining values of speedups, efficiency and computation time. These results show that the algorithm has considerable volume of potential parallelism and high quality structure from the parallelizing point of view.

In the research we considered the lid-driven cavity flow problem with Reynolds numbers up to 10000. Obtained results of the simulation were compared to the results of the research work [13, 14, 15]. Fig. 2 shows the average velocity profile of the three-dimensional problem of a lid-driven cavity. Fig. 3 presents dynamics of change of flow functions in time for the three-dimensional problem on a lid-driven cavity.

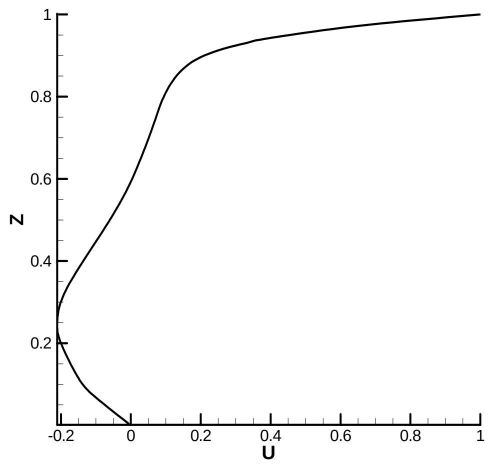

Figure 2. Velocity profile of the three-dimensional problem in the center of area $x = 0.5$ and y = 0.5, at Re=400

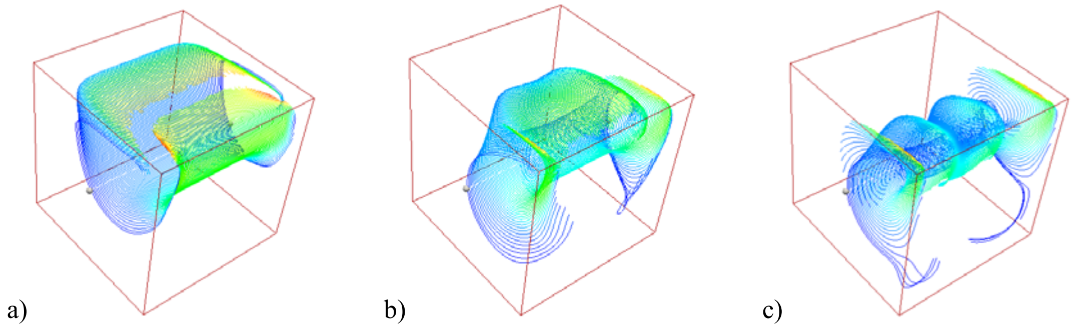

Figure 3. Dynamics of current streamline changes in time: (a) t=0.5, (b) t=0.75, (c) t=1.5

References

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