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PROGRAM COMPLEX FOR LOW COMPRESSIBLE FLOWS SIMULATION ON GPU-BASED COMPUTER SYSTEMS

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The development of the most powerful modern computer systems based on massively parallel multicore processors with powerful accelerators such as general purpose graphics processing units (GP-GPUs) opens possibilities for reducing the cost of a computer system per unit of performance and significantly reduces power consumption. However, the difficulties in the efficient use of such systems are much greater than those in using conventional high performance computers. A lot of the existing sophisticated numerical methods are often not sufficient for modern HPC systems which require software being created to take into account different types of processing units and a hybrid structure of memory. The experience shows, that for an effective application it is preferable to apply the algorithms as simple as possible from the logic point of view. In this regard very promising are the explicit schemes, which can be easily adapted to the computer systems with different architectures.

Usually the explicit schemes impose stringent stability limitations on a time step, especially when the parabolic equations are solved, $\Delta t \sim h^2$, which is not appropriate for fine grids used in HPC calculation. In [1] the flux relaxation approach was proposed. The main idea of this method is a statement that the fluxes of conservative variables at any time moment cannot achieve new values instantly. They have to relax to them, starting from the previous values with some characteristic time of flux relaxation. Being physically founded this approach permits to achieve practically Courant like stability condition for parabolic equation and equation systems by the optimal choice of the relaxation parameter.

Using this approach and kinetically consistent finite difference schemes based on quasi gas dynamic (QGD) equation system [2, 3], written in the form of approximation of the conservation laws, the program complex was constructed for low compressible viscous gas flows simulation. This system differs from Navier-Stokes equations in some additional dissipative terms. These terms are small compared to the terms of natural viscosity and conductivity. They can be interpreted as efficient numerical stabilizers. These schemes belong to the class of kinetic or Boltzmann schemes which are presently often used in the CFD [4, 5].

The program complex oriented on heterogeneous GPU-based computer systems was presented in [6]. The use of this complex was limited by rectangular grids. Here we present a

new version of this program complex, which uses no orthogonal curvilinear structured grids. The approximation of the conservative variables fluxes is based on the finite volume method. The control volumes are connected with the faces of grid cells.
Parallel realization is based on the geometrical parallelism principle. Simulation domain is divided into subdomains – blocks. Each block is processed by one device (GPU or CPU's core). Each device can process one or several blocks serially. Intel C++ language was used for programming. As the communication environment we used shmem (shared memory).
The program complex was tested on a number of test problems such as 2D flow around a bump, 2D and 3D flows around a square and circular cilinders and so on. Some calculation results will be presented at the conference and in the full paper. A detailed investigation of speed-up and scaling were made for a 3D problem. The calculation times were measured for a fixed number (1000) of time steps. The results are presented in the table. The efficiency is normalized to 4 GPU because the size of a task doesn't allow starting it on fewer than 4 GPU.

Table 1: Parallel efficiency obtained on a grid consisting of 27 million cells (strong scaling).

#GPUs	4	8	16	32	64	128	256	512
Time, s	414.8	209.8	110	62.9	33.9	16.6	8.7	4.76
SpeedUp	1.0	1.98	3.77	6.6	12.2	25.0	47.7	87.2
Efficiency %	100	98.9	94.3	82.4	78.1	76.5	74.5	68.1

The efficiency was investigated of use of a large number of GPU's accompanying by proportional increasing of problem size (weak scaling). In this case the parallel efficiency when using 1024 GPUs was about 94%. The maximum grid size (corresponding to the maximum number of GPUs) was about 3.5 billion cells.

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