NUMERICAL MODELLING OF HIGH-SPEED RAREFIED GAS FLOWS USING SUPERCOMPUTERS

V.A. Titarev
FRC "Computer Science and Control" of RAS,
119333, Vavilov str., 40, Moscow, Russia.

Recent years have seen rapid progress in creation of software and methods to solve kinetic equations with approximate (model) collision integrals as applied to complex three-dimensional gas flows, e.g. [1-4]. Good agreements with another leading approach, direct Monte-Carlo simulation method, for many complex flows have been established.

Since the numerical solution of kinetic equations for 3D flows is quite computationally costly and typically requires the use of billions of cells in six-dimensional phase space, good parallelisation strategies become essential. Such strategies must allow for the use of tens of thousands of CPU cores and be applicable to computations on arbitrary meshes, rather than simple uniform hexahedron meshes in cubical domains.

The present work is devoted to the review of the results of the author for steady high-speed three-dimensional calculations using Nesvetay-3D solver for kinetic BGK and Shakhov models. The two-level parallelisation strategy, approaches for velocity mesh creation and examples of calculations using both traditional multi-core and modern many-core supercomputers will be presented. Such examples include both simple verifications studies as well as flow over a complex wing-shaped space craft model.

The work has been supported by the Russian Foundation for Basic Research project 18-08-00501 and 18-07-01500. Calculations have been run on RSK Petastream supercomputers, installed at Joint Supercomputing Center of the Russian Academy of Sciences and the Peter the Great St. Petersburg Polytechnic University.

References

[1] Arslanbekov R., Kolobov V., Frolova A., Zabelok S. Evaluation of unified kinetic/continuum solver for computing heat flux in hypersonic blunt body flows // AIAA-2007-4544. 2007.

[2] V.A. Titarev. Efficient deterministic modelling of three-dimensional rarefied gas flows // Comm. Comp. Phys. 2012. V. 12, N. 1, pp. 162-192

[3] Baranger C., Claudel J., Herouard N., Mieussens L. Locally refined discrete velocity grids for stationary rarefied flow simulations // J. Comput. Phys. 2014. V. 257. P. 572 - 593.

[4] Titarev V.A. Application of model kinetic equations to hypersonic rarefied gas flows // Computers & Fluids. Special Issue Nonlinear flow and transport. 2018. V. 169. P. 62-70.