Verification and validation of an adaptive lattice Boltzmann method coupled with complex sub-grid scale turbulence models

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ABSTRACT

The standard discretisation of the Lattice Boltzmann Method (LBM) based on finite differences imposes the use of Cartesian grids. This restriction leads inevitably to expensive simulations for complex geometries and high Reynold number flows of engineering interest. A solution to this problem is the use of Adaptive Mesh Refinement (AMR) techniques. To this course, an LBM solver has been integrated into the in-house AMROC framework [1] that provides the capability of the block-structured AMR method after Berger and Collela. Some preliminary results have been reported in [2], demonstrating the potential of the proposed methodology. Moreover, the results have shown that the new solver was about 16 times faster than OpenFOAM's PISO implementation.

The integrated LBM solver is based on the single relaxation time and the *D3Q19* model. To deal with turbulent flows, a variety of Large Eddy Simulation (LES) models have been incorporated, namely the constant Smagorinsky and the recently added dynamic Smagorinsky and WALE models. The application of the LES models is achieved through an effective relaxation time estimated locally per cell. For a better performance close to solid boundaries, the wall model of [3] has been currently implemented.

To verify the new components, a campaign of test cases has been launched. Initially, forced and decaying homogeneous isotropic turbulence in a periodic box have been simulated and a comparison between direct numerical simulation and the available LES models has been carried out. A model spectrum [4] has been employed as a benchmark, based on which an indication for the resolution requirement for the fully resolved dissipation range of the described LBM has been derived. Furthermore, the test case of a 3D bi-periodic channel flow was chosen to verify the implementation of the wall function and its integration with the LES models and the AMR algorithm. Finally, a square cylinder will be simulated to validate the solver against external flows with wakes behind obstacles, a typical situation for engineering applications.

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