Extended comparison between lattice Boltzmann and Navier–Stokes solvers for unsteady aerodynamic and aeroacoustic computations

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Computational Fluid Dynamics (CFD) has become an important tool in aerospace sciences enabling both researchers and engineers to get more insight into complex fluid phenomena. The increasing computational power and the growing need of high-fidelity methods has lead to the development of Large Eddy Simulations (LES) tools among which structured finite-type Navier-Stokes (NS) methods and lattice Boltzmann methods (LBM) are the most promising ones to achieve industrial level computations [1]. Consequently, one question which naturally arises is: Which method is the most competitive, in terms of accuracy and computational cost, on canonical aerodynamic and aeroacoustic applications ?

Previous work on the comparison of the LBM with traditional NS methods focused on different topics such as convergence order [2], achievable error [3] and runtimes [4]. However, there still is a lack of fair one-to-one comparisons. Indeed, runtime-based results were obtained with two different solver developed independently and having different levels of optimisation. In addition, the numerical properties of the lattice Boltzmann method are highly dependent on the collision operator [5] such that the conclusions of [3] have to be tempered.

This work aims at rigourously comparing a lattice Boltzmann solver with an LES-type finite-volume Navier-Stokes solver. The comparison takes place in ONERA's Cassiopée/Fast CFD environment implementing high-performance flow solvers relying on the same optimisation layers. To do so, an extended von Neumann analysis of both lattice Boltzmann and Navier-Stokes schemes is proposed. The study is completed by numerical test cases to highlight the capabilities of each method. The implementation and computational times are also discussed. Finally, some trends about the performance of each methods are outlined.

References

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