Falcon

Foreseeing the next generation of Aircraft

D2.2. Report on the validation of the fluid solvers

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1.Validation of the LaBS fluid solver for rigid and flexible motion of solids (AMU-CS)

This first paragraph presents the implementation in LaBS of the boundary conditions for free rigid motion of solid, and of the Immersed Boundary method (IBM) for free flexible motions of solids. Subsequently, it presents the validation results obtained within WP2 by AMU, focusing on the assessment of the Lattice Boltzmann Method (LBM) coupled with IBM in LaBS for predicting external flows around bluff bodies. A series of academic test cases involving flow around a sphere at various Reynolds numbers were performed to evaluate accuracy, convergence, turbulence modelling, and numerical robustness. The results show that the LBM–IBM framework demonstrates consistent convergence, adequate reproduction of drag, separation, and vortex-shedding characteristics, and acceptable agreement with well-established reference data. The slight overestimation of drag and the underestimation of separation angle and Strouhal number, is now being corrected. Overall, WP2 confirms the suitability of the numerical framework to be used in the FALCON project to tackle TC1, TC2 and TC3.

2. Validation of the OpenLB fluid solver (KIT)

The fluid solver for wall-modeled fluid-structure interaction (WM-FSI) developed by KIT is realized in the context of OpenLB. The fluid solver developments described in the present report will be combined into a monolithic FSI solver together with the LBM-native structure solver (D2.1). The code optimization of both solvers is covered by WP5. In the context of FALCON, a novel wall-model for use with a homogenized lattice Boltzmann method (HLBM) was developed and implemented efficiently both for vectorized execution on CPUs and accelerated processing on GPUs.

In order to evaluate stability and accuracy of the wall-modeled fluid solver in isolation, it is first validated for one-way coupled rotor simulations, i.e. the structure motion was prescribed externally. This is a suitable validation case for wall-modeled LES of moving geometries, both with respect to the turbulent flow behavior and the surface forces imparted by the flow on the structure.

Accurately capturing the dynamic forces acting on rotors, as well as their wake effects, presents a significant challenge for computational fluid dynamics (CFD). This is due to the high Reynolds numbers involved and the large range of spatio-temporal scales required to resolve both the blade boundary layer and the far wake.

This report details the development and validation of a novel blade-resolved Wall-Modeled Large Eddy Simulation (WMLES) approach based on LBM. Specifically, we have implemented a homogenized hybrid regularized recursive collision scheme targeting the filtered Brinkman-Navier-Stokes equations.