On the assessment of wall-modeled LES strategies for the CRM-HL

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In this work, low-dissipation schemes together with wall models and physical based SGS closures are assessed in the context of free air simulation of full aircraft in high-lift conditions. The simulations are performed using the code Alya, which is a parallel multi-physics/multi-scale solver developed at the Barcelona Supercomputing Center to conduct high-performance computations efficiently. The spatial discretization is second order, and the convective term is discretized using a conservative Galerkin finite element (FEM) scheme. The scheme preserves linear momentum, angular momentum, and kinetic energy at the discrete level. In the present formulation, neither upwinding nor any equivalent momentum stabilization is employed. Pressure stabilization, by means of a fractional step scheme, is introduced to use equal order elements. A semi-implicit CN/RK3 method combined with an eigenvalue-based time-step estimator is used for the temporal integration of the equations. As SGS closure four different models are assessed, Vreman, WALE, SIGMA and ILSA. Finally, a wall model is used to alleviate the stringent grid-resolution requirements necessary to resolve the small-scale flow motions in the near-wall region. In the wall model, the no-slip boundary condition at the wall is replaced by a wall-stress boundary condition. Two different algebraic wall models are assessed: the first model is based on equilibrium assumptions, whereas the second model allows for non-equilibrium effects by means of the pressure gradient corrections. The third off-wall grid point is used as the exchange location method, and the effect of the selected different matching locations is also investigated. Additionally, the effect of the mesh convergence is evaluated with grid sizes of 40M, 140M, 270M and 513M elements. As expected, the results exhibit improving accuracy with mesh refinement. Additionally, a study of the use of isotropic compared to anisotropic grids elements has revealed that the former is better suited for WMLES. Preliminary results also indicate that modelling choices and grid resolution have significant impact on the predictions at high angle of attack.

REFERENCES

[1] Konrad A. Goc, Oriol Lehmkuhl, George I. Park, George I. Park, Sanjeeb T. Bose, Parviz Moin, Large eddy simulation of aircraft at affordable cost: a milestone in CFD, Flow (2021), in press.
[2] O. Lehmkuhl, U. Piomelli, and G. Houzeaux. On the extension of the integral length-scale approximation model to complex geometries. Int. J. Heat Fluid Flow, 78:108422, 2019.
[3] O. Lehmkuhl, G. Houzeaux, H. Owen, G. Chrysokentis, and I. Rodriguez. A low-dissipation finite element scheme for scale resolving simulations of turbulent flows. J. Comput. Phys., 390:51 – 65, 2019.