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DYNAMIC WALL MODELLING FOR LARGE-EDDY SIMULATIONS. APPLICATION TO HIGH REYNOLDS NUMBER AERODYNAMICS OF COMPLEX GEOMETRIES.

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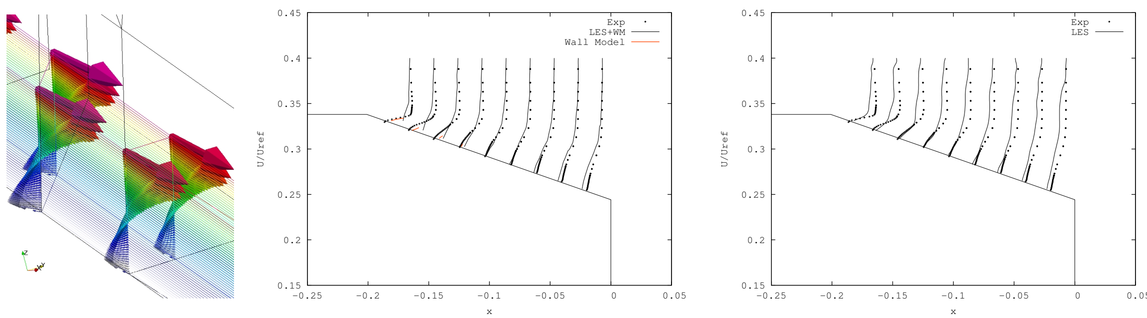
At present, Large Eddy Simulations (LES) calculations are still prohibitively expensive at high Reynolds Number, specially for aerodynamic applications where wall flows are present. Different strategies can be found in the literature in order to reduce mesh requirements at the near-wall region such as hybrid Reynolds Averaged Navier Stokes (RANS)/LES approach or Wall Functions. Dynamic wall models in which this paper is focused, are part of these strategies. The present model is intended to make feasible calculations of industrial applications that are computationally prohibitive until now. Since complex geometries are found in most of these applications, the model has been formulated for unstructured meshes. The case of Ahmed Car is presented. The model will also be tested with the DU-91-W2-250 Wind Turbine Dedicated Airfoil.

Mathematically and numerically, the turbulent flow is described by means of LES using symmetry-preserving discretizations for the spatial filtered and discretized Navier-Stokes equations. The LES models used in the present work are the Wall-Adapting Local-Eddy (WALE) model [1] for the Ahmed Car case and the WALE model within a variational multiscale framework [2] (VMS-WALE) that will be used for the airfoil. The governing equations have been discretized on a collocated unstructured grid arrangement by means of second-order spectro-consistent schemes. For the temporal discretization of the momentum equation a two-step linear explicit scheme on a fractional-step method has been used for the convective and diffusive terms, while for the pressure gradient term an implicit first-order scheme has been used.

The dynamic wall model is based on the implicit resolution of the RANS equations in a fine embedded mesh between the wall and the first off wall node generated by extrusion of the superficial mesh of the solid face [3]. Dirichlet boundary conditions are prescribed at the outer surface for velocities and pressure taking its values from the LES, while at the solid face, no-slip and Neumann conditions are applied for velocities and pressure respectively. Finally, if side boundaries do exist, the same boundary conditions than LES domain are applied to them. Turbulent eddy viscosity for RANS equations is obtained according the Spalart-Allmaras model. Once the mean velocity field is obtained, an accurate mean wall shear stress can be computed and used to feed the global LES calculation as a boundary condition through the diffusive term. The main advantage of this methodology arises from the fact that the explicit LES-domain mesh (LDM) is much coarser than the implicit RANS/wall-domain one (WDM). Hence, a much bigger time step can be used compared to the one that should be taken if the LDM size were of the same order of magnitude than the WDM one.

The standard benchmark case of the Ahmed Car has been computed at Reynolds Number $Re = 7 \times 10^5$ with an slant angle of 25°. The LDM size is 1.7×10^5 control volumes (CV) while the WDM has been extruded in 40 layers.



(a) (b) (c)

Figure 1: Detail of velocity field on the WDM and the LDM (a) Ahmed car mean velocity profile with wall model (b) and without model (c).

On figure 1, the mean velocity profiles at different positions are shown either with (b) and without (c) model and compared with experimental results provided by Erlangen University (Nuremberg). A significant improvement of the results is observed when using the model. Similar results compared to the modeled wall LES have been obtained without model but using a six times finer mesh of 1×10^6 CV [4].

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