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Effect of wall-stress model and grid-cell topology on the predictive accuracy of LES for wall-bounded flows

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The simulation of wall-bounded turbulence puts special requirements on the modelling of turbulent boundary layers (TBLs), as well as on grid resolution. The choice of modelling approach also has severe implications for the resulting computational cost. For instance, for the simulation of a TBL over a flat plate with aspect ratio b/l, the number of grid cells for wall-modelled large-eddy simulation (WMLES) increases as, $N_{wm} \sim \mathrm{Re}_b$, whereas for wall-resolved LES, $N_{wr} \sim \mathrm{Re}_l^{1.85}$, see [2].

The predictive accuracy of a general WMLES approach, which is applicable to complex geometries, is in the present paper evaluated for the test case of a zero-pressure gradient TBL on a flat plate, up to $\mathrm{Re}_\theta \approx 4\,000$. The approach, [3],is based on a formally second-order accuracy finite volume discretization on arbitrary polyhedral cells. A wall-stress model [3,1] is applied in which the wall-distance of the velocity sampling can be set independently of the grid.

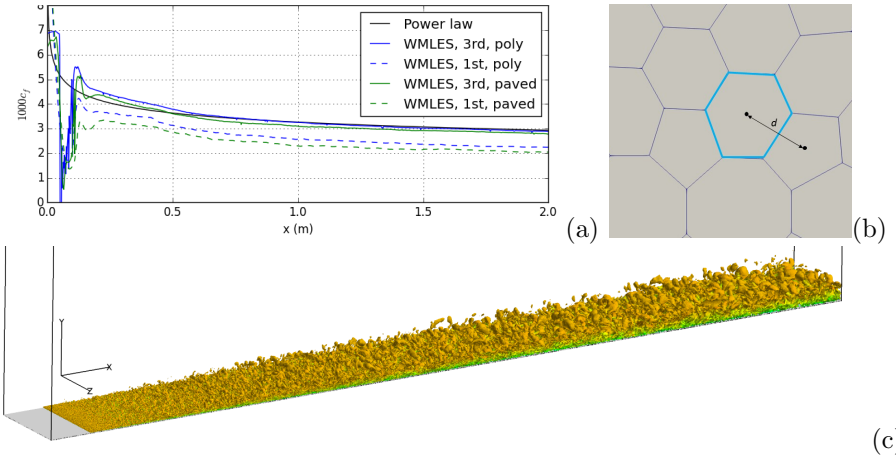

Figure 1: (a): Prediction of the friction coefficient along the plate. Comparison of different WMLES with a power law. (b) Illustration of the surface mesh for the polyhedral grid. The different grids are constructed so that the average distance between cell-centres, d, is the same. (c) The flow illustrated by an iso-surface of the second invariant of the velocity gradient, colored by axial flow velocity.

The computational grid density is adapted to the local thickness of the TBL. The grid is constructed by first meshing the surface, then extruding mesh layers through the TBL, and finally rapid coarsening in the free-stream. Two approaches are compared for the surface meshing; polyhedral and hex-dominant unstructured ("paved mesh"). The velocity sampling for the wall stress model is taken at a fixed fraction of the local TBL thickness. It is demonstrated that results are systematically improved by a judicious choice of sampling location, as compared to sampling in the wall-adjacent cells which is generally used in WMLES simulations previously reported.

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