LARGE-EDDY SIMULATIONS OF TURBULENT FLOW AROUND A WALL-MOUNTED CUBE USING AN ADAPTIVE MESH REFINEMENT APPROACH

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Abstract In the present work two LES models for predicting turbulent flow and an Adaptive Mesh Refinement (AMR) technique are proposed and tested for a fully 3D geometry: turbulent flow around a wall-mounted cube at $Re_h = 7235$. The wall-adapting eddy viscosity model within a variational multiscale method (VMS-WALE) and the QR model are tested to predict the flow around the body. The numerical algorithm used to solve the governing equations preserves the symmetry and conservation properties. AMR algorithm is applied to get enough grid-resolution to solve the vortical structures near the body, adapting the mesh according to physics-based refinement criteria. High order conservative schemes are applied in the connection between coarse and fine regions. The numerical results obtained are assessed and compared to the results of the direct numerical simulations (DNS) on the basis of first and second order statistics.

MATHEMATICAL FORMULATION AND PROBLEM DEFINITION

The complex behavior of turbulence and the subsequent difficulty of describing the physical phenomena due to the presence of multiple length scales limit the impact of numerical studies. Due to its complexity, Large-Eddy Simulations (LES) approach is playing an important role in the modelization and understanding of complex turbulent flows. In the present work, the turbulent flow is described by means of Large Eddy Simulation (LES) using symmetry-preserving discretizations. Moreover, a conservative discretization for unstructured meshes with an efficient self-adaptive strategy for the explicit time-integration of Navier-Stokes equations are presented. The spatial discretization preserves the symmetry properties of the continuous differential operator, ensure stability and conservation of the global kinetic energy on any grid. These conservation properties are studied in detail by Verstappen and Veldman [1]. The computational grid is changed using adaptive mesh refinement algorithms that are effective in treating problems with a wide range of length scales. This kind of approach permit local mesh refinement, minimizing the number of computational cells and providing the spatial resolution required for the study of turbulent flows past bluff bodies. The proposed AMR algorithm borrows from previous work by Berger[2, 3], and Powell [4] that describes an AMR formulation for Cartesian meshes and cell-based AMR methods. Mesh adaptation is accomplished by coarsening and dividing a group of cells following a refinement criteria based on our physical understanding of the problem. In regions where spatial resolution needs to be increased, a parent cell is refined by dividing itself into four (two dimensions) or eight (three dimensions) children (Figure 1). However, in areas that are over resolved, the refinement process can be reversed by coarsening four or eight children into a single parent cell. In any case, the grid adaptation is constrained such as the cell resolution changes by only a factor of two between adjacent cells and the maximum resolution is determined by the Kolmogorov scales derived for this problem. The proposed mesh refinement scheme is based on linear interpolation, this scheme is performed by averaging the adjacent vertex coordinates of the parent cell. In addition, high order conservative schemes are used in the connections between fine-coarse regions and a tree data structure is used to keeping track of the computational cell connectivity to transmit the information between the old and new mesh. Finally, the time-integration scheme presented is based on a one-parameter second-order explicit scheme, where the eigenvalues of our dynamical system are bounded and the linear stability domain of the time-integration method is adapted in order to maximize the time-step [5].
The studied case corresponds to a fully-3D geometry turbulent flow around a wall-mounted cube at $Re_h = 7235$ (based on the cube height and the bulk velocity) . This case cover some of the turbulent flows features like flow separation, vortex shedding , appearance of vortex at the upstream face and in the wake of the cube. The selected LES models to be tested are: WALE model within a variational multiscale framework (VMS-WALE) [6] and QR eddy-viscosity model [7]. This case will be validated using DNS data [8] on the basis of first and second order statistics. In the figure 2, instantaneous velocity field and preliminary results for the streamwise component of the velocity at a position in the wake area are shown. The numerical results will be carried out by using the CFD code TermoFluids which is an intrinsic 3D parallel CFD object-oriented code applied to unstructured-collocated meshes.

CONCLUDING REMARKS AND FUTURE WORK

LES of a wall-mounted cube on a channel flow at $Re_h = 7235$ has been carried out using a symmetry-preserving formulation and AMR approach. Numerical results of the velocity average and fluctuations will be assessed in order to obtain converged statistical data. A comparison between the LES results and the DNS reference will be analyzed in

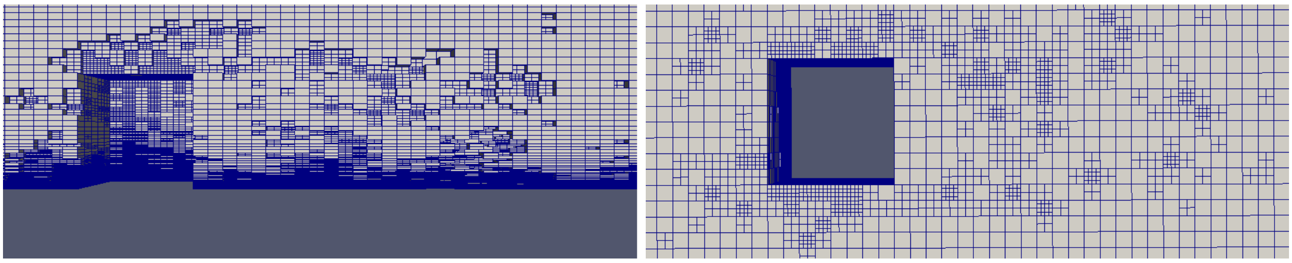

Figure 1: Illustration of AMR technique applied to a 3D Mesh. Left: In the central mid plane. Right: In the cube mid-height

different zones, where the grid adaptation has been applied. The computational cost benefits using LES-AMR approach will be studied. More simulations for different kind of configurations, schemes, meshes, AMR formulations will be presented in order to assess the potential of this kind of numerical simulations in the final paper.

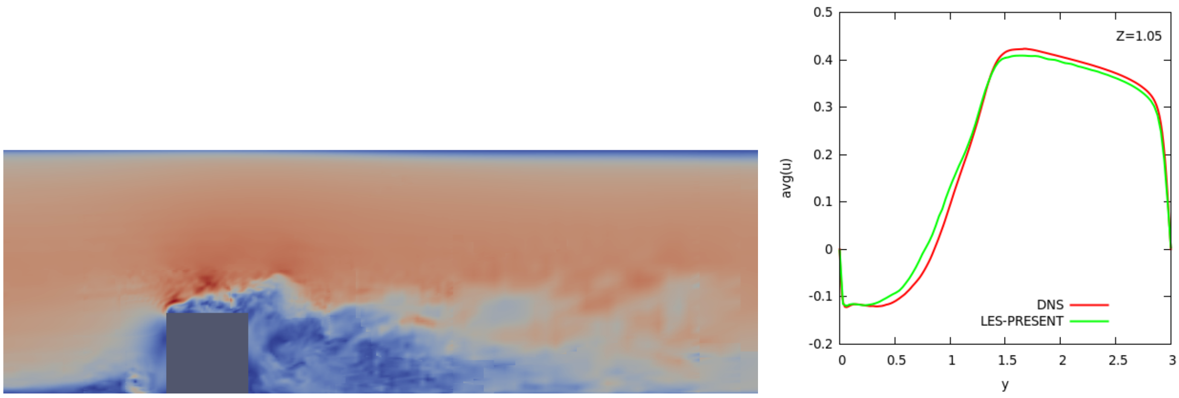

Figure 2: Turbulent flow around a a wall-mounted cube. Left: Instantaneous velocity field at the central mid plane. Right: Preliminary results for the averaged streamwise velocity at the central mid-plane in the wake area at $z = 1.05$.

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