LES and PANS of passive and active control of flows around generic vehicle bodies

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Energy-efficient ground vehicles require careful geometrical styling to decrease drag, primarily due to the formation of the wake region. However, commercial vehicles such as trucks and buses do not permit any great change of the rear part of the vehicle. Instead of changing their geometry, attempts can be made to influence the flow using flow control, which can be either active or passive.

This paper discusses a number of applications of large eddy simulation (LES) and Partially-Averaged Navier-Stokes (PANS) for control of flow around ground vehicles. We start with application of LES for passive flow control devices in form of suitable shaped cylindrical elements on the roof of simplified vehicle (Ahmed body). As discussed in (1), the separation on the rear-end of a simplified vehicle is suppressed by means of large-scale coherent streaks forced on the roof of the model by an array of short cylinders. The present LES shows that drag reduction of about 10% can be obtained when the cylinder array on the roof of vehicle has optimal configurations. After validation of the LES results with the experimental data (1), the LES results are used to explore the flow control mechanism.

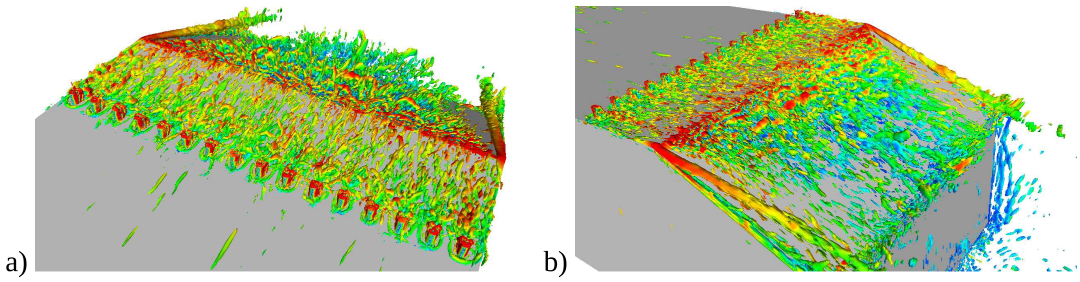

Figure 1: An isosurface of the second invariant of velocity gradient coloured with velocity magnitude. View from a) front and b) rear.

Second application is that of LES for control of trailing vortices formed around A-pillars of simplified vehicles (Fig. 2). These vortices have an influence on both the aerodynamics and the aero-acoustics of passenger vehicles. Active flow control of the shear layers using tangential blowing is applied in agreement with previous experimental study. Both the standard Smagorinsky sub-grid scale model and the local sub-grid model based on coherent structures are used and results are compared. One of the most important feature of the flow around the simplified A-pillar studied here is the vortex breakdown, which causes an increase in the cross-section of the drag inducing longitudinal vortices originating at the A-pillar and thus increases the drag of the body. The results of the present LES show that the breakdown of this vortex is sensitive and, although it can be controlled by tangential actuation, the level of actuation is important and in some cases can result in unusual instabilities of the longitudinal vortices. A better understanding of the modification of the flow around the A-pillar in the flow control process is of great importance, and LES is found to be a technique that is useful for this purpose.

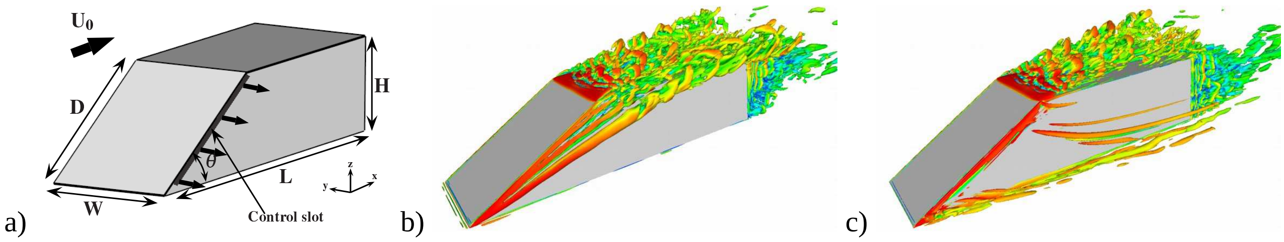

Figure 2: a) Geometry of the generic vehicle with actuator along the A-pillar. Second invariant of the velocity gradient on the side of the modle with actuation slot for b) natural flow and c) actuation with suction.

The last application of LES that will be presented is that of active flow control around a two-dimensional vehicle geometry (Fig. 3). The body has a lateral shape similar to a so called Ahmed body. The interaction of the upper and lower shear layers after the trailing edges of the 2D Ahmed body results in von Karman-like instabilities. Such instabilities rapidly produce two large 2D vortices in alternating order. As the vortices are formed very early, the near-wake separation bubble (the dead water) is short, producing a low base pressure and large drag. An increase of the base pressure can be achieved by an elongation of the near-wake region and suppression or delay of the shear layer interaction. To achieve this objective, the present work applies the strategy of periodic blowing and suction used in previous experimental investigation to force symmetric vortex shedding and thereby delay the wake instabilities

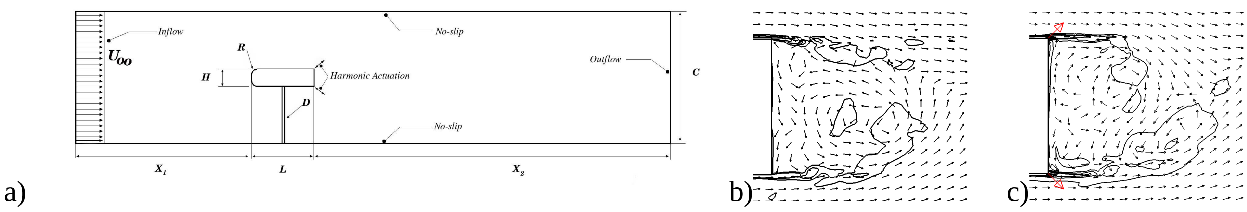

Figure 3: a) Set-up of the body with active flow control placed in the wind tunnel. Velocity vector field and vorticity, ω_z for b) natural flow and c) actuated flow

After successful application of LES, the paper continues with application of newly developed Partially-Averaged Navier Stokes (PANS) technique for this flow. The motivation behind application of PANS is the need for development of hybrid numerical technique that can be used for prediction of flow control processes at high Reynolds numbers of flows around vehicles where LES requires enormous computational effort. The results of PANS show good agreement with both LES and experimental data. Although the present PANS results are encouraging, further studies including different flow control cases are needed before we can draw final conclusions about applicability of PANS in flow control predictions.

References

[1] G. Pujas, S. Depardon, C. Cossu: Drag reduction of a 3D bluff body using coherent streamwise streaks. *Exp. Fluids*, 48 (2010), 1085–1094.