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Numerical investigation of the flow around a simplified estate car using hybrid RANS/LES method

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Abstract: In this work, numerical simulations are performed and validated with homemade experiments in order to accurately predict the flow around a real estate car. The first part of the work is related to the study of the flow around the 25° Ahmed body. Numerical parameters and grids have been fitted in order to reproduce the flow accurately. Then, the validated numerical setup is applied to the flow around a real estate vehicle.

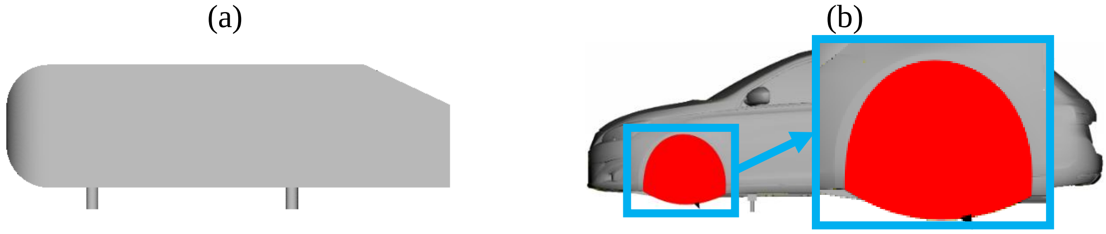
1. Problem statement

The aim of this work is to numerically study and reproduce complex flows (separation areas, A/C pillar vortices, etc.) around different simplified vehicles. Bluff body flows are characterized by separated regions, containing wide spectra of turbulent scales. These regions, especially in the wake behind the body, are responsible for the main part of the drag forces. An accurate computation of these areas is a difficult task. Based on previous work by the authors [2], hybrid RANS/LES method has been chosen, in particular the Delayed Detached Eddy Simulation (DDES) model [3]. This method allows a quite affordable computational cost in attached boundary layers using RANS modeling, and accurate prediction when flow separation occurs with LES resolution. In order to get the best numerical procedure, the grid design is as critical as the model influence. DDES simulations are compared to RKE RANS model.

2. Geometries presentation

Three different geometries are studied and presented on Fig. 1: (a) the 25° Ahmed body [1], (b) the simplified estate shape from Groupe PSA without wheels, replaced by rounded fairings (in red) with small spoiler (in black, not at real scale) to control the separation area and (c) the simplified estate shape with wheels. “Simplified” estate shape means that the underbody is smoothed and the underhood closed. The 25° Ahmed body, which is widely used as the generic simplified car geometry, represents some main features of the flow around a real car and is a complex case as we observed a separation/reattachment area on the rear-slanted surface, longitudinal vortices and a 3D wake. However, the majority of new car geometries include some artefacts (spoilers, deflectors etc.) with different rear angles leading to massive separation. Therefore, a coupled study of the flow around this body and car geometries seems helpful to investigate the complementarity of their behavior. The vehicle configurations used in this work correspond to full-scale simplified estate car geometries as described before.

(a) (b)



(c)

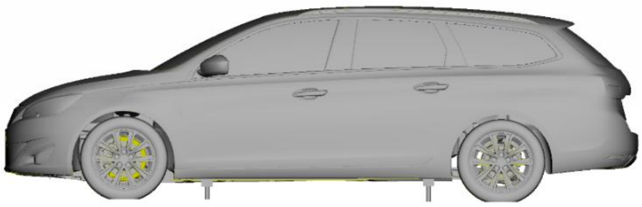


Fig. 1: Representation of the three geometries studied

3. Results and discussion

Table 2 compares SCd (drag coefficient multiplied by the projected frontal area of the vehicle, S) for the geometry without wheels for SST DDES, RKE RANS computations and experiments. Fig. 3 shows the mean streamwise velocity profiles in the wake of the vehicle in two Y planes (symmetry plane Y=0 m and offset plane Y=0.25 m). Even though the drag coefficient is more accurate with RKE RANS model, mainly due to errors cancellations all over the body, the averaged streamwise velocity Vx profiles clearly show a better flow topology with DDES model in the wake of the car. Cp coefficients are also closer to experiments with DDES (not shown here due to limited space).

Estate shape	SCd	Error
Experiments w/o wheels	**0.552**	-
DDES	0.590	6.9%
RANS	0.544	-1.4%

Table 1: Evolution of aerodynamics forces

(a) Y=0 m (b) Y=0.25 m

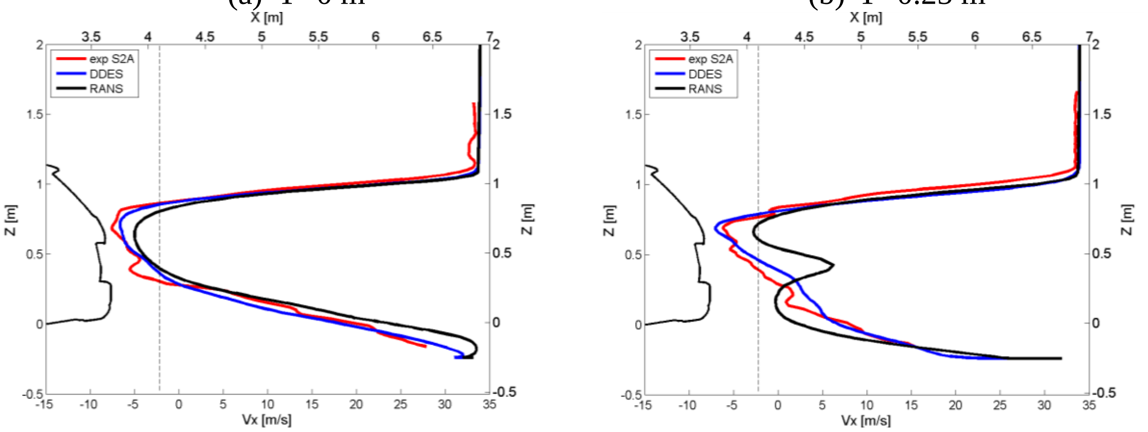


Fig. 2: Streamwise velocity profiles Vx in the wake of the simplified estate shape without wheels, 400 mm behind the body

References

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