On PANS-ζ-f model assessment by reference to car aerodynamics

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The present work discusses the predictive capabilities of the PANS-ζ-f model of turbulence (Partially-Averaged Navier Stokes) by means of simulating the flow past different car configurations including also overtaking maneuver cases. The investigated car configurations include a 40% down-scaled BMW model (Schrefl, 2008, PhD thesis, ISBN 978-3-8322-7010-0) as well as the so-called "DrivAer" car model (Heft et al., SAE Technical Paper No. 2012-01-0168) representing a 'generic realistic car configuration' created by 'merging' the original geometries of two medium sized cars from the Audi A4 and the BMW 3 series. Different rear end shapes of the latter model – notchback, fastback and estate back - have been simulated. All investigated car configurations account for the mirrors, detailed underbody including exhaust system and differential gear and rotating wheels including brake discs and rim details. Two overtaking maneuver cases representing an 'on-road' event with moving vehicles and a 'quasi-stationary' configuration, realized by considering eight discrete relative positions between the car and truck models in a wind tunnel, have been experimentally investigated by Schrefl (2008).

The main objective of the present study is the validation of the recently proposed computational method denoted as PANS, Basara et al. (AIAA J., 49(12), 2011). This variable resolution method represent a hybrid RANS/LES (Large Eddy Simulation) scheme which should capture the unsteady flow features more accurately compared to the conventional Unsteady RANS (Reynolds-Averaged Navier-Stokes) method. This so-called bridging method provides smooth and seamless transition from URANS to LES, i.e. to DNS in terms of a "filter-width control parameter" variation; that is the transition from a fully-averaged computation to a completely resolved simulation. The above-mentioned, appropriately modified RANS-$\zeta - f$ formulation models correspondingly the unresolved turbulence.

All simulations were performed by using the CFD (Computational Fluid Dynamics) software package AVL FIRE. As a result of simulations detailed mean flow and turbulence fields are obtained and compared with experimental findings, thus enabling the study of spatial wall-pressure distribution on this ground vehicle, forces (drag, lift and side forces) and moments (rolling, yawing and pitching moments), i.e. the relevant aerodynamic coefficients, as well as some unsteady flow phenomena in the car wake. Figures 1-3 display some of the results of an intensive simulation campaign by employing the PANS-$\zeta - f$ model formulation illustrating its predictive capabilities in capturing unsteady features and corresponding time-averaged flow properties in a wide range of car configurations considered.

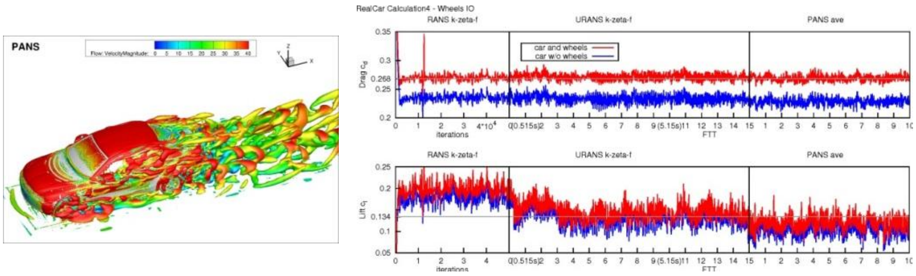

Figure 1: Flow past a BMW car model: (left) flow field visualized by the Q-criterion ($Q = 5000\ s^{-2}$) and (right) history of the drag and lift coefficients obtained by RANS, URANS and PANS.

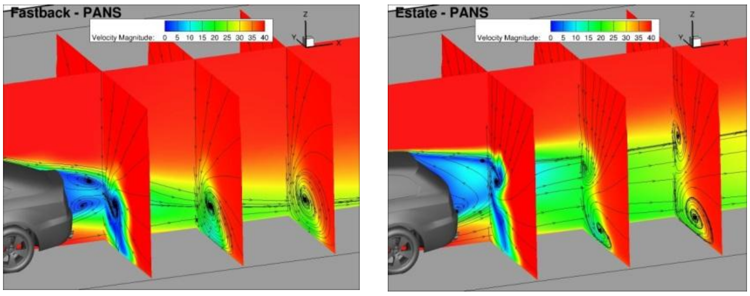

Figure 2: Time-averaged streamline patterns in the wake of the DrivAer car model in terms of different rear end shapes colored by the magnitude of the axial velocity component

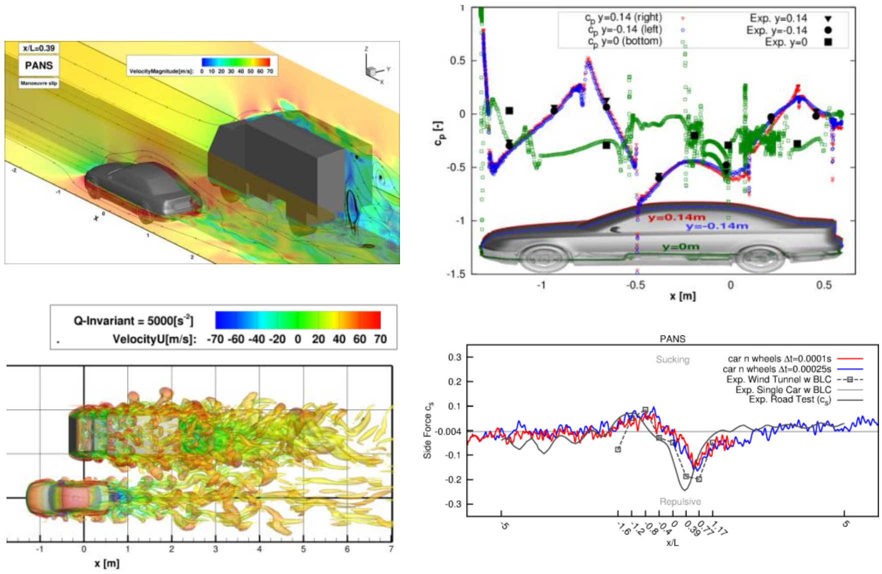

Figure 3: “On-road” overtaking maneuever: instantaneous streamline pattern and corresponding iso-contours of the mean velocity magnitude (upper left), pressure distribution over the car top and underbody surfaces (upper right), flow field visualized by the Q-criterion ($Q = 5000\ s^{-2}$) (lower left) and variation of the car-related aerodynamic coefficient associated with the side force C_s (lower right)