REPRESENTATIVE FLOW STRUCTURES BEHIND AN AHMED VEHICLE MODEL

X.W. Wang*, Y.F. Pin* and Y. Zhou*
*Department of Mechanical Engineering, The Hong Kong Polytechnic University, Hung Hom, Hong Kong

Summary The Ahmed body is the most widely studied simplified car model. Our knowledge of flow around this model is however incomplete, which directly contributes to the un-impressive performance of active drag reduction techniques reported in the literature. This work revisited the turbulent wake of the model (Re_H = 5.26×10^4) based on extensive particle image velocimetry (PIV) measurements in three orthogonal planes. A number of findings have been made, resulting in modified flow structure models in representative flow regimes, as per classical models.

Extended Summary

A thorough understanding of the flow structure behind the Ahmed vehicle model, which is a three-dimensional bluff body, may possibly provide breakthrough on vehicle drag reduction investigations. The Ahmed body (Ahmed *et al*. 1984) is a benchmark simplified car model for studies. Its blunt forebody is designed without separation so that the aerodynamic forces and the flow structure depend largely on its after-body slant angle. The present investigation was performed for two rear slant angles (α = 25º and 35º), representing two distinct flow regimes in terms of the flow structure and pressure drag variation.

Experiments were carried out in a closed circuit wind tunnel with a 2.4-m-long square test section (0.6 m x 0.6 m). A 1/3-scaled Ahmed vehicle model was placed in the test section. Measurements were conducted at a Reynolds number, Re =5.26 x 10^4, based on the model height and incident flow velocity (U_∞). A DANTEC standard PIV system was used to measure flow around the Ahmed model. PIV measurements were performed in a number of planes for catching highly three-dimensional flow structure, including the x-z or symmetry plane, the x-y plane at mid-height of the model from the floor, and the y-z plane in both near- and far-wake. The x, y and z are the coordinates along longitudinal, transverse and spanwise directions, respectively. A total of 1100 PIV images were captured in each plane, which have been verified to be adequate for the mean and fluctuating flow quantities to converge to their asymptotes within 2% uncertainty.

The flow structure of the Ahmed model is unsteady, very complicated, and highly three-dimensional. Both instantaneous and time-averaged PIV data (Fig 1 & 2) show three major components in the wake, i.e., a recirculation bubble over the slanted surface ("A" or "B" in Fig 3), longitudinal C-pillar vortices originating from the two side edges ("C" in Fig 3) and a recirculation torus in the base of the model ("D" in Fig 3). The strength and behaviors of these three types of coherent structures and their interactions depend on α. The results are consistent with previous reports. Furthermore, the data disclose flow features that have not been previously documented. The new findings, as summarized in Table 1, lead to the proposition of considerably modified flow structure models (Fig 3), as per classical models.

Table 1 Summary of the modifications of the flow structure model

Model with α = 25º (below the critical angle)	**Model with α = 35º (above the critical angle)**
1. Additional flow detaches from the edge between the top and slant surfaces; 2. While part of the shear layer separated from the slant is drawn into recirculation bubble "A", the other part forms a quasi-periodical wavy spanwise roll flowing over "A"; 3. The flow between the model underside and the floor is partially drawn into recirculatory bubble "B" and partially rolls up, forming spanwise structures, which are imbedded with alternately signed longitudinal vortices. 4. Side vortex ("I" in Fig 3a) forms, which interacts and mergers with the C-pillar vortex; 5. Lower vortex ("H" in Fig 3a) occurs at the lower side of the vehicle side surface; 6. Gap vortex ("G" in Fig 3a) occurs.	1. The shear layer, developed over the top of the vehicle, separates from the upper edge of the slant surface, forming spanwise structures imbedded with alternately signed longitudinal vortices. 2. Recirculation bubble "E" over the slant and "A" behind the base merge into one 3. The flow between the model underside and the floor is partially drawn into the recirculatory bubble and partially rolls up; 4. Side vortex ("I" in Fig 3b) forms, which interacts and mergers with the C-pillar vortex; 5. Lower vortex ("H" in Fig 3b) occurs at the lower side of the vehicle side surface; 6. Gap vortex ("G" in Fig 3b) occurs.

Acknowledgement
YZ wishes to acknowledge support given to him from Research Grants Council of HKSAR through grant PolyU 5329/11E.

References

Ahmed SR, Ramm G, Faltin G (1984) "Some salient features of the time averaged ground vehicle wake. *SAE Technical Paper* No.: 840300.
Lienhart H, Becker S 2003 Flow and turbulence structures in the wake of a simplified car model. *SAE Technical Paper* No.: 2003-01-0656.
Krajnovic S, Davidson L 2003 Numerical study of the flow around the bus-shaped body, *ASME Journal of Fluids Engineering*, 125, 500-509.

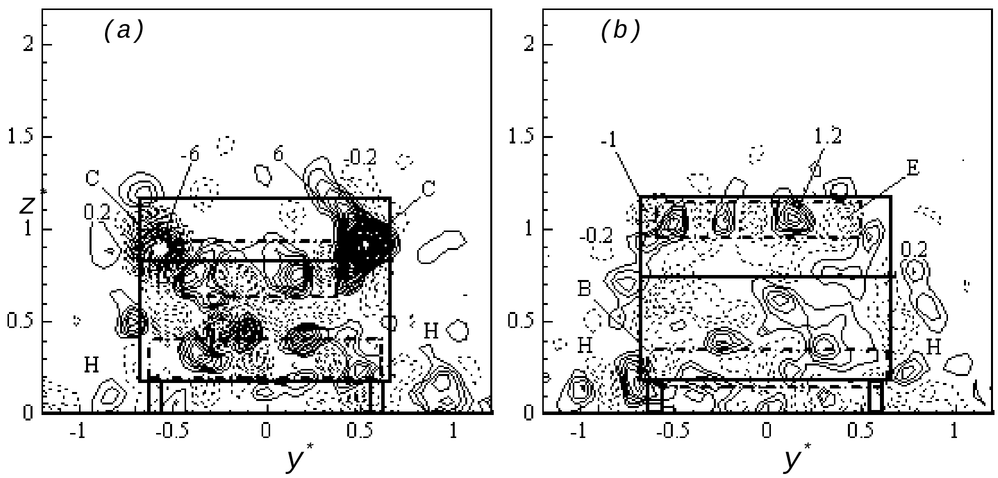

Figure 1 Iso-contours of instantaneous streamwise component, Ω_x^*, of vorticity in the *y*-*z* plane: (a) α = 25°, (b) 35°.

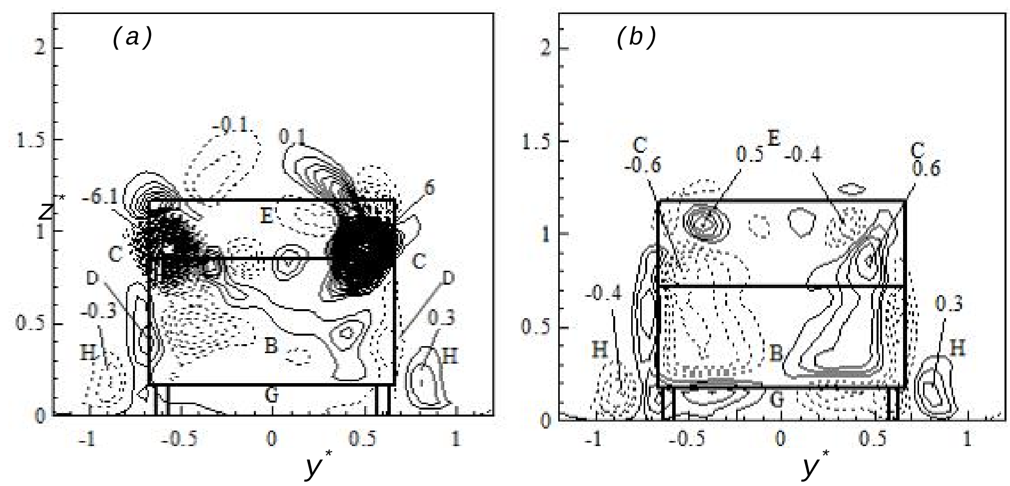

Figure 2 Iso-contours of time averaged streamwise component, $\overline{\Omega_x}^*$, of vorticity in the *y*-*z*: (a) α = 25°, (b) 35°.

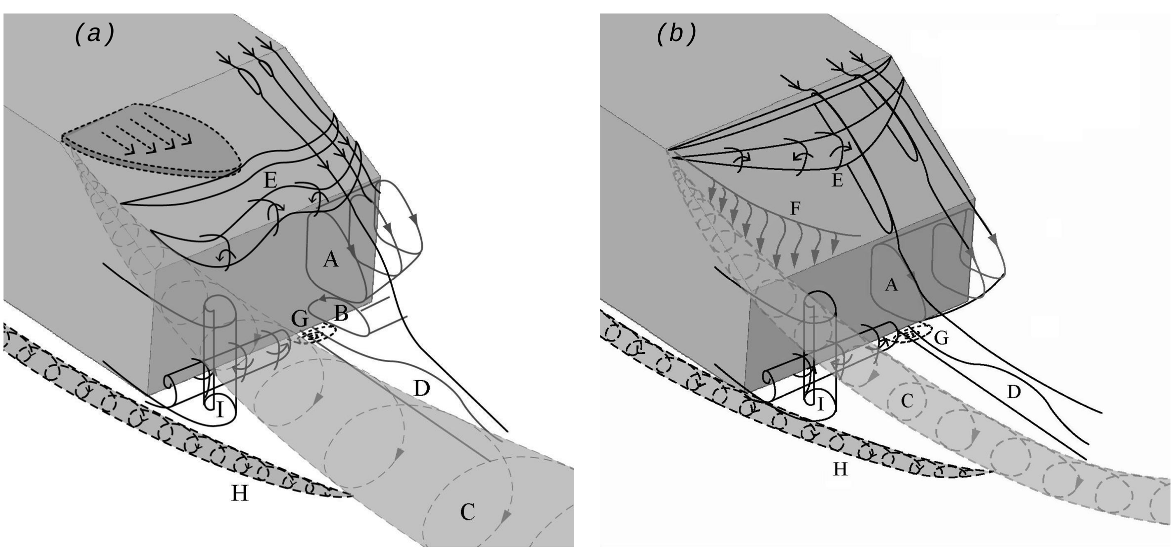

Figure 3 Schematic of flow structure models: (a) α = 25°, (b) 35°.