Seventh HRLM Symposium, 19-21 September 2018, Berlin, Germany

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# Prediction of wake topologies of an elongated bluff body at yaw using PANS and LES

**Anirudh Rao[1], Jie Zhang[1], Guglielmo Minelli[1], Branislav Basara[2], Siniša Krajnović[1]**

**[1]Department of Mechanics and Maritime Sciences, Chalmers University of Technology, Göteborg 41296, Sweden.**

**[2]AVL List GmbH, Advanced Simulation Technologies, Hans-List-Platz 1, 8020 Graz, Austria.**

## Abstract

Recent numerical investigations in the wake of an elongated bluff body (also known as the ground transportation system – GTS, representative of an integrated tractor-trailer geometry) at Reynolds number of 2.7 x $10^4$ has revealed the existence of two flow states/bi-modal solutions when the incoming flow is at an yaw angle (β) of $0^o$. The mean flow topology in the vertical midplane was asymmetrical in each flow state, and the two flow states were found to be anti-symmetrical to each other across the lateral midplane. The occurrence of these two flow states was found to be dependent on the spatial resolution of the domain, differencing schemes used for the convective terms, and the turbulence modelling approach used. Here, the existence of the flow states in the near wake of the GTS when the incoming flow is yawed at $\beta = 0^o$ and $10^o$, at gap heights of 0.14*H* and 1.1*H* above the ground (where, *H* is the height of the GTS), and a combination of the two aforementioned parameters is investigated using Partially-Averaged Navier–Stokes (PANS) simulations and large eddy simulations (LES). For $\beta = 0^o$, PANS simulations predict flow state I (a topology similar to that observed in the experimental studies of [1] and [2]), while LES predict flow state II (see [3]). Furthermore, the flow topology in the vertical plane remained invariant for gap heights in excess of 0.14*H* (see [1], [3]).

When the GTS model is close to the ground and the incoming flow is at an angle of $\beta = 10^o$, the flow topology observed using PANS simulations in the vertical planes are *nearly* anti-symmetrical to those observed when it is away from the ground. The flow topologies observed in the vertical planes of the LES are identical at both gap heights, with a near-symmetric

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distribution of the vortices, as compared to the asymmetric topology observed in PANS. Furthermore, the near-wake topologies in the lateral planes in PANS are nearly anti-symmetrical to those obtained from the LES at the two gap heights. Although the reflectional symmetry across the vertical midplane is broken as a result of the incoming flow at an yaw angle, the near-wake topology exhibits symmetries similar to that observed when the incoming flow is at $\beta = 0^{o}$ (also see [4]). The flow topologies observed are also analysed using the distribution of the pressure coefficient, Reynolds normal stresses to compare the near-wake symmetries.

For the incoming flow at $\beta = 10^{o}$, the merging of the (two) top corner vortices is observed downstream of the near-wake region when the GTS model is near the ground, while the bottom corner vortices merge when the GTS model is away from the ground plane. These corner vortices merge to form a single large vortex, which spans the height of the model. The dominant far-wake dynamics for the GTS model at a gap height of $1.1H$ are anti-symmetrical across the lateral midplane as compared to that observed for the GTS model at a gap height of $0.14H$ in both PANS and LES.

These simulations collectively show that the PANS turbulence modelling approach can be reliably used to predict flow around elongated bluff bodies in cross-wind, where the complex far-wake dynamics are seemingly independent of the near-wake flow topologies and the symmetries they exhibit.

## References

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