CWE-8
June 7-11, 2026
London, ON, Canada

Aerodynamic characterisation of the DrivAer car model under crosswind through wind tunnel testing

C.E. Araya Reyes [a], S. Negri [b], G. Tomasini [c]

[a]*Politecnico di Miano, Milan, Italy, carlosesteban.araya@polimi.it*
[b]*Politecnico di Miano, Milan, Italy, stefano.negri@polimi.it*
[c]*Politecnico di Milano, Milan, Italy, gisella.tomasini@polimi.it*

SUMMARY

Resilience of transportation systems is increasingly recognised as a critical societal challenge. The maintenance of safe and operational road networks under adverse weather conditions requires reliable assessment of vehicle stability under crosswind, which depends on accurate evaluation of aerodynamic forces acting on vehicles. In this work, a database is presented to provide researchers with robust and reliable benchmark data intended to support direct application in dynamic stability simulations and to facilitate validation of CFD models. The dataset comprises aerodynamic coefficients for the DrivAer model, representative of a realistic road saloon car, measured in the wind tunnel at Politecnico di Milano using a 1:4 scaled model in notchback configuration.

Keywords: *Wind tunnel, crosswind, DriveAer, resilience, wind engineering, CFD.*

1. INTRODUCTION

The resilience of transportation systems is increasingly recognised as a societal challenge in the context of climate change and extreme weather. Severe wind events represent a critical hazard, with rising storm activity reported across Europe, North America, and Asia (European Environment Agency, 2024; Deehan et al., 2025; Intergovernmental Panel on Climate Change, 2023). For road vehicles, crosswinds can cause lateral displacement, loss of control, or rollover, and accident statistics confirm strong correlations with storm events (Coleman and Baker, 1990; Baker and Reynolds, 1991; Becker et al., 2022).

Research on road vehicles has traditionally prioritised aerodynamic drag reduction, with comparatively limited attention devoted to crosswind stability. ISO 12021:2010 specifies a full-scale open-loop test in constant lateral wind, but does not prescribe wind tunnel methodologies, limiting systematic aerodynamic characterisation. Existing studies (Cheli et al., 2006; Sterling et al., 2012; Han et al., 2013) provide valuable insights but remain fragmented, often restricted to specific vehicle categories or constrained conditions. Most wind tunnel investigations have concentrated on high-sided vehicles, highlighting the influence of yaw angle, turbulence, and infrastructure (Cheli et al., 2011; Dorigatti et al., 2012; Liu et al., 2016). By contrast, compact cars have received limited attention. The DrivAer geometry a realistic car model (Heft et al., 2012), has been widely tested for drag-related data for CFD validation (Wieser et al., 2014; Heft et al. 2018), but crosswind analyses have generally been confined to small yaw angles.

This lack of aerodynamic data for compact road vehicles represents a limitation, particularly for CFD validation and stability simulations. Within the PRIN project CROSS-STORM, which aims to develop methodologies for assessing vehicle stability under thunderstorm-like conditions, this study provides a database of aerodynamic coefficients for the DrivAer model in crosswind, obtained from wind tunnel tests and compared them with CFD results.

2. METHODOLOGY

The aerodynamic characterisation of the DrivAer model in notchback configuration under crosswind conditions was conducted in the Wind Tunnel at Politecnico di Milano, a closed-circuit facility with two vertically configured test sections. Tests were performed in the low-turbulence test section, measuring 4 m × 3.84 m × 6 m, with turbulence intensity below 0.1%.

The 1:4 scale DrivAer model was instrumented with a six-component dynamometric balance (RUAG Aerospace Model 192, strain-gauge technology) to measure aerodynamic forces and moments. It was mounted on a splitter plate with a rotating turntable, enabling tests across yaw angles (α) from 0° to 180° in 5° increments under a flat-ground configuration representative of open-road conditions (Figure 1a). Aerodynamic coefficients were derived using a reference area of 5 m^2 and a reference length of 2.5 m. The reference system followed ISO 8855, with the origin located at road level and centred at the midpoint of the wheelbase and track width (Figure 1b). A nominal free-stream velocity of 50 m/s was applied, corresponding to a Reynolds number of 2.08×10^6.

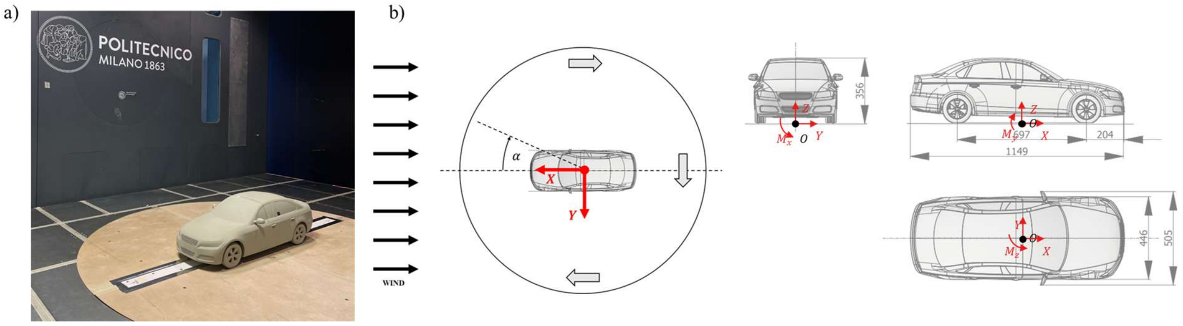

Figure 1:Wind tunnel tests on the DrivAer model: a) 1:4 model in the wind tunnel and b) Reference system and scaled model dimensions.

A corresponding CFD model is being developed to extend the analysis to different vehicle typologies. Implemented in OpenFOAM, it employs a steady-state RANS approach with the k–ω SST turbulence model. The computational domain and boundary conditions were defined to replicate the wind tunnel configuration, with refinement regions and surface layers introduced as shown in Figure 2.

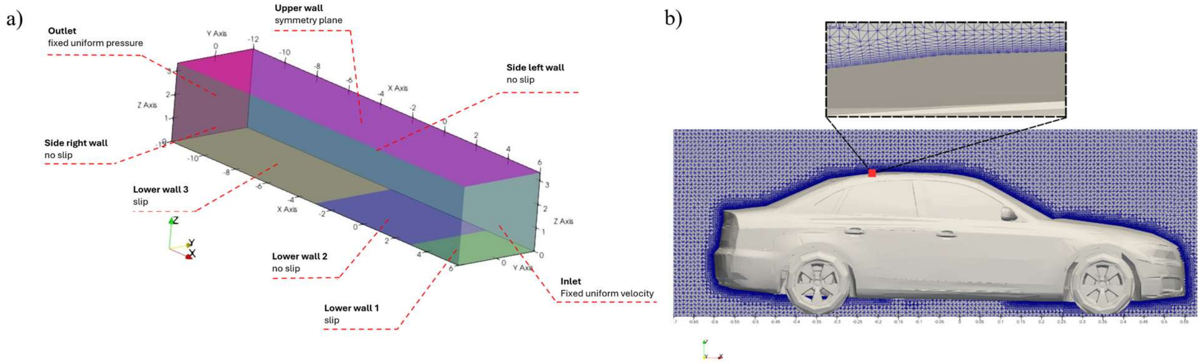

Figure 2: CFD model: a) Boundary conditions b) Surface mesh layers.

3. RESULTS

In this section, the results obtained for the saloon car, based on the DrivAer geometry in notchback configuration, are presented. Figure 3 provides the aerodynamic coefficients under crosswind across yaw angles ranging from 0° to 180°. In the figure are shown also the aerodynamic coefficients obtained from the preliminary CFD model.

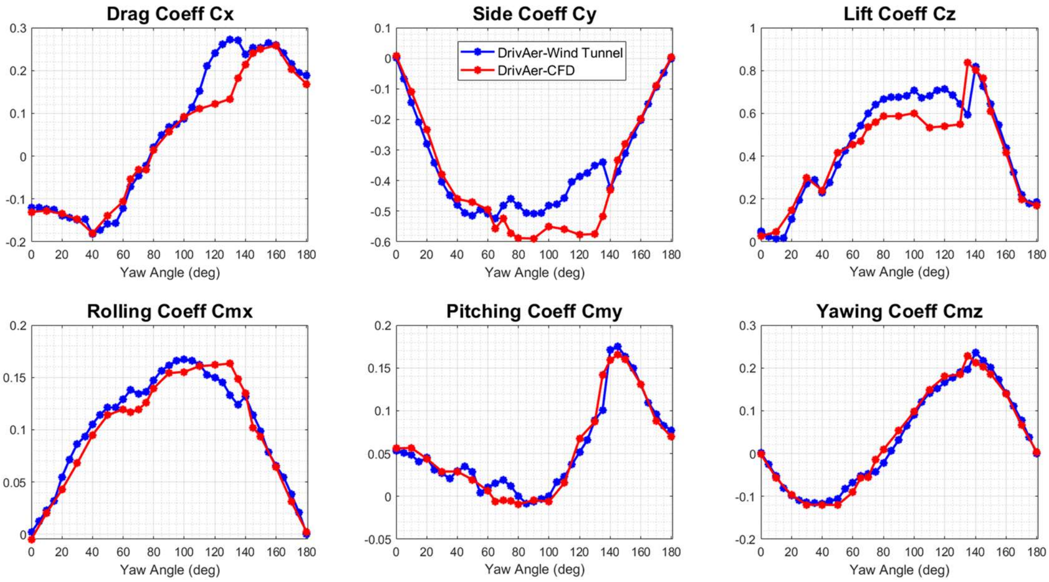

Figure 3: Aerodynamic coefficients of the DrivAer model obtained from wind tunnel measurements (blue) and CFD (red). Scaled model (1:4) in notchback configuration under flat-ground conditions, at a nominal free-stream velocity of 50 m/s.

The negative longitudinal aerodynamic force increases approximately linearly up to a yaw angle of 55°. Beyond this, the magnitude decreases, reaching zero near 80°, and becomes positive at larger angles. When acting from the rear, the longitudinal force is about 25% greater, attributable to the more square and angular geometry of the rear end of the car.

Abrupt variations are observed in the wind tunnel results between 50°–60° and 130°–150°, particularly in coefficients, C_{Fy}, C_{Fz}, and C_{Mx}. These transitions reflect significant changes in the flow field, in which the vortex structures near the windward A-pillar, observed at lower angles (Wieser et al., 2014), appear to weaken and disappear at higher angles. A positive pitch moment is observed under headwind conditions, which is counter-intuitive but explained by rear-biased lift (Wieser et al., 2014): the rear generates lift while the front produces downforce, yielding a positive pitch moment at lower angles of attack.

Overall, good agreement is observed between the CFD model and wind tunnel results, particularly at lower yaw angles. Some discrepancies arise at intermediate angles, especially in longitudinal and vertical force. These differences can be attributed to a slightly altered separation point, likely in the roof region, which does not affect the pitch coefficient. In the CFD model, separation occurs earlier, leading to a larger lateral force and reduced lift.

4. CONCLUSIONS

This study has presented a wind tunnel investigation of the DrivAer model in notchback configuration under crosswind conditions, complemented by CFD simulations of the corresponding case.

The resulting aerodynamic coefficients, measured across a wide yaw angle range and at representative flow velocities, provide a consistent dataset for compact passenger vehicles. This benchmark contributes to addressing the current lack of standardised experimental data for both vehicle dynamic simulations and the validation of CFD approaches with the aim to support the development of methodologies for assessing vehicle stability under thunderstorm-like conditions.

ACKNOWLEDGEMENTS

The project CROSS-STORM has been funded by EU, NextGenerationEU, M4C2I1.1, Pro-ject PRIN 2022 PNRR "CROSS-STORM", Prot. 202284ZER9 – CUP D53D23003170006.

REFERENCES

European Environment Agency, 2024. European Climate Risk Assessment. EEA Report 01/2024. Publications Office of the European Union, Luxembourg.

Deehan, M., Yaary, S., Longmire, K., Newcomb, L., Slocum, C., Sylvander, B., Allen, M., Arzayus, F., Decker, C., Oakes, S., Cromwell, M., Grasso, M., Murphy, T., Wielgus, J., Rosenlof, K., Schepel, K., Sims, C., Gillespie, A., Conran, J., Davis, S., 2025. NOAA Science Report 2024. Technical Memorandum. NOAA, Silver Spring, MD, USA. https://doi.org/10.25923/mh4h-pm52

Coleman, S., Baker, C., 1990. The aerodynamics of ground vehicles in cross winds. University of Nottingham.

Baker, C.J., Reynolds, S., 1991. Wind induced accidents of road vehicles. Accident Analysis & Prevention 24, pp. 559–575.

Becker, N., Rust, H.W., Ulbrich, U., 2022. Weather impacts on various types of road crashes: a quantitative analysis using generalized additive models. European Transport Research Review14,37. https://doi.org/10.1186/s12544-022-00561-2

Cheli, F., Belforte, P., Melzi, S., Sabbioni, E., Tomasini, G., 2006. Numerical–experimental approach for evaluating cross-wind aerodynamic effects on heavy vehicles. Vehicle System Dynamics 44, 791–804. https://doi.org/10.1080/00423110600886689

Sterling, M., Quinn, A., Hargreaves, D., Cheli, F., Sabbioni, E., Tomasini, G., Delaunay, D., Baker, C., Morvan, H., 2010. A comparison of different methods to evaluate the wind-induced forces on a high-sided lorry. Journal of Wind Engineering and Industrial Aerodynamics.

Han, Y., Hu, J., Cai, C.S., Chen, Z., Li, C., 2013. Experimental and numerical studies of aerodynamic forces on vehicles and bridges. Wind and Structures 17, 163–184. https://doi.org/10.12989/was.2013.17.2.163

Cheli, F., Corradi, R., Sabbioni, E., Tomasini, G., 2011. Wind tunnel tests on heavy road vehicles: Cross-wind induced loads – Part 1. Journal of Wind Engineering and Industrial Aerodynamics.

Dorigatti, F., Sterling, M., Rocchi, D., Belloli, M., Quinn, A., Baker, C., Ozkan, E., 2012. Wind tunnel measurements of crosswind loads on high-sided vehicles over long-span bridges. Journal of Wind Engineering and Industrial Aerodynamics.

Liu, X., Han, Y., Cai, C.S., Levitan, M., Nikitopoulos, D., 2016. Wind tunnel tests for mean wind loads on road vehicles. Journal of Wind Engineering and Industrial Aerodynamics 150, 15–21.

Heft, A.I., Indinger, T., Adams, N.A., 2012. Introduction of a new realistic generic car model for aerodynamic investigations. SAE Technical Paper Series 2012-01-0168. SAE International. https://doi.org/10.4271/2012-01-0168

Wieser, D., Schmidt, H.-J., Müller, S., Strangfeld, C., Nayeri, C., Paschereit, C., 2014. Experimental comparison of the aerodynamic behaviour of fastback and notchback DrivAer models. SAE International Journal of Passenger Cars – Mechanical Systems 7, 653–661. https://doi.org/10.4271/2014-01-0613

Heft, A.I., Indinger, T., Adams, N., 2018. Experimental and numerical study of the DrivAer model aerodynamics. SAE International Journal of Passenger Cars – Mechanical Systems 11, 115–127. https://doi.org/10.4271/2018-01-0741