# Flow Separation Dynamics in Cars Under the Influence of Turbulent Inflows

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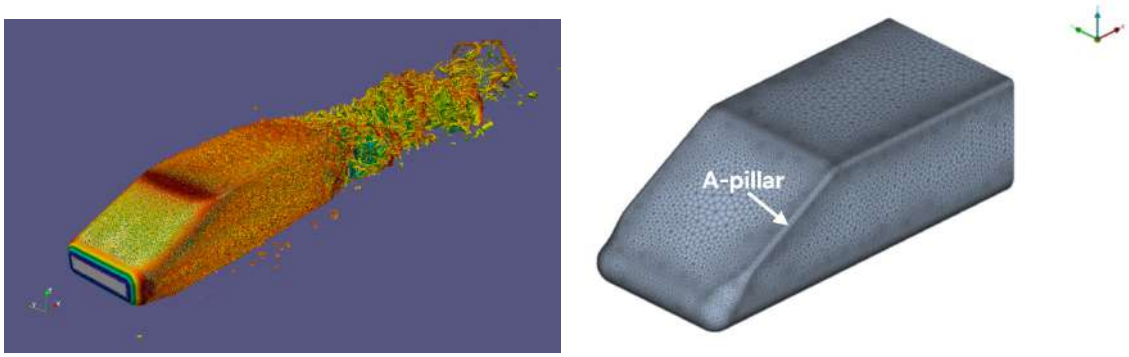
During early development phases, vehicle exterior surface optimization has mainly focused on steady wind flow conditions in both wind tunnel experiments and numerical simulations. However, on-road conditions introduce additional variables, such as environmental effects, leading to variations in upstream wind speed and direction, and free-stream turbulence intensity. These factors directly influence noise sources and impact the comfort level inside the car cabin.

This study investigates the effects of free-stream turbulence on a simplified car model through high-fidelity simulations using high-order spectral element code SOD2D[1] for compressible flows. Figure 1a shows the Q-criterion colored by streamwise velocity for a Windsor body model. However, the transition from the windshield to the side glass in the Windsor body is not adequate for understanding sound generation caused by flow separation around the A-pillar of a real vehicle. To address this limitation, we employed an idealized generic vehicle model[2] with a realistic A-pillar profile, as presented in Figure 1b.

In this work, an assessment of the flow separation around the A-pillar under both uniform and turbulent free-stream conditions is conducted using high-fidelity simulations. The analysis primarily focuses on evaluating how free-stream turbulence influences the characteristics of coherent structures that develop around the A-pillar, which are critical for sound generation mechanisms. By comparing both uniform and turbulent inflow cases, key differences in flow behavior, such as vortex shedding, recirculation regions, and turbulence intensity near the A-pillar, are identified. Additionally, the study investigates the interaction between these coherent structures and the surrounding turbulent flow, with the aim of understanding their role in the amplification or attenuation of aerodynamic noise. The findings provide new insights into the complex relationship between flow separation, turbulence, and sound generation, with potential implications for designing quieter vehicles.




(a) Windsor body model (b) Idealized generic vehicle model

Figure 1: Scale-resolving simulation results for Windsor body and geometry definition considering a realistic A-pillar profile

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[1]Gasparino et al., *Computer Physics Communications* **297(2024)**
[2]Islam et al., *14th AIAA/CEAS Aeroacoustics Conference*