

Wind Tunnel Evaluation of Combined Active Aerodynamic Systems on a CUV-type EV

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ABSTRACT: The Electric Vehicle (EV) market is currently experiencing stagnation due to rising prices and mileage limitations. To mitigate this issue, enhancing aerodynamic performance to extend driving range is essential. Active aerodynamic systems possess the capability to optimize aerodynamics based on varied driving conditions. However, research on the interactions among these systems remains insufficient. This study investigates the combined effects of the Active Rear Diffuser (ARD), Active Spoiler Module (ASM), and Active Air Skirt (AAS) on a CUV-type EV through wind tunnel evaluations. The results demonstrate that the aerodynamic efficiency of each system is maintained even when integrated. These findings serve as fundamental data for the development of effective combination and control strategies for EV active aerodynamic systems, ultimately contributing to improved energy efficiency and driving stability in next-generation EVs.

KEY WORDS: EV, Active Aerodynamic System, Active Rear Diffuser (ARD), Active Spoiler Module (ASM), Active Air Skirt (AAS), Aerodynamic Performance, Wind Tunnel Test, Combined Effect

1. Introduction The EV market is experiencing a temporary slowdown due to high vehicle prices, insufficient charging infrastructure, and consumer concerns over limited all-electric range (AER) per charge, making aerodynamic drag reduction critical to extending driving range. Active aerodynamic systems can optimally control drag by changing the shape or angle of vehicle components in real time, but research on the effects of applying multiple such systems in combination remains insufficient. Building on a preceding CFD study, this work installs the Active Rear Diffuser (ARD), Active Spoiler Module (ASM), and Active Air Skirt (AAS) on an actual CUV-type EV, as shown in Fig. 1, and quantitatively measures the drag and lift coefficient changes (ΔC_d , ΔC_l) for each system combination through wind tunnel evaluation.

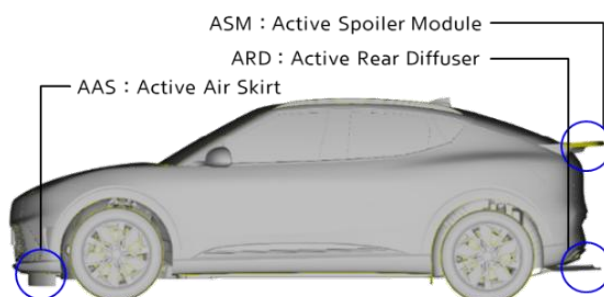


Fig. 1 Mounting positions of the active aerodynamic systems for evaluation

2. Main Body The AAS deploys from the front bumper underbody above 60 kph to control underbody airflow and reduce front-tire vortex drag. The ARD tilts down from the rear bumper underside above 60 kph, delaying underbody flow separation and recovering wake-region pressure. The ASM is a sliding-type spoiler that extends rearward from the tailgate, lengthening the vehicle and reducing wake size. A full-vehicle wind tunnel test with road-simulation and wheel-rotation conditions was conducted up to 200 kph, measuring C_d and the front/rear lift coefficients (C_{l_f} , C_{l_r}) for each system and their combinations. Combining all three systems achieved a total ΔC_d improvement of 0.023 relative to baseline, equal to the sum of each system's individual improvement, indicating negligible interaction between the systems and that overall drag performance can be predicted by linearly summing individual component effects. However, the combination also deepened the vehicle's lift balance in the negative direction, mainly driven by the AAS's large reduction in front lift, which raises concerns for high-speed cornering stability. Adding a tilting function to the sliding-type ASM was shown to actively reduce rear lift (ΔC_{l_r} decreasing 0.10-0.12 as tilt angle increases from 30° to 40°), shifting the lift balance from negative to a neutral or positive state on demand.

3. Conclusion This study empirically verified, through actual vehicle wind tunnel testing, that combining the AAS, ARD, and ASM active aerodynamic systems on a CUV-type EV improves ΔC_d by 0.023 with negligible inter-system interference, so the combined drag benefit can be predicted by linearly summing each component's individual effect. At the same time, the combination deepens the vehicle's lift balance in the negative direction, showing that high-speed driving stability must be considered together with drag reduction when combining active aerodynamic systems; adding a tilting function to the ASM was confirmed as an effective way to control this lift balance within a target range. These findings provide foundational data for developing integrated control logic for multiple active aerodynamic devices in next-generation EVs.