

Development of Truck Aerodynamic Technologies to Achieve Carbon Neutrality in the Logistics Sector

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The logistics sector is a key area for achieving carbon neutrality. Coefficient of Drag (CD) of trucks is generally about twice that of passenger vehicles, therefore, reducing CD directly improves fuel efficiency and reduces CO₂ emissions. Toyota's expertise in aerodynamics for passenger vehicles is considered applicable to reducing CD of trucks, but understanding of truck-specific aerodynamic characteristics is still limited. This study evaluated CD reduction potential of trucks using wind tunnel test and CFD analysis, and based on truck-specific constraints, more practical aerodynamic measures were proposed.

A small van body truck was chosen as the test vehicle because it can be tested in a wind tunnel, allowing detailed, quantitative aerodynamic measurements. CFD result for this truck showed momentum-loss-based "micro drag" map behind vehicle, and identified regions with large contributions to overall drag. Based on this map, we applied passenger car-proven insights to propose measures and evaluate each region's CD reduction potential(Fig.1). Wind tunnel quantification indicated the roof-upper, underfloor, and engine room/ventilation areas had the largest impact on potential. Each of these regions could yield roughly 5–10% reductions in total vehicle CD. However, practical implementation must consider trade-offs with other vehicle performance factors, cost, weight and structural constraints which are unique to trucks.

For the areas identified above as having high potential, we implemented practical measures for two truck-specific structures: (1) the roof-upper, where the cabin roof meets the van body, and (2) the engine room, where ventilation architecture is constrained by the cab-tilt mechanism. (1)At the roof-upper area, separated flow from the roof front edge impinges on the van front, elevating pressure and drag. Full roof deflectors can push separated flow upward and reduce the pressure on the van front, but are high-cost and heavy. To prevent separated flow from entering the gap between the cabin rear edge and the van and being forced downward, we proposed a low-cost , lightweight "gap seal" that closes the gap and forces the flow to lift over the van front(Fig.2). CFD showed that this seal reduced pressure on the van front(Fig.3). The optimized seal produced about 25% of the drag reduction achieved by a full roof deflector. Rough estimates indicated the seal costs and weighs less than 10% of a deflector, yielding superior cost/mass efficiency per unit CD reduction. For (2)engine room area, to avoid interference with the cab-tilt mechanism, ducts connecting the grill openings and heat exchangers cannot be routed, so inlet air bypasses the heat exchangers and exit laterally, increasing drag and reducing cooling efficiency. The proposed solution consolidates multiple grille opening into a single large bumper lower opening placed outside the cab-tilt range and incorporates a duct to supply airflow to the heat exchanger(Fig.4). Wind tunnel test showed that this scheme achieved about 44% of the CD reduction potential obtained by fully closing intake openings, while producing approximately 6% increase in mean flow through the heat exchanger. This result demonstrated simultaneous aerodynamic and cooling benefits without compromising cab-tilt functionality.

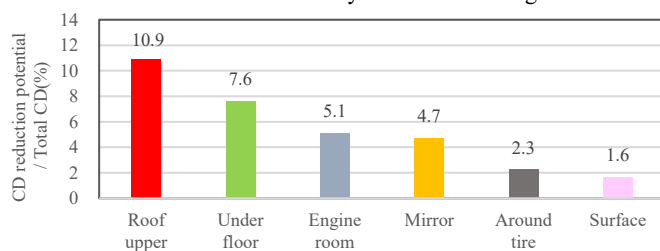


Fig.1 CD reduction potential for each area

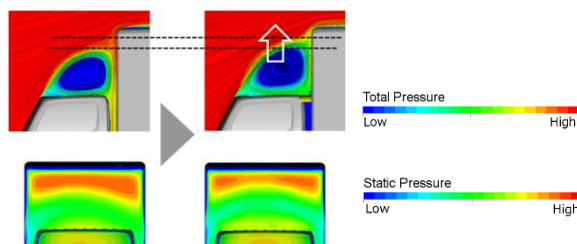


Fig.3 Total and Static pressure distribution
Base (Left), With Cab to van body seal (Right)

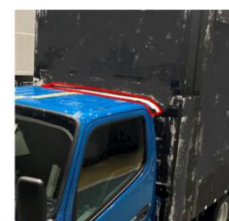


Fig.2 Cab to van body seal

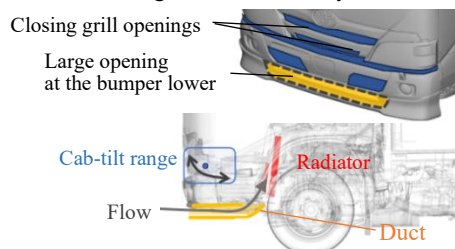


Fig.4 Bumper lower cooling duct