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Vehicle wakes subject to side wind conditions

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Abstract

Passenger vehicles are associated with travel flexibility, today it is clear that this flexibility impacts the environment. Passenger vehicles account for more than one-tenth of all greenhouse gasses in Europe with approximately a quarter of the vehicle's energy consumption wasted as aerodynamic drag. Drag reduction has been and continues to be an active topic impacting fuel efficiency and electric vehicle range. This thesis is on aerodynamic drag of passenger vehicles in side wind conditions. The goal is to increase the knowledge of how vortical structures near the wake relate to the base pressure. The presented work is focused on vehicle wakes and optimisation with the aim to aid in the design of future energy efficient vehicles.

Vehicle wakes are often studied by comparing different configurations. The number of designs and possible combinations to be investigated is often limited due to time constraints. Instead of limiting the possible designs, optimisation was used to aid in the development of a low-drag reference geometry. A surrogate model-based optimisation method was developed and benchmarked against other common techniques. The surrogate model featured adaptively scaled Radial Basis Functions which performed well for the tested benchmark problems. The developed algorithm was used to optimise the geometry at the rear of a vehicle at yaw. This resulted in unexpected designs with good performance.

The investigated geometries featured a base cavity with small angled surfaces, or kicks, at the trailing edge. This kick angle altered the wake balance, reducing the sensitivity to side wind. The wake's unsteady behaviour changed when altering the cavity. Based on the results, it was not possible to find a consistent trend of the unsteadiness of the wake and its relation to drag alone. The results indicate that the improvements to the base pressure were primarily a result of altering the wake balance. The wake balance proved to be the most reliable indicator of drag, with and without additional side wind.

Keywords: aerodynamics, drag, wake, side wind, wind averaged drag, real world conditions, cycle averaged, cavity, tapered extensions, optimization, surrogate model, Radial Basis Functions, Proper Orthogonal Decomposition, Latin Hypercube Sampling