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How Vortex Generators can Save Fuel and Reduce CO2 Emissions for Trucks

Air resistance – or aerodynamic drag – increases exponentially with the velocity of a vehicle. In practice, this means that drag is the single largest source of resistance to movement for a truck at around 80 km/h on a flat road. Consequently, drag is responsible for a considerable portion of the fuel consumption and CO2 emissions at high speeds. But this does also mean that if the drag of a particular truck can be decreased, the fuel consumption will follow. A general estimation in the automotive industry is that a 2 % decrease in drag corresponds to a 1 % reduction in fuel consumption for internal combustion engine trucks. For an electric vehicle, the correlation between drag and energy consumption is even higher.

What are the causes of drag?

The dominating phenomenon of air resistance for ground vehicles is called pressure drag. A common example is that if you put your hand out through a window of a car on a highway, you will need to tense the muscles in your arm and shoulder to keep the hand steady. Part of the explanation for this is straight-forward; you need to apply a force because there is an abundance of air molecules "pushing" on you, since you are forcing them to take a longer path around your hand. What might be less intuitive is that this is only half of the truth. On the leeward side of your hand, the situation is the opposite. Because the air will not be able to follow the shape of the hand, the flow will separate and create a low pressure zone. The disturbed region behind the hand is called a wake, and it generates a suction force that you need to counteract with your arm.

With this in mind, it becomes clearer that the drag of a truck not only originates from the front and windshield, but also to a large extent from flow separation around sharp edges and features such as side-view mirrors, the roof of a trailer sticking up above a cab, and the back end of the trailer.

What is a vortex generator?

A vortex generator is a small, usually V-shaped, device which is used to control the air flow around an object. They are commonly arranged in pairs or rows and can often be seen on aircrafts, wind turbines and race cars. A vortex generator works by directing air to create a swirling motion (vortex), thereby moving air with high kinetic energy closer to the surface. This makes the flow able to “stick” to surfaces where it would otherwise separate. If correctly placed, vortex generators can:

- Delay flow separation and decrease the size of low pressure zones (wakes), thereby reducing aerodynamic drag
- Create an overall smoother airflow, which could for instance minimize unwanted soiling
- Improve handling characteristics of the vehicle and reduce sway, since the wake does not only affect the drag but also side- and lift forces.

How well does V-Spoilers reduce drag?

To better understand the performance of V-spoilers’ product, EDRMedeso has carried out computational fluid dynamics (CFD) simulations. CFD is a method to estimate and visualize the flow around an object by solving the three-dimensional equations that governs the physics of fluid flow, and could be thought of as a virtual wind tunnel. The simulations were performed using Ansys Fluent®, a fluid simulation software commonly utilized in the automotive industry. The technical details of the simulations are summarized in the breakout box.

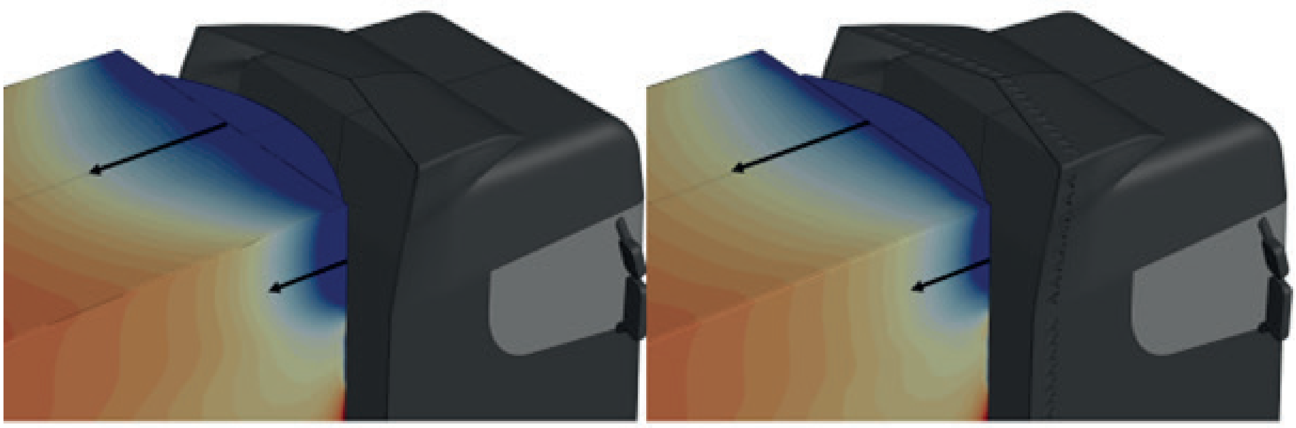

Figure 1. A comparison of serpation zones on the trailer of the baseline truck (left) and with V-Spoilers added to the back of the cab (right). The colors indicate the pressure on the surface of the trailer, where blue means low pressure (separated flow) and red means attached flow. The black arrows have the same length in both images. In the simulation with V-Spoilers, the separation zone is shorter. Note also that the deep blue area (lowest pressure) is smaller.

Simulations were performed at 60 and 89 km/h for a truck with and without V-Spoilers, assuming a straight headwind and flat road. Figure 1 shows an example of the results, where it can be seen that the vortex generators helps to energize the flow before the transition between the truck cab and trailer, making it stay attached for longer at the trailer roof and side compared to the case without V-spoilers. Depending on the placement of the vortex generators, EDRMedeso's simulations indicates that the drag force of the truck in this case could be reduced by up to 7 %. By common estimation, the drag reduction would translate to 3.5 % fuel savings in real-world conditions. This is in line with empirical testimonials from V-Spoilers' customers.

It should be noted that the exact drag reduction that is possible with V-Spoilers depends on the shape of the specific truck and the exact positioning. While some truck models are relatively streamlined, many have a design that is open to aerodynamic improvement. The purpose of the simulations was to exemplify how vortex generators work, rather than to optimize for maximum drag reduction.

Simulation details

The simulations followed the methodology outlined in the Ansys CFD Processes for Open-Wheel External Aero, developed by Andy Wade, PhD.

Software	Ansys Fluent 20R1
Type of simulation	Steady-state
Turbulence model	*k-w* BSL2 with curvature correction
Pressure-velocity coupling	Coupled
Spatial discretization	Second order
Turbulence discretization	Second order
Mesh type	Poly-hexacore
Mesh size	36 million cells (symmetry)

Summary

- Aerodynamic drag is a large source of resistance to movement for ground vehicles and increases exponentially with speed. If it can be reduced, fuel consumption and emissions efficiencies will follow.
- Flow separation is a major cause of drag since it creates low-pressure zones behind the vehicle. Vortex generators can help in controlling the airflow, minimizing flow separation and thereby reducing drag.
- A 7 % drag decrease was estimated for a generic truck with V-Spoilers from computational fluid dynamics simulation results, which would correspond to a fuel consumption reduction of around 3.5 %. The real-world drag reduction of a specific truck will depend on its design and the position of the V-Spoilers.

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