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Reduction of overturning moment of a heavy truck in cross-wind conditions

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Abstract: Vehicles, in particular high-sided lorries and trucks, can be at risk of wind-induced accidents such as overturning and/or side slip, especially on exposed sites such as embankments, viaducts and bridges. A first solution, lies in designing fences and a lateral shield to be placed both at the edges of the bridge and close to the tower, thereby shielding the vehicle from cross-wind. Nevertheless, it is also possible to optimize the aerodynamic response of the vehicle. In this work, Front-rear trailer devices, previously designed and patented by the author, positioned on the sides of the trailer reduced the overturning moment by about 8 %. Steady state and time variant CFD simulations were used. The results were validated with wind tunnel test on a scale 1:10 model.

Keywords: Aerodynamics, road vehicles, CFD, numerical simulation, experiments, flow control, passive divice

1 Problem Statement

Vehicles, in particular high-sided lorries and trucks, can be at risk of wind-induced accidents such as overturning and/or side slip, especially on exposed sites such as embankments, viaducts and bridges. Since this represents a serious concern for the running safety of vehicles, it has been widely investigated in literature [1]-[6].

In this condition, the yaw angle (the angle between the vehicle speed and the wind direction) can be higher than 30°. Higher is the lateral wind, higher is the yaw angle experienced by the vehicle, and higher is the side force and the yawing moment as example [7]. At this crosswind, the aerodynamic of the vehicle is mostly effect from the box shape of the trailer. Higher is the yaw angle, higher is the quantity of the flow that directly hit the side of trailer. The flow, approaching the side of the vehicle is deviated over the surface of the side of the truck in the vertical direction: some of said flow moves down, and some moves up. On the top corner of the trailer, the flow separates generating high turbulence responsible of the previous mention change in the aerodynamic forces.

This may lead the vehicle, in the worst case, to vehicle rollover or undesired lane changes and thus represents a critical concern for running safety.

The negative effects of later wind on the heavy truck handling are even worst when the vehicle is passing through the wake of towers of bridges largely exposed to crosswind.

A first solution to reduce this problem lies in designing fences and a lateral shield to be placed both at the edges of the bridge and close to the tower, shielding the vehicle from cross-wind.

The design of these shields is however an extremely challenging task since it must account for dynamic coupling of aerodynamic loads (depending on the infrastructure layout) and vehicle-driver response.

However, it is also possible to optimize the aerodynamic response of the vehicle.

The simplest way to reduce the side force acting on the heavy truck was to change the shape of the trailer from the standard rectangular one, making the corner between the top and the side of the trailer as smooth as possible. Unfortunately, in this way, also the load capacity of the vehicle is reduced. Consequentially, the strategy of adding "external passive device" to the existing trailer shape, it is considered the most suitable one for the porpoise of this work.

It was decided to test the performance of the Front-rear trailer device, previously developed and patent from the author's [7], [8]. The device, apart to be installed on the front and rear of the trailer, was also mounted on the top sides of it: this configuration is called Lateral-top trailer device and it is divided into a lateral trailer device (device "H", see Figure 1) and a top trailer device (device "I", see Figure 1). The Lateral-top trailer device was developed to be fully integrated with the Front-rear trailer device, so as to couple both the drag reduction performance and the one for reducing the overturning risk. The results were validated with wind tunnel test on a 1:10 scale model (see Figure 2).

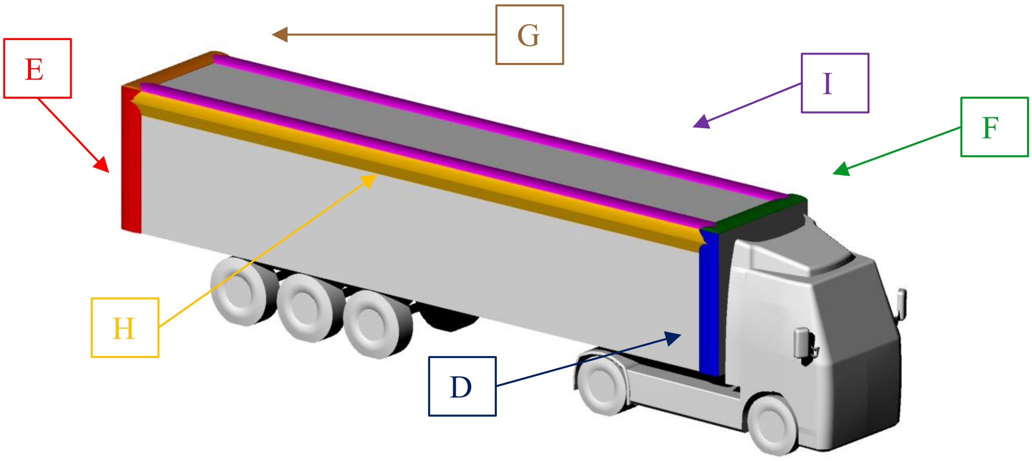
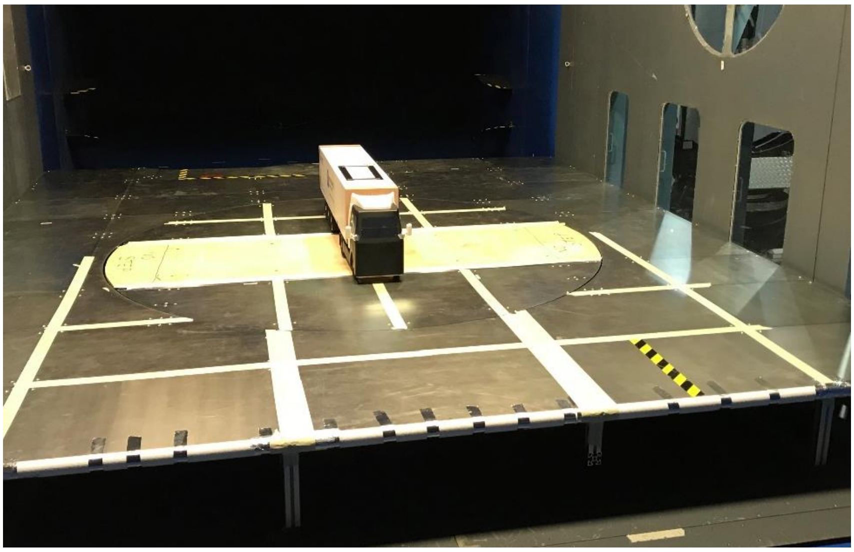


Figure 1. Front-rear devices installed along the sides/top of the trailer.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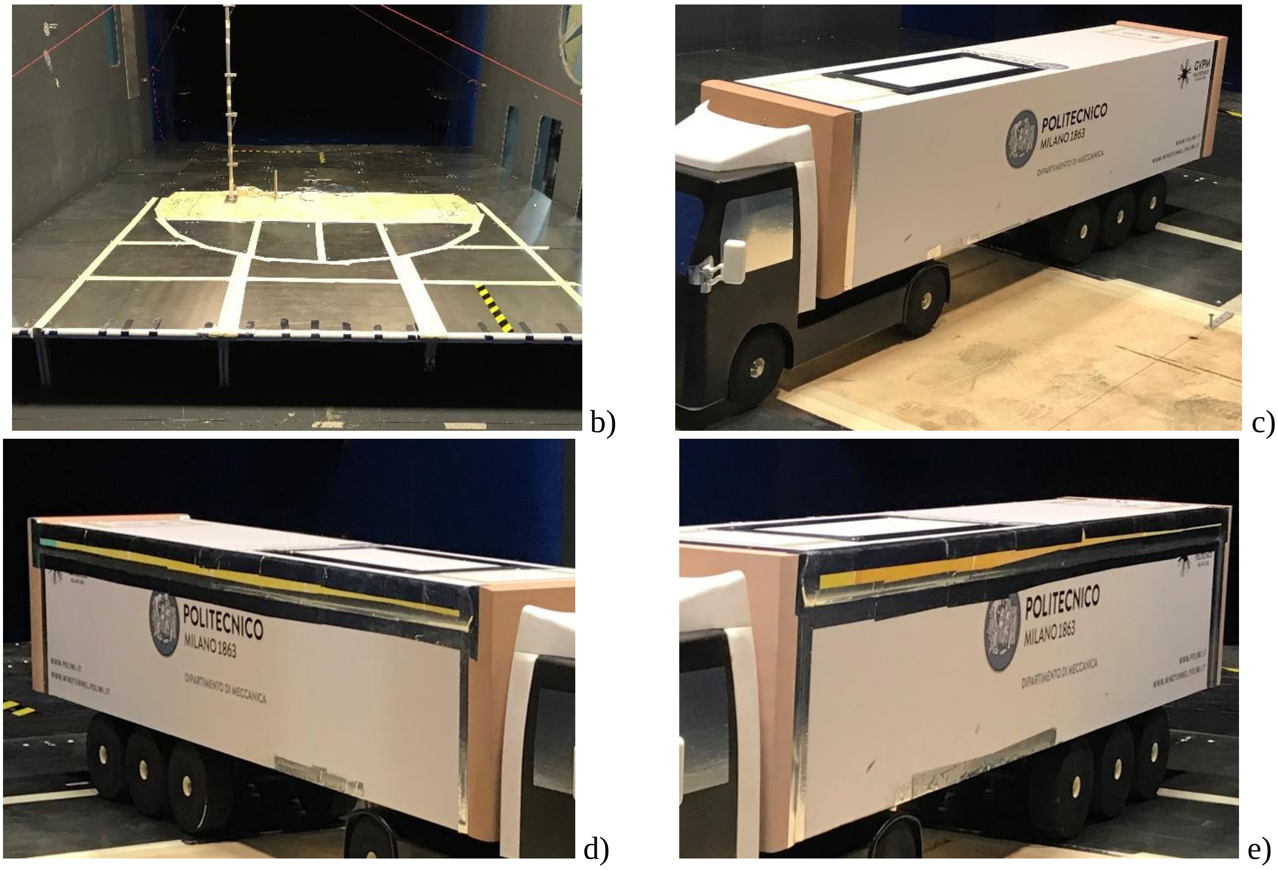

Figure 2. a) Target vehicle, b) Ground board 2, c) Device “B+C”, d) Device “B+C+H”, e) Device “D+E+H”.

2 Results and discussion

performance of the proposed devices “B+C”, “B+C+H”, “D+E+H” were tested with yaw angle from *0°* to *90°*.
In Figure 3, the reduction of the overturning moment, for each device, was reported in function of the yaw angle. In general, a good match can be observed compared to the numerical simulation at the yaw angle 30°. The predicted overturning moment reduction was observed to be around 7%, while in the numerical simulation it was slightly higher.
When the later device “H” was installed on the heavy truck there was an overturning moment reduction around 7% compared to the target vehicle or when the device “B+C” was installed on the trailer. Device “B+C+H” maximizes both the performance in drag reduction than in the overturning one. The configuration devices “D+E” and “F+G” seem to be promising strategies for reducing drag, especially in Countries where increasing the maximum vehicle height or width can be problematic. Current regulations already allow aerodynamic devices to exceed the maximum permitted width no more than 5 cm of the size of the trailer. Therefore, the combination of devices “D”, “E” and “H” was tested with satisfactory results.

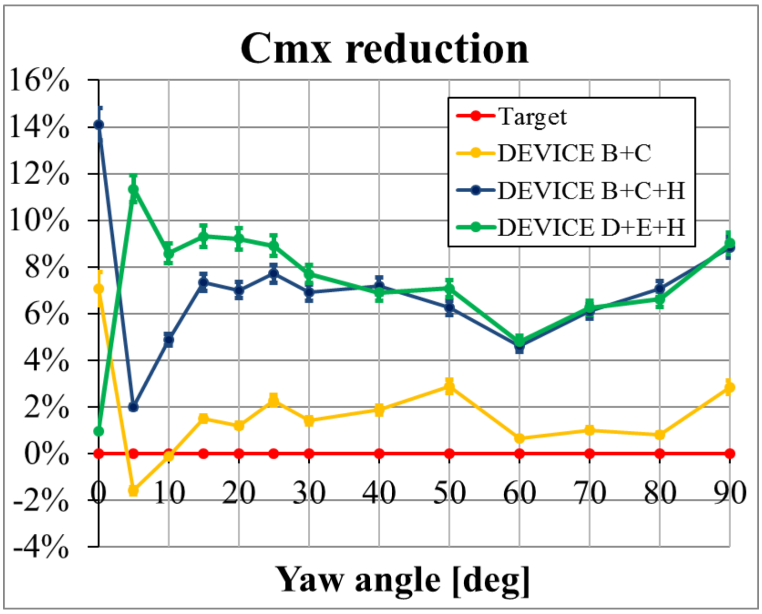

Figure 3. Experimental overturning moment reduction over the yaw angle.

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