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# A Computational Study on the Effects of Installing Cap Roof Deflectors on the Drag Reduction of Trucks

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**ABSTRACT**

Enhancing vehicle performance, fuel and aerodynamic efficiencies through drag reduction is a crucial concern for the automotive industry, especially for commercial vehicles. This study examined the impact of installing add-on devices such as cab deflectors on the reduction of drag of a locally produced truck with elevated body box structure. The study included modelling flat and circular deflectors with different radii. For each case, computational fluid dynamic (CFD) analysis was then applied to examine the ideal aerodynamic deflector for truck at various gaps between the cab deflector rear end and the truck box. The simulation results show that the maximum drag reduction obtained for the curved deflector with no gap distance. The drag coefficient reduced by 28.5% using deflector with radius of 1.75 m compared to the baseline truck.

***Keywords:*** *Aerodynamic, CFD, Drag reduction, Cab deflector.*

## I. INTRODUCTION

The automotive industry nowadays demands a reduction in the fuel consumption of vehicles. Commercial vehicles such as trucks have high fuel consumption in comparison to other ground vehicles, due to high aerodynamic drag. Aerodynamic enhancement is one of the most crucial technologies for reducing fuel consumption in trucks. Trucks are designed to minimize the aerodynamic drag. A truck consumes around 65% of its fuel consumption to overcome aerodynamic resistance, Das *et al* [1]. Moreover, the aerodynamic drag generated at 100 km/h usually consumes about 70% of the engine power. Chowdhury *et al* [2] studied experimentally the trucks aerodynamics drag. Their test rig contained a scaled model of a baseline truck and two front deflectors commonly utilized in their local market. The results showed that bluff shaped deflectors used on these trucks are not aerodynamically efficient and surprisingly, increased the aerodynamic drag by up to 58%. However, replacing these deflectors with an acronym one reduced fuel consumption by about 13%. Although the maximum road speed limit of tractor-semitrailer combinations is comparatively low, the impact of using different add-on devices proved experimentally to have a considerable improvement in their aerodynamics drag, Chowdhury *et al* [3].

The aerodynamic drag was measured on the baseline truck including different external attachments such as front deflector, side skirting and gap filling at different operating speeds and yaw angles, and with different combinations. The results showed that the aerodynamic deflector has a noticeable impact on aerodynamic drag. The front deflector alone can reduce drag by about 17%. Further, drag reduction of up to 26% is possible using combinations of aerodynamic front fairing and gap filling. CFD analysis to enhance the aerodynamic drag at different longitudinal speeds for heavy commercial vehicles has been carried out by Khosravi *et al* [4]. The add-on parts were classified as parts that have been added to the cab and parts added to the container. The results reveal that the most effective part is the deflector. The drag coefficient decreased considerably by 21% at an optimum angle.

Yang and Ma [5] used two different drag reduction devices (passive) using the CFD method. A deflector is installed on the cab of the truck at different shrink angles. The shrink angle is changed on both sides from 0° to 45°, then add cylinder-shaped devices on the edges of the top and bottom of the tail. The results showed that the drag coefficient reduction amounted up to 22.8% at a shrink angle of 25°. However, the installed cylinders have a limited effect on the drag coefficient reduction. Salati *et al* [6] studied experimentally the effects of front and rear add-on devices on the drag of a heavy tractor semitrailer using 1:10 scaled model. The Front-Rear trailer devices were separated into several parts (top, side, front and rear) to analyze which one reduced the drag more. Optimization was carried out on the combinations of several parts of the same device simultaneously installed on the trailer, in addition, Tests were performed both in front wind and crosswind conditions. The results obtained showed that the maximum drag was reduced by 9.5% when both the front and the rear trailer were installed on the tractor.

Jing Peng *et al* [7] designed a new shape for the truck cab. A parametric design protruding cab was created and the length of the protruding part and the angle between this protruding part and the A-pillar were designed. The drag coefficients of twelve parametric cab design cases were quantitatively evaluated by CFD simulation. Among these experimental results, the optimum 500 mm/125 degrees cab design largely reduced the drag coefficient of the tractor-trailer model by 8.49 %. Kim *et al* [8] studied the effect of different cab roof fairing (CRF) designs on the aerodynamic drag reduction for a heavy commercial truck. The drag reduction effects of typical and modified CRF models were tested via wind tunnel and numerical simulation. The 2D CRF attached to the vehicle model reduces the drag coefficient by 15.05% relative to the reference baseline truck model. In addition, rounding the side edges of the 2D CRF increases drag reduction to 15.97%. Moreover, the vehicle model with a modified CRF exhibited drag reduction by 18.6%.

In the current study, two types of cab deflector shapes are designed in addition, study the effect of both deflectors at a different spacing from the truck box. The drag reduction effects on the truck are evaluated using a simulation approach. The results would provide a new design concept to improve the aerodynamic performance of similar trucks.

## II. MODELING AND SIMULATIONS

A commercial truck is modeled using Ansys Design Modeler as shown in Figure 1. A wind tunnel of air enclosure is created for simulation with a blockage ratio (BR) 2% as shown in Figure 2. The dimensions of base line truck and the air enclosure are given in Table 1. Afterwards, Meshing is carried out and the model position of the inlet, outlet, and wall was defined in the meshing process. The truck speed was set at 25 [m/s]. The vehicle model was imported to the ANSYS CFD simulation environment. The details of the boundary conditions are tabulated in Table 2.

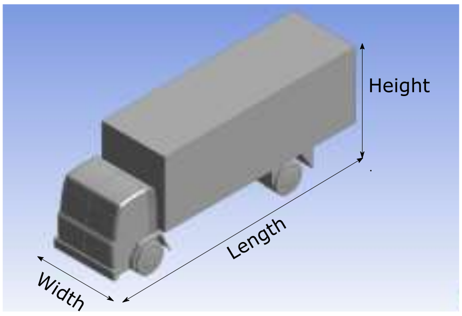


**Figure 1: Baseline truck model**

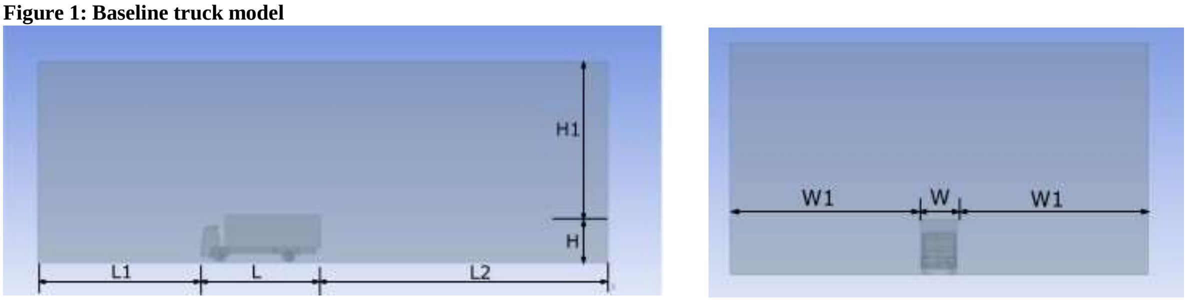


**Figure 2: Size of wind tunnel enclosure**

**Table 1 Dimensions of base line truck and the air enclosure.**

| Parameter | Dimension (m) |
|---|---|
| Truck Height (H) | 3.65 |
| Truck Length (L) | 9.20 |
| Truck Width (W) | 2.40 |
| L1 | 12.56 |
| L2 | 22.20 |
| H1 | 11.85 |
| W1 | 12.80 |

**Table 2: Details of the boundary conditions**

| **Parameter** | **Dimension (m)** | **Value** |
|---|---|---|
| Inlet | Velocity Inlet | 25 m/s |
| Outlet | Pressure Outlet | 0 Pa (gauge) |
| Wall | Wall Boundary | Non-equilibrium wall |
| Truck Surface | Wall Boundary | No-slip |
| Reference | Ambient | 101.325 kPa |

In this study, five cab deflectors are used. One flat deflector in addition to a curved deflector at four different radii numbered from R1:R4. The curved deflector radius is designed to be: 1.75, 2.20, 3.10, and 4.10 [m] respectively. The flat and curved deflectors are shown in Figures 3 and 4 respectively. Parameter x is the distance between the cab deflector and the truck box ranging from 0 to 20 [cm] with a step 5 [cm]. furthermore, the parameter R is the radius of the cab deflector.

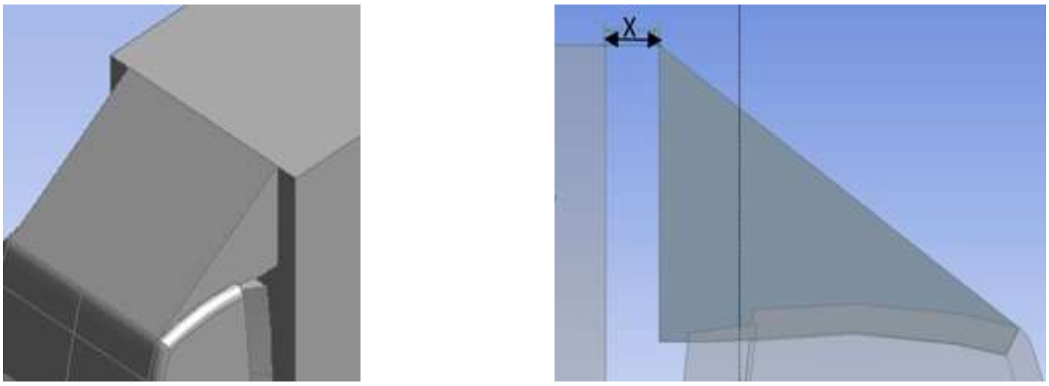


**Figure 3: Flat deflector used in the simulation.**

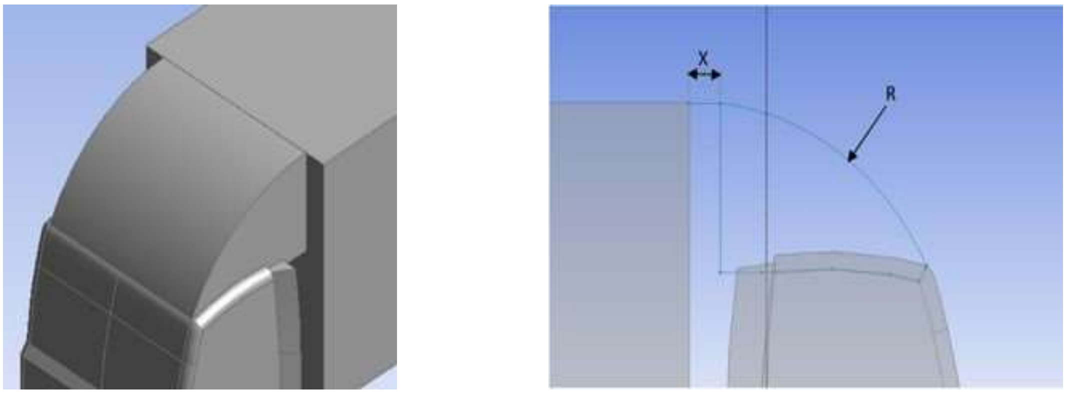


**Figure 4: curved deflector used in the simulation.**

## III. RESULT AND DISCUSSION

The results of drag coefficient ($C_d$) for the baseline truck with the different types of cab deflectors were presented and visualized in Figure 5. The results obtained from the simulations are tabulated in Table 3. The baseline truck without any cab deflectors shows the highest value of $C_d$ which is around 0.64. The maximum drag reduction is when there is no gap between the deflector and the truck box as shown in Figure 5. The highest drag reduction is for the curved deflector with a radius equal to 1.75 [m].

**Table 3: The drag coefficients at a different spacing from the truck box.**

| $C_d$ | | | | | |
|---|---|---|---|---|---|
| x [cm] | R1 | R2 | R3 | R4 | Flat |
| 0 | 0.46 | 0.465 | 0.468 | 0.471 | 0.475 |
| 5 | 0.464 | 0.473 | 0.477 | 0.482 | 0.506 |
| 10 | 0.471 | 0.479 | 0.481 | 0.487 | 0.511 |
| 15 | 0.478 | 0.482 | 0.484 | 0.496 | 0.519 |
| 20 | 0.481 | 0.486 | 0.487 | 0.51 | 0.522 |

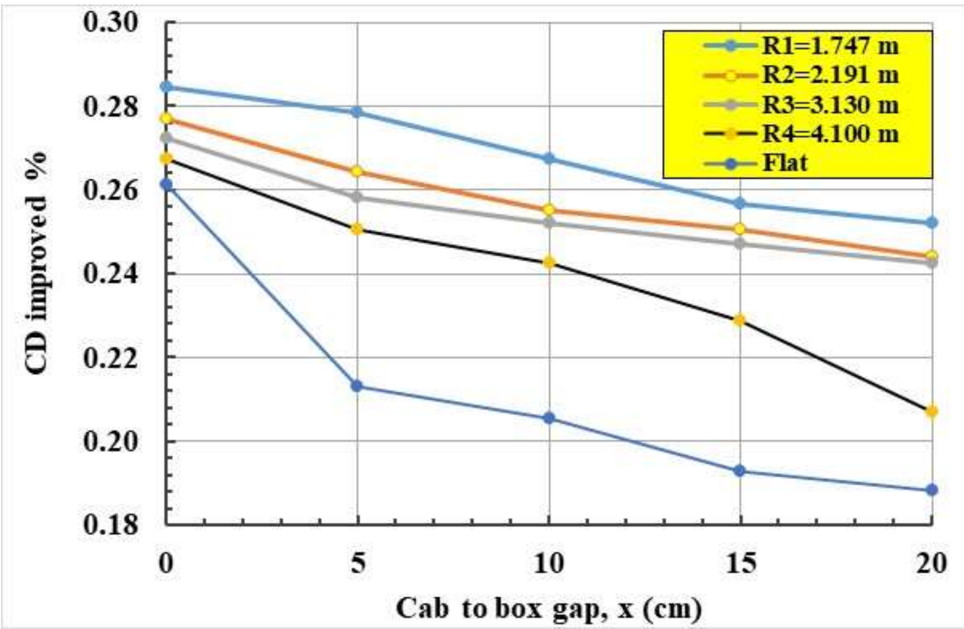


Figure 5 The drag reduction for the five deflectors.

The streamlines originate from the edge of the plane and were obtained on a plane that is positioned horizontally across the truck. The velocity streamlines for the baseline truck are shown in Figure 6. The high-velocity streamlines in front of the container due to flow separation. The high pressure mainly occurs at the frontal area of the cab and container. The air trapped between the cab and truck box which cause swirled airflow in this region results in a high-pressure region. The flow separation on the truck's front edges can be reduced by adding cab deflectors as shown on Figures 7 and 8.

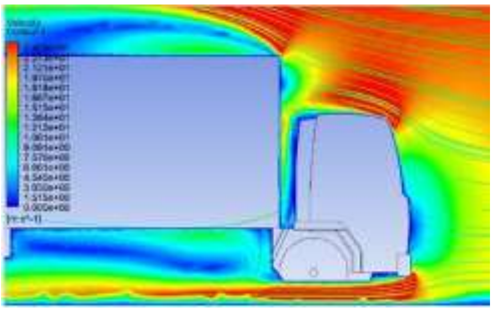

**Figure 6 Side view of velocity streamlines for baseline truck.**

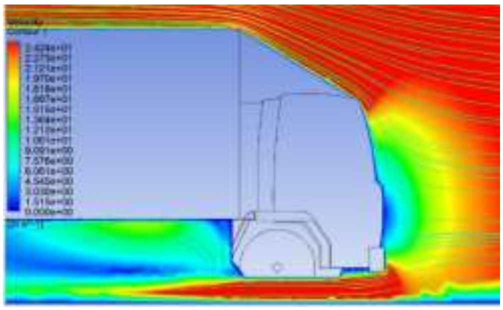

**Figure 7 Side view of velocity streamlines for flat cab deflector.**

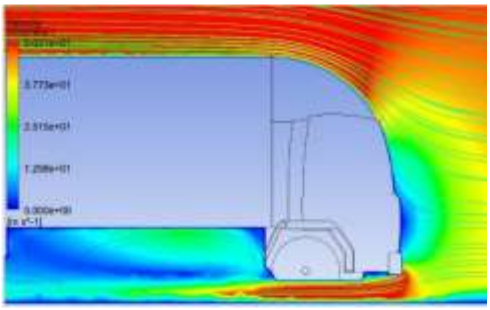

**Figure 8 Side view of velocity streamlines for curved cab deflector (R1).**

## IV. CONCLUSION

Five cab deflectors are tested in this paper, which are flat and curved deflectors at four different radii mounted on top of the head of the truck at different gap spacing from the truck box. The simulation shows that the additional devices influence the drag reduction. The curved deflector with a radius equal to 1.75 [m] has the highest reduction value. The drag coefficient decreased considerably by 28.5% compared to the baseline truck. It is concluded for all the deflectors that the highest reduction values are when there is no gap between the deflector and the truck box. Therefore, a minimum practical gap must be implemented since the truck cabs are usually mounted on suspensions.

## V. REFERENCES


[1]. P. Das, M. Tsubokura, T. Matsuuki, N. Oshima, and K. Kitoh, “Large Eddy Simulation of the flow-field around a full-scale heavy-duty truck,” Procedia Eng., vol. 56, pp. 521–530, 2013, doi: 10.1016/j.proeng.2013.03.155.

[2]. Chowdhury, H., Loganathan, B., Mustary, I., Moria, H., & Alam, F. (2017). Effect of various deflectors on drag reduction for trucks. Energy Procedia, 110, 561-566.

[3]. Chowdhury, H., Moria, H., Ali, A., Khan, I., Alam, F., & Watkins, S. (2013). A study on aerodynamic drag of a semi-trailer truck. *Procedia Engineering*, *56*, 201-205.

[4]. Khosravi, M., Mosaddeghi, F., Oveisi, M., & khodayari-b, A. (2015). Aerodynamic drag reduction of heavy vehicles using append devices by CFD analysis. Journal of Central South University, 22, 4645-4652.

[5]. Yang, X., & Ma, Z. (2014). Drag reduction of a truck using append devices and optimization. In Parallel Computational Fluid Dynamics: 25th International Conference, ParCFD 2013, Changsha, China, May 20-24, 2013. Revised Selected Papers 25 (pp. 332-343). Springer Berlin Heidelberg.

[6]. Salati, L., Schito, P., & Cheli, F. (2017). Wind tunnel experiment on a heavy truck equipped with front-rear trailer device. *Journal of Wind Engineering and Industrial Aerodynamics*, *171*, 101-109.

[7]. Peng, J., Wang, T., Yang, T., Sun, X., & Li, G. (2018). Research on the aerodynamic characteristics of tractor-trailers with a parametric cab design. *Applied Sciences*, *8*(5), 791.

[8]. Kim, J. J., Lee, S., Kim, M., You, D., & Lee, S. J. (2017). Salient drag reduction of a heavy vehicle using modified cab-roof fairings. Journal of Wind Engineering and Industrial Aerodynamics, 164, 138-151.