

AN EXPERIMENTAL STUDY OF THE AERODYNAMICS FORCES ACTING ON A TRUCK

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Abstract

The aim of this project is to show the aerodynamics experiment results in the front area of a truck in terms of drag coefficient (C_d) within aerodynamics forces. The test was conducted in the Wind Tunnel laboratory at the University of South Australia in the school of Mechanical and Manufacturing Engineering. To perform the test, wood scaled dimensions was used. In addition to the test, fairing and without fairing effects were investigated. Results, C_d truck with fairing was lower than that of without fairing by 0.108 or from 0.518 to 0.41. By adding the fairing on the truck's cap, fuel consumption could be saved.

Keyword: drag coefficient and fairing

1. Introduction

As one of the activities over the development in vehicle technology is to conduct a practical study to obtain aerodynamic drag. This is one of the most important factors for vehicles which have great influence on fuel consumption. The effect of cross-wind on the aerodynamic forces is very significant as stated by Taylor (2006) in his excellent lecture notes. Traveling through still air the drag force acts on the relatively small frontal area of the truck and is directed nearly parallel to its longitudinal axis. However in the presence of a cross-wind the magnitude of the relative velocity between the truck and the air is increased and its direction is skewed to the direction of motion so that the large side area of the trailer is exposed. The resulting drag force is much larger and it has components both parallel and normal to the direction of the truck's motion. Substantial lift can also be generated in cases of separated flow over the top of the trailer.

The component of drag normal to the longitudinal axis of the truck is referred to Bettel et al., 2003. Therefore, the more aerodynamic drag is reduced, the more fuel can be saved. Wind tunnel experiment is traditionally method to obtain aerodynamics characteristics.

Aerodynamic efficiency of a car is determined by its coefficient of drag (C_d). Coefficient of drag is independent of area; it simply reflects the influence to aerodynamic drag by the shape of object. Theoretically, a circular flat plate has C_d 1.0, but after adding the turbulence effect around its edge, it becomes approximately 1.2. The most aerodynamic efficient shape is water drop, whose C_d is 0.05. However, we cannot make a car like this. A typical modern car is around 0.30.

In general, to study vehicle's drag, Ahmed body car is used as a simulation model, but it is mostly for rear drag slant not the front area. Guilmineau (2008) intensively investigated the influence of rear body structure by using Computer Fluid Dynamics (CFD) simulations. However, in this paper, a Wind tunnel simulation with wood truck scaled dimensions was used as in Figure 1 both with and without fairing. It is also considered the front testing area of the drag. Baker and Humpreys (1996) make use a lorry and container in their simulations model. Interesting experiment was done by Wood and Bauer (2003). They observed trailer of a tractor-trailer truck with speed variations. To begin this research, Wood and Bauer model was modified with only 2 wind speed variations and only frontal area of the truck.

2. Coefficient of drag (C_d)

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3. Methodology

To perform the Wind tunnel test, a scaled dimension model is produced as in Figure 1. Before testing, calculating the frontal area (m^2) is done. Based on the weight and height of the truck that was measured, the frontal area can be calculated as follows:

$$A_F = h \cdot w \text{ (m}^2\text{)} \dots\dots\dots(1)$$

Where:

A_F = frontal area

h = height of frontal area (mm)

w = width of frontal area (mm)

The measurement result is depicted in Table 1 while Table 2 shows the force balance calibration of Wind tunnel apparatus.

Table 1. Frontal Area

Model	Height (mm)	Width (mm)	Frontal Area (A_F) m^2
Truck	158	98.7	1.559

Table 2. Force balance calibration:

Known mass (pounds)	Horizontal force (N)	Strain gauge reading
1	4.5	211
2	9	427
3	13.5	633
4	18	855
5	22.5	1088

There is only one coefficient of drag for an article which is exposed to a given wind in a certain angel. This means that C_d is not dependent to the wind speed (fan 1 or fan 1+2). If there is no error during the experiment, the results acquired from experiment 1, truck without fairing for both conditions (fan 1 was active and fan 1 + 2 were actives) must be the same. However, as it can be observed from the last right column in the Table 3, the amount of C_d obtained from the experiment one (fan 1 is active) is slightly different from the second experiment (fan 1 and 2 are active) and this happened for both fairing and without faring truck. The reason is some errors which normally happen over the experiments. The more accurate and calibrate are the measurement instruments, the more reliable outcomes would be achieved.

a. Truck without fairing

To calculate the coefficient of drag, the formula is:

$$C_d = \frac{F_d}{\frac{1}{2} \rho A V^2} \dots\dots\dots(2)$$

Having the data for strain gauge and horizontal force, it can be drawn a line. The slope of the line is calculated (m) and is used for calculating

force for other amounts of strain gauge; Calculation of slop (m):

$$m = (427-211)/(9-4.5) \rightarrow m = 48$$

$$\text{So, } m = (430-427)/(F_d-9)$$

$$48 = (430-427)/(F_d-9)$$

$F_d = 9.0625 \text{ N}$, where F_d is forces acting on the frontal area of the scaled truck. To calibrate the apparatus, height and pressure gauge reading are calculated as follows:

$$\Delta h = 160 / 5 \rightarrow \Delta h = 32$$

$$\Delta p = \rho \cdot g \cdot \Delta h \rightarrow \Delta p = 1.2 \times 9.8 \times 32$$

$$\Delta p = 376.5 \text{ Nm}^{-2}$$

$$\Delta p = \frac{1}{2} \rho V^2 \rightarrow V^2 = (2 \times 376.32) / 1.2$$

$$V^2 = 627.2 \rightarrow V = 25.04 \text{ m/s}$$

Then,

$$C_d = 0.54$$

With the same means for all fans are active, the coefficient of drag (C_d) is 1.518. Means

that the higher the wind speed/aerodynamics forces are acting on the frontal area of the truck, the bigger is the C_d on the truck with no fairing.

b. Truck with cab fairing

Truck with cab fairing where fan 1 was active; with the same above steps then C_d is 0.43

For both fan 1 and fan 2 are active to perform wind speed, the C_d is 0.41.

According to the calculations, the coefficient of drag (C_d) calculated for the track *with fairing* and *without fairing* are as depicted in Table 3.

4. Results and Analysis

The below table figures out the result of model test.

Table 3. Coefficient of drag (C_d) for a truck with cap and without fairing

Model	fan	slats	Manometer reading	V (m/s)	Strain gauge reading	F_d (N)	C_d
Truck without fairing	1	Open	160	25.04	430	9.0625	0.54
	1 + 2	Open	306	34.6	810	16.98	0.518
Truck with cab fairing	1	Open	160	25.04	398	8.39	0.43
	1 + 2	Open	310	34.58	755	15.93	0.41

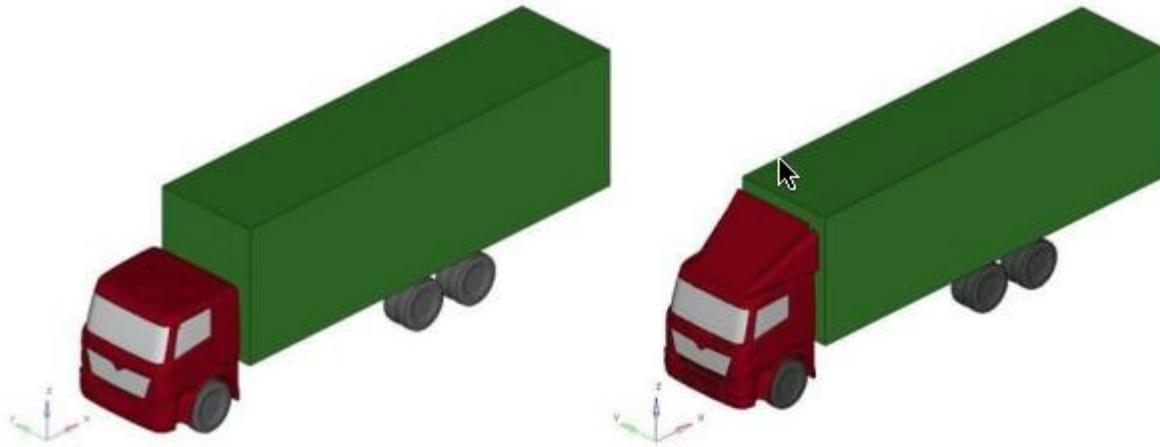


Figure 1. A truck with and without fairing

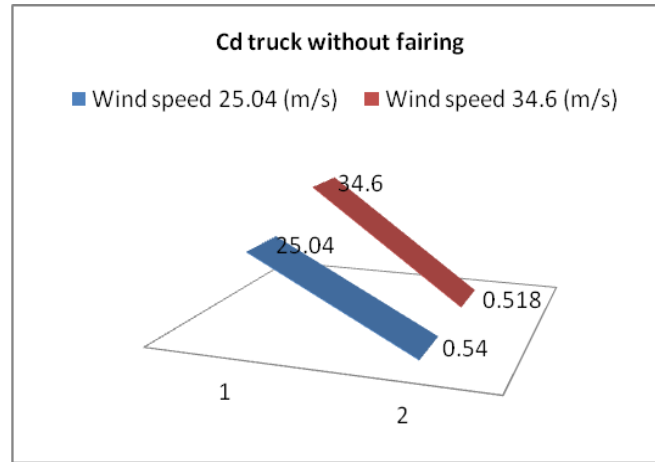


Figure 2. Coefficient drag of truck without fairing

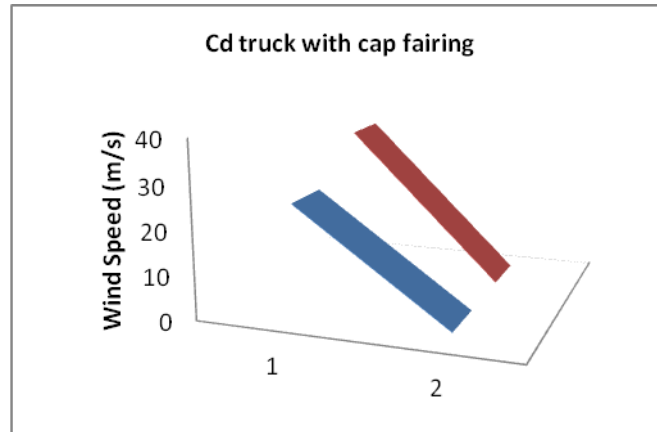


Figure 3. Coefficient drag of truck with fairing

Both Figure 2 and 3 have shown the wind speed effect to the drag coefficient on the truck with and without fairing. Different with 10 m/s, C_d decrease slowly. It is clearly seen that truck with fairing, drag coefficient is lower than of the without fairing. That's why, currently trucks use the cap fairing, particularly for trailer truck. Due to the tiny error occurred over the experiment, the average is applied and the percentage of reduction is formulated as C_d (without fairing) is $(0.54 + 0.518)/2$ equal 0.529; with fairing, C_d is 0.42 with the same means. In addition to the fairings shown above, many researches are being conducted to find out the optimum shape and design for truck fairings. For instance, the figures below are ideas for aerodynamic drag reduction. NASA is one of the institutions which have been making trucks

more aerodynamics, (www.nasaexplores.nasa.gov/show).

Other improvements/modifications can be made to a truck to provide additional improvements in drag reduction. Firstly, the truck frontal area has a significant role to determine its C_d . Therefore, one approach can be reducing the frontal area as much as possible. This results in reducing the height and width of the container behind and truck itself [4]. Secondly, another approach would be covering the spare space between the truck and its container using a cover made by fibre glass or plastic to avoid vortex happening. Thirdly, using a under body fairing and/or modified spoiler at the back of the vehicle to improve the separation and minimise drag. Fourthly, according to the answer of previous

question, adding flaps, trailer skirt and gap splitter plate can be feasible approaches to improve in drag reduction. Lastly, using advance simulation software enables engineers to simulate and predict the effect of using different types of fairings on aerodynamic drag reduction.

5. Conclusion

Over the experiment conducted about aerodynamic drag, this is observed that the influence of fairing for reducing aerodynamic drag for truck is considerable. Due to the errors over the experiment associated with measurement instruments the result for C_d were slightly different for each obstacle exposed to wind in wind tunnel. However, wind tunnel is a reliable and good experiment for acquiring C_d . It is recommended to use computer simulation with the same test data.

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6. References

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