DETERMINATION OF AERODYNAMIC DRAG FORCE ACTING ON MOVING HEAVY DUTY TRUCK-TRAILER IN MALAYSIA

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"I declare this report is on my own work except for summary and quotes that I have mentioned its sources"

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To my beloved family

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ABSTRACT

The purpose of this project is to study the aerodynamic of the heavy vehicle which is normally can be founded at Malaysian highway. To understand the detail of this project, the study of the aerodynamic theory and the related factor and the previous development on the heavy vehicle aerodynamic should be done. The drag coefficient, Cd, of the aerodynamic force will be determined by simulation using Computational Fluid Dynamic"CFD". Hence the collection data from the experiment will be analyzed and propose a suitable measure to improve the drag coefficient, Cd, value.

ABSTRAK

Projek ini dijalankan bertujuan untuk mengkaji sifat aerodinamik kenderaan berat yang terdapat di Lebuhraya Malaysia. Untuk memahami projek ini secara mendalam, kajian terhadap teori aerodinamik dan unsur-unsur yang berkaitan serta pembangunan yang telah dibuat terhadap aerodinamik kenderaan berat, akan dijalankan. Pekali seretan, Cd, untuk daya aerodynamic akan dikaji dengan melakukan simulasi pergerakan bendalir berkomputer "CFD". Setrusnya data yang diperoleh akan dianalisis dan memberikan cadangan yang sesuai untuk pengubahsuaian bagi memperbaiki nilai pekali geseran, Cd.

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LIST OF SYMBOLS

A	=	Frontal area m^2
C_D	=	Drag coefficient
D_p	=	Pressure drag
D_f.	=	Friction drag
ρ	=	Density, kg/m^3
v	=	Speed, m/s
Re	=	Reynolds number
l	=	Turbulence length scale
μ	=	Dynamic viscosity, kg/m
Cp	=	Pressure coefficient

CHAPTER I

Introduction

1.1. Background

In commercials vehicle study such as heavy vehicle, the external flow remains the famous criteria to be concern. When the truck is in dynamic condition, the air exerts a force through it frontal area and this situation will resists a motion between them. This force is known as aerodynamic drag, and it has a significant impact on the performance of steady horizontal travel at normal road speeds.

The pressure drag will produce due to its body shape, frontal area and its speed on the road. The drag coefficient directly relates with the vehicle shape to the amount of air resistance experienced. By doing some modifications on its shape to be more streamlined flow, the value of drag coefficient, C_d can be reduce hence its result is better than before.

1.2.Objective

The objectives of this project are:

1. To determine the drag coefficient of typical heavy duty truck moving on the highways.
2. To simulate the flow conditions in CFD software and attempt to correlate the findings.
3. To suggest a suitable measure to reduce the drag coefficient on Malaysian truck operation.

1.3. Scope

1. Determination of drag coefficients for heavy duty truck-trailer vehicle in terms of a numerical value C_{D}.
2. Determination of Numerical values of pressure drag and skin friction drag for the truck bodies.
3. Study the effect of front pressure drag and cab-trailer drag on the aerodynamic performance of vehicle.

1.4. Problem Statement

In real life, the significant of aerodynamic term is referring to the vehicle design and its styling concept. The good styling design in vehicle is ability on the aerodynamic function which is more streamline flow and produce low pressure drag. A poor initial aerodynamic design is increases the overall drag on a vehicle hence creates the turbulence flow around the vehicle body.

In heavy vehicle reduction method, the substantial improvements can be readily achieved by using add-on aerodynamic styling features. This is because a lot of money is required to replace with the new truck if compare to the add on features.

Generally the add new styling designs or the add on features of vehicle should be prove by an experiment. It consists of two methods which is conventionally using the wind tunnel testing or using the Computational Fluid Dynamic (CFD) simulation. Normally a conventional experiment like wind tunnel is to expensive due to the modeling part and the probability to running the testing in many session and variable modeling is lower. In CFD simulation it's become better than that. The designer can directly test the aerodynamic flow of design on the desk and can running the testing in much time. Hence at the same time they can update their design and running the testing again.

1.5. Project Outline

The outline of this project is planning to ensure the flow of this research study is done properly. Besides that, this outline also can help the readers to fully understand the objective and the content of the study.

Begin from the Chapter 1 the summary of the project is presented. It consist the objective and scope of project, background project and the problem statement for this study.

In chapter 2, the stage is presented the documentation of literature review this chapter is consist of aerodynamic of heavy vehicle, previous development on truck aerodynamic, aerodynamic concept and its factor, Computational Fluid Dynamics (CFD). This chapter will be the knowledge source and the understanding about the aerodynamic theory.

The Methodology session in Chapter 3 is about the project flow from the starting until the end. In this chapter a briefly explain the creation the numerical model. It consists of the theoretical for the CFD simulation solution solver and the parameters as a model setup.

Chapter 4 is the discussion stage where the result and the finding are presented. It consists of the explanation for the data and the problem occurred since the research begins and the update design to improve the finding result.

Chapter 5 is the conclusion stage where the summary of the introduction, literature review and methodology of the project were come out. Hence the suggestion for the future relate in this study

1.6. Outline Gant Chart

Planning For PSM1

No	Item	Weeks	July-October													
			1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
1	Introduction	2	■	■												
2	Study on The Previous Aerodynamic Development	2			■	■										
3	Study The Related Aerodynamic Theory	3				■		■	■							
4	Study The Truck Model Shape and Measure The Dimension	2							■	■						
5	Develop 3D Truck Modeling Using CATIA VR16	4							■	■	■	■				
6	Understanding The Relation Cd With Testing Method	2									■	■				
7	Report Writing.	4										■	■		■	■

Planning For PSM2

NO	ITEM	WEEK(S)	**January - April**													
			1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
1	Study / Make Improvement to PSM1	3														
2	Study and Explore GAMBIT and CFD Software	8														
3	Simplified (rebuild) trailer CAD model	2														
4	Meshing and CFD Simulation	5														
5	Analyze The Data and Make Discussion	2														
6	Reshape / Improve Truck Cab-Roof Fairing Design and Recommendation	2														
7	Report writing.	2														

1.7. Conclusion

As a conclusion of this chapter, the background of this project can give the imagination to the reader to understand it. The problem statement of this chapter will introduce the problem occur in the commercial transportation; hence help them to understand the objective and the scope of this project.

CHAPTER II

LITERATURE REVIEW

2.1. The Aerodynamic of Heavy Vehicle

The performance of tractor-trailer trucks shows, the primary resistance forces are drive train losses, rolling friction, and aerodynamic drag. This situation make vehicle speed increase the force required to overcome both aerodynamic drag and rolling friction increases.

However, the rate of increase in aerodynamic drag due to increasing vehicle speed is much greater than rolling friction. As shown in (Figure 2.1), the force required to overcome aerodynamic drag was exceeds compare to the requirement to overcome rolling friction. *"The higher the speed the more energy consumed in overcoming aerodynamic drag"* (Rose McCallen, etl. al.(2000).

All of these factors must be addressed when developing technologies to improve in term of fuel economy and performance of heavy vehicles. The improvement of heavy vehicles performance can be achieved by altering truck shapes to decrease the aerodynamic resistance (drag). It is conceivable that present day truck drag coefficients might be reduced by as much as 50 %.(Rose McCallen etl. al., 2000). There are also a number of geometric factors called drag coefficient, C_D that influence the aerodynamics of tractor-trailer trucks.

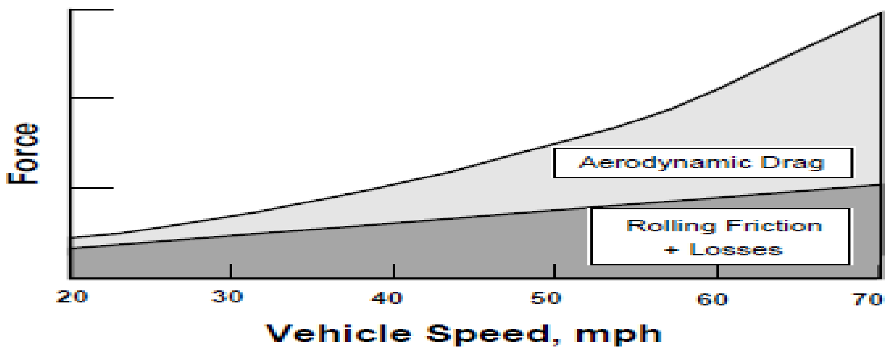


Figure 2.1. Graphic depicting representative horsepower requirements versus vehicle speed for a heavy vehicle tractor-trailer truck.(Rose McCallen ,etl. al., 2000)

The aerodynamic design of heavy trucks is presently based upon estimations of performance derived from wind tunnel testing.(Rose McCallen, etl. al., 2000). Besides that the estimation and prediction of aerodynamic performance can be done using the CFD. By doing this estimation, the trucking manufacturer or community has focused on reducing the aerodynamic drag of the forward facing surfaces of both the tractor and trailer. Normally aerodynamic drag will be reduce through aerodynamic shaping of the tractor cab and the forward face of the trailer by adding aerodynamic fairings to the trailer in order to direct the flow away from the trailer front face.

2.2. Historical Development on Heavy Vehicle Aerodynamic

The development of heavy vehicle aerodynamics has been evolved many years ago. During 1947 (Rose McCallen ,etl, 2004) , Labatt Brewing Company has developed a streamlined truck for advertising purpose and to provide large capacity and higher cursing speed.

The great achievement of this project is shown by the comparison when the Labatt truck can travel at 50 mil/h with a fifty percent large load while the truck of the day travelled at 35 mi/h. But nowadays the truck manufacturing is focus more on the energy conservation in term to minimize the usage of fuel because the fuel price is increase over the years

Figure 2.2: 1947, Labatt Streamliner (Rose McCallen , etl ,2004)

According to the Rose McCallen, etl , 2004 in their book The Aerodynamics of Heavy Vehicles: Trucks, Buses and Trains, the effort to improve truck performance and fuel consumption has been done since 1950's. This project, funded by Trailmobile which was undertaken by the University Maryland to investigate the aerodynamic of tractor and trailers.

On 1960's Seldon Saunders and Chet Willey done the detail look at truck aerodynamic include edge rounding, rounded trailer front face, skirts and boat-tailing. They provoked a new development of the air deflector called Airshield which is the add-on aerodynamic device. The next develop, Nose Cone trailer streamlining fairing which was realized by Fritzgerald when he working at Thermoking.

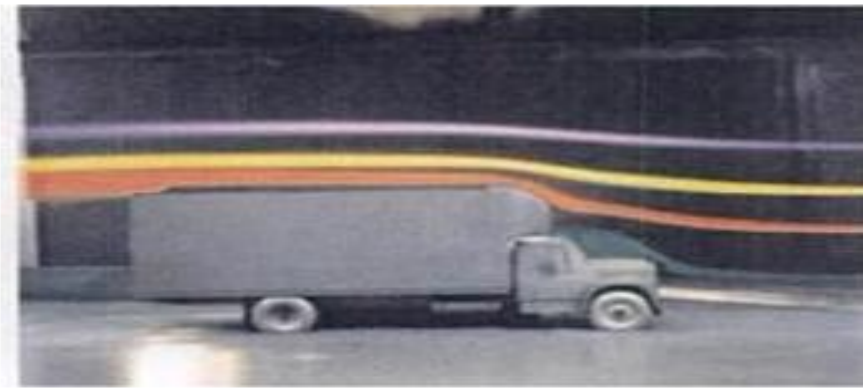
The National Research Council of Canada (NRC) took the task of comparing the commercial device of the day on the late 1970s.

(a)

(b)

Figure 2.3: Show smoke flow over the standard tractor-trailer (a) and modified Tractor-trailer added with deflector (air shield),(b). (RoseMcCallen, etl, 2004).

(a)



(b)

Figure 2.4: Show Smoke Flow over the Standard Straight Truck (a), and modified straight truck added with nose cone (b). (Rose McAllen, etl, 2004)

During the late 1970s and early 1980s the SAE and US DOT, leading to the SAE/DOT Voluntary Bus and Truck Fuel Economy study on the aerodynamic reduction activities. This government/industry cooperative venture was to demonstrate the reduction of truck fuel consumption. It concentrates on a set of four pairs of truck, two tractor trailer combinations and straight truck. Each pair of truck consisted of a standard truck for the time and identical partners fitted with an aerodynamic package and were tested on the road and run in fleet service.

Between 1973 and 1982, the NASA Dryden Flight Research Center conducted “coast-down” test to determine the extent to which adjustments in the shape of trucks reduced aerodynamic drag and improved efficiency. During the tests, the vehicle's sides were fitted with tufts, or strings, that showed air flow. The investigators concluded that rounding the vertical corners front and rear reduced drag by 40 percent, yet decreased the vehicle's internal volume by only 1.3 percent. Rounding both the vertical and horizontal corners cut drag by 54 percent, resulting in a three percent loss of internal volume. A second group of tests added a faired underbody and a boat tail, the latter feature resulting in drag reduction of about 15 percent.