AERODYNAMIC STUDY OF A NEW CAR ROOF BOX USING CFD

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A report submitted
in fulfilment of the requirements for the Degree of
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DECLARATION

I declare that this project report entitled “Aerodynamic Study of a New Car Roof Box Using CFD” is the result of my own work except as cited in the references.

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APPROVAL

I hereby declare that I have read this project report and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering (Thermal-Fluid).

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DEDICATION

This project is wholeheartedly dedicated to my sweet and loving Father and Mother, whose affection, love, encouragement and pay of day and night make me able to get success and honour. This project is also dedicated to my brothers, sister, mentor, friends and classmates who shared their knowledge and encouragement to finish this project.

ABSTRACT

Aerodynamic is very common to public. Aerodynamic nowadays mostly are embedded in the automobile. The aerodynamic play a major important in the automobile. Therefore, installation of the car roof box on the car is depend on the aerodynamic. Car roof box can use as the extra storage of the car and can store some things such as sleeping bag, camping material, clothes and other. This project explains that the design of the car roof box plays an important role in drag coefficient and the velocity flow of the car roof box. Online article and journals were chosen as the sources of the data and the Google Scholar was the online database used. The main objective of this project is to design a new car roof box and to determine and compare the drag coefficient,C_d and velocity flow between the car roof box in the market and new car roof box. From this project, it was discovered that the design of the car roof box can affect the value of the drag coefficient and it bring some benefit to the driver which is can reduce the fuel consumption of the car. For example, with the new design of the car roof box the drag coefficient of the new design is lower than the car roof box that available in the market can reduce the fuel consumption. One model of new car roof box and one model of Thule 667ES are design in this project with the dimension range length of 130-150 cm, width is 80-95 cm and thickness is 40-50 cm. Aerodynamic is often found in the aerospace and automobile. This project focus for those who install the car roof box on their vehicle and for those who need to reduce the fuel consumption after they have installed the car roof box. From this project they will know which design of the car roof box will have the less drag coefficient and reduction of fuel consumption. In this project, the design of the car roof box is designed via the SOLIDWORKS 2018 and the data is analyzed via the CFD simulation. The drag coefficient of the new car roof box is 0.087 which is reduction of 3.11% compare to the Thule 667ES which is 0.090. From this project, there show that the new design car roof box has lower drag coefficient and has the reduction of fuel consumption compare to the car roof box that available in the market.

ABSTRAK

Aerodinamik merupakan sesuatu yang biasa terhadap masyarakat. Pada masa kini, aerodinamik biasanya digunakan dalam bidang kenderaan. Aerodinamik merupakan sesuatu yang sangat penting dalam bidang kenderaan. Oleh itu, pemasangan kotak bumbung kereta pada kereta bergantung pada aerodinamik. Kotak bumbung kereta digunakan untuk menyimpan barang seperti baju, beg tidur, alat-alat perkhemahan dan lain-lain.Projek ini menjelaskan bahawa rekabentuk kotak bumbung kereta memainkan peranan penting dalam pekali seretan dan aliran kelajuan kotak bumbung kereta. Artikel dan jurnal atas talian dipilih sebagai sumber data dan Google Scholar merupakan pangkalan data atas talian yang digunakan. Objektif utama projek ini adalah mereka kotak bumbung kereta yang baru dan menentukan serta membandingkan pekali seret dan aliran kelajuan antara kotak bumbung kereta yang berada di pasaran dengan rekabentuk kotak bumbung kereta yang baru. Melalui projek ini, ia mendapati bahawa rekabentuk bumbung kereta dapat mempengaruhi nilai pekali seret dan rekabentuk kotak bumbung kereta dapat memberi faedah kepada pemandu iaitu dapat mengurangkan penggunaan petrol. Sebagai contoh, dengan rekabentuk kotak bumbung kereta yang baru, pekali seretan lebih rendah berbanding dengan kotak bumbung kereta yang terdapat di pasaran dan rekabentuk kotak bumbung kereta yang baru dapat mengurangkan penggunaan petrol. Dalam projek ini, satu model kotak bumbung yang baru dan Thule 667ES kotak bumbung kereta telah direkakan dengan dimensi panjang 130-150 cm, luas ialah 80-95 cm dan tebal ialah 40-50 cm. Aerodinamik biasanya dijumpai di bidang aeroangkasa dan kenderaan. Projek ini menumpukan kepada seseorang yang memasang kotak bumbung kereta pada kenderaan mereka dan menumpukan kepada seseorang yang telah memasang kotak bumbung kereta yang mahu mengurangkan penggunaan petrol. Melalui projek ini, pemamdu dapat mengetahui bahawa reka bentuk kotak bumbung kereta yang mana satu mempunyai pekali seretan yang lebih rendah dan dapat mengurangkan penggunaan petrol. Dalam projek ini, rekabentuk kotak bumbung kereta direka melalui SOLIDWORKS dan data dianalisis adalah melalui simulasi CFD. Pekali seretan untuk kotak bumbung kereta yang baru ialah 0.087 menunjukkan bahawa mempunyai pengurangan sebanyak 3.11% berbanding dengan Thule 667ES iaitu 0.090. Dari projek ini, ia menunjukkan bahawa rekabentuk kotak bumbung kereta yang baru mempunyai pekali seretan yang lebih rendah dan dapat mengurangkan pengguanaan petrol berbanding dengan kotak bumbung kereta yang terdapat di pasaran.

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LIST OF ABBEREVATIONS

2D	Two dimensional
3D	Three dimensional
CAD	Computer-Aided Design
CAE	Computer-Sided Engineering
CFD	Computational Fluids Dynamics
HVAC	Heating, Ventilation, and Air Condition
IAQ	Indoor Air Quality

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Most of the cars, mini vans and busses are installed with some add-ons, for example roof-rack, roof box, ladder, rack of bicycle, signboard, police's sirens taxi sign and so on. The vehicles that equipped with these add-ons mostly for personal, advertising or professional uses. These add-ons will give effect on the aerodynamic drag due to the add-ons will generate some extra aerodynamic drag. Present of the add-ons for example roof box as shown in Figure 1.1 will change the external shape, size and weight of the vehicles, therefore the aerodynamic drag will change due to the roof box. The shape of the car roof box also will influence the aerodynamic drag. Different type of the roof box will influence the aerodynamic drag. The roof box was one of the main contributors to the extra drag, so the rationalization of the roof box shape was prominent in reducing the drag (Abdul Latif et al. 2017).

Aerodynamics is the air flow around the object (NASA 2011). Usually, the principle of the aerodynamic mostly describe how an aircraft can fly, explain how the rocket blasting off the launch. Aerodynamic also apply to cars because air flows around the cars. For automobile, automobile started to use aerodynamic shape in the early of their history racing cars and those aim to break the record of the land speed were the first cars to embrace better in aerodynamics or streamline. Based on the racing car aerodynamics, Dr. Joe David, which is professor of mechanical and also aerospace engineering, and at North Carolina State University many of them know him as "Mr. Stock Car", he said, "most of the horsepower

produced by the racing engine is absorbed by the high-pressure air pressing the front of car and a partial vacuum pulling the car from behind with the low-pressure air." (Jim Lucas 2014)

Aerodynamic drag is a force that make the object difficult to move. This is because the drag generates the resistance which will make the object difficult to move such as, we difficult to move through the water compare to the air. This is because air will generate less drag compare to the water. The shape of a body also influences the value of drag. (NASA 2017). The type of the surface also influences the drag produced, for example the round surfaces will generate less drag force compare with the flat surfaces while the narrow surfaces will generate less drag compare to wide surfaces. A roof box is a box which is can be installed securely on the car roof. To have the additional storage space for things like suitcases, outdoor or camping equipment or personal uses the car roof box is designed to full fill the requirement. The shape of the car roof box depends on the requirement of the owner, but different size and shape of the car roof box will cause the aerodynamic drag different with the original drag.

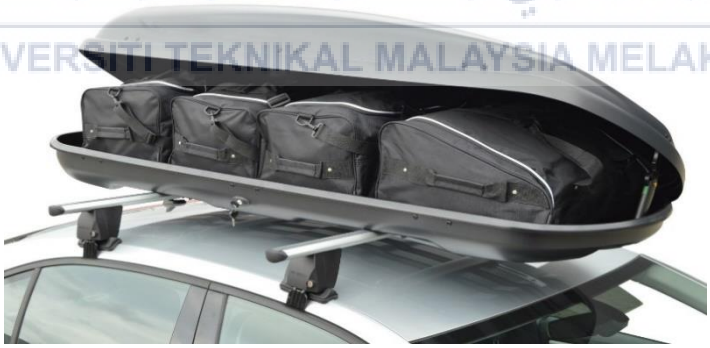

Figure 1.1: Car roof box with roof rack.

Aerodynamic drag proportional to the square of speed, this is because the power that needed to overcome the aerodynamic drag that produce by the car is proportional to the cube of the velocity. This will cause more energy need to use, so the many fuels needed to produce energy to overcome the aerodynamic drag. Therefore, there are very strong relationship

between the aerodynamic and the fuel consumption. When the car roof box is equipped, this mean the aerodynamic drag will different with the original drag, this will cause the fuel consumption also different.

1.2 PROBLEM STATEMENT

Car roof box is a box that install at the upper part of the car which is the roof of the car as show in Figure 1.2. Car roof box can use as the extra storage of the car and can store some things such as sleeping bag, camping material, clothes and other. The car roof box at the top of the car will influence the air flow of the car, the type car roof box will increase the weight of the car and effect the aerodynamic of the car. Hence the air flow influence by the car roof box, therefore the drag force of the car also influenced. When the drag force influence, the speed of the car also not same with the other, to overcome the reducing of the speed more energy apply to the car to maintain the speed. As a result, fuel consumption will increase to overcome that wasted energy. Therefore, this research will be conducted to design a new car roof box which will reduce the drag force compare to the available roof car box in the market.

Figure 1.2: A car with a car roof box. (Picture from internet)

1.3 OBJECTIVE

The objective of this project:

1. To design a new car roof box.
2. To determine and compare the drag coefficient, C_d and velocity flow between the car roof box in the market and new car roof box.

1.4 SCOPE OF PROJECT

The scopes of this project are:

1. One of the car roof box that available in the market with brand name Thule which is Thule 667ES is draw to compare with the new design of the car roof box.
2. One of the car roof boxes is designed and analyse to compare with the car roof box in the market which is Thule car roof box with dimension range length 130-150 cm, width 80-95 cm, thickness 40-50 cm.

CHAPTER 2

LITERATURE REVIEW

2.1 AERODYNAMIC

Aerodynamic is the study of the motion of the air that move around the things and it affected by some solid object such as airplane wings, car and other. Definition of aerodynamic is a branch of dynamic that deals with the motion of air or other gaseous fluids and with the forces acting on bodies in motion relative to such fluids. Aerodynamics is the study of how the gas interact with certain moving objects, since the air is the gas they encounter most, aerodynamics is mostly concerned with the forces of drag and lift that generated by air flowing through and around the rigid bodies (Jim Lucas,2014). When the engineer designs some things such as airplane, car, bridge even a ball they also need to apply the principle of the aerodynamics into their design. The engineering that apply the principle of aerodynamic is Aerospace engineering. The primary field of engineering that concerned with the development of the spacecraft and aircraft is aerospace engineering. The aerospace engineering has two major branch which is Aeronautical engineering and Astronautical engineering while the Avionics engineering also same but the electronic side of aerospace engineering is deal with Avionics engineering. For Astronautical engineering, it mainly deals with aircraft that function outside the Earth's atmosphere while the Aeronautical engineering use the fundamentals of aerodynamic to construct aircraft that flying within the atmosphere of the Earth. Based on NASA, 2011 stated that the way of air moves around things is aerodynamics. The principles of aerodynamics describe how to fly an aircraft. Whatever travels that moves through the air responds to aerodynamics. A kite in the sky and a rocket

launching off the launch pad respond to aerodynamics. Aerodynamic also impacts to the automobiles, this is because air flows through them.

2.2 DRAG FORCE

Drag is the force that slow somethings down and it make the object hard to move, most of the aerodynamic force that apply to everything that moves by the air is drag. Drag is a mechanical force which is created when the object is contract and interaction with fluid (gas or liquid). The force field cannot generate the drag, in the sense of an electromagnetic or gravitational field. To generate the drag, there must be interaction between the fluid and the object. There is no drag because there is no fluid. The different in velocity between fluids and the solid object also can generate the drag. There must be a transition between fluid and object. If there is no drag, because there don't has motion. It is unchanged if the object flows through a static fluid or if the fluid flows through a rigid solid object (NASA 2015). Based on NASA, 2014 stated that the force that against an aircraft's motion through the air is drag. When the direction of the air is moving and it meets the solid object the drag is generated. In certain situations, drag is undesirable in automobile and aircraft because it takes force or power to elimate it (Jim Lucas, 2014). Drag have basic type which is Parasite drag and Induced drag. Parasite drag is that caused by the aeroplane's shape, materials and construction-type. If an aircraft has a rough surface, it will generate more parasite drag than the smooth surface. In the Parasite drag, there have three type of drag, for example Form drag, Interference drag and Skin Friction drag (Swayne Martin, 2015)

Due to the area and the shape of the object cross-section that passes through the fluid, the form drag is formed. If the object has the blunt shape and wide cross-sectional, it will have a large form drag, but if it has small cross-sectional area and a sharper shape, it will have a less form drag (Team Arcis, 2017)

Interface drag is generated if there have two or more airflows with different speeds interfere together. Next, this drag can also will occur from the interference of multiple aeroplane parts, which is because of the combination of airflow across the fuselage (Swayne.M, 2015).

Next, for the skin friction drag, it is created because of the friction between a body and a fluid. Skin friction drag is an aerodynamic resistance that generated by the aircraft because of contract of air with respond to the aircraft's surface. If the surface is smooth, it will have the less skin friction drag but if the surface is rough, it will create high skin friction drag (Team Arcis, 2017).

Induced drag is the second basic type of drag. It proves the physical reality, that is no mechanical device can be 100% effective. Therefore, the necessary work is obtained at the expense of any additional work that is loosed or lost in the system. If the efficient of the system is more, the loss is smaller. (John.S.D, 2016).

Besides that, there are many types of the drag, for example profile drag, pressure drag, wave drag, viscous drag, and ram drag.

Profile drag is defined as the total of the form drag and skin friction drag. Pressure drag is produced by more compact (pushed together) air particles on the front facing surface and more spread out on the back surface. This is happened if the air layers split and start to swirl away from the surface. This is called as turbulent flow.

Viscous drag is a force of resistance that applied on a moving body with a nontrivial dependence on speed. Wave drag is produced at the supersonic speed and transonic speed. The shock waves will produce due to the high speed of airflow. This will create an airflow disruption and this disturbance will raise the aircraft's drag, therefore, the wave drag is formed. Ram drag is the increasing of the velocity of the air entering the engine make the

loss of thrust in a turbojet and turbofan engine. Ram drag is the difference between net thrust and gross thrust.

2.3 AUTOMOTIVE AERODYNAMIC

Aerodynamic of automotive is the study of aerodynamic of vehicles that on the road. At the early of 1920s, the engineers want to reduce the aerodynamic drag when there at the high speeds so they start to think the automobile shape that can apply to this. The main goals of the engineer start to consider this automobile are reducing wind noise and drag, avoidance of unwanted lifting force and the minimization of noise pollution and other factors of high-speed aerodynamic instability. In this case, air is also considered a fluid. Regarding the G.lombardi, F.Beux and S.Carmassi, 2002, in the process of development the new vehicle configurations, the role of the aerodynamic is very important, because of its inherent difficulty, the designer requires more support and assistance to improve their options and discard unacceptable solutions. When the engines became more effective, the car can move faster compare to the less power engine, the automotive engineers found that the speed of the vehicle was greatly impeded by the wind resistance. Therefore, the racing cars and those trying to break the land speed record were the first vehicles to apply better streamlining or aerodynamics. Based on Kartikeya Akojwar, 2016, automotive aerodynamic is different compare to aircraft aerodynamic in several ways. Firstly, the characteristic shape of the vehicle is less streamlined compared to an aeroplane. Next, the vehicles such as van, car, bus and so on are mostly operate at the ground more than in the free air. Then, the aerodynamic drag varies as the square of the velocity, therefore the operating velocity are lower and the drag also greatly decrease. Fourth, road vehicles have less degree of freedom compare to the aircraft, and aerodynamic forces are relatively less influenced by their motion. Fifth, there

are some particular design restrictions for the passenger and commercial road vehicles, such as intend purpose, high safety standards and some regulations and certifications.

2.4 DRAG COEFFICIENT

Drag coefficient is a dimensionless quantity which is used in a fluid environment, such as air and water to measure the resistance or drag of an object. The object will have less aerodynamic or hydrodynamic drag because in the drag equation, there have a lower drag coefficient. A specific surface area is always correlated with the drag coefficient. Based on Heinz Heisler MSc., 2002 state that the indicator of the effectiveness of a streamline aerodynamic body shape is drag coefficient that can minimize the resistance of the air to vehicle's forward motion. The vehicle that with a streamline shape and a low drag coefficient can move easily through the surrounding viscous air with a minimum resistance while the vehicle that with a worse streamlining body profile, it will have the high drag coefficient, therefore when the vehicle is moving it will have a high air resistance. Based on NASA,2015, the number that used by the engineer or aerodynamicists to model all of the complicated form, flow conditions on the dependence of aircraft drag and inclination is drag coefficient. Basically, this equation is a rearrangement from the drag equation, which is the drag coefficient is solved in terms of the other variables. The drag coefficient Cd is formed by using the drag equation which is the drag coefficient is equal to the drag and divided by three variables, that is density ρ times with the Area and times with half of the square of the velocity. Equation below shows the equation of the drag coefficient.