WIND TUNNEL TEST: WHETHER BETWEEN SIMPLIFIED AND DETAILED MODEL SHOWS ANY DIFFERENCE IN COEFFICIENCE OF DRAG AND LIFT

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Laporan ini dikemukakan sebagai
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‘Saya /Kami* akui bahawa telah membaca
karya ini dan pada pandangan saya/kami* karya ini
adalah memadai dari skop dan kualiti untuk tujuan penganugerahan
Ijazah Sarjana Muda Kejuruteraan Mekanikal (Termal-Bendalir)’

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Tarikh :……………………………………

"Saya akui laporan ini adalah hasil kerja saya sendiri kecuali ringkasan dan petikan yang tiap-tiap satunya saya telah jelaskan sumbernya"

Tandatangan :……………………………..

Nama Penulis :……………………………

Tarikh :……………………………………

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ABSTRACT

This paper presents the verification to the fact that whether a simple model shows any different in terms of drag and lift value compared to the detail model when tested using wind tunnel. The models have been scaled down to 1:25 ratio and will be tested in atmosphere condition. Commonly, for wind tunnel testing, the model been used has been stripped and simplified for some reason, mostly because on a small model the difference is not significance. It is to proof whether the ignorance could affect the experiment or have any direct impact to the drag force and lift force value and at the same time giving difference in the Coefficient of Drag and Lift.

ABSTRAK

Kertas kajian ini adalah mengenai pembuktian untuk perbandingan sebuah model yang dipermudahkan keperinciannya ke atas sebuah model yang diperincikan.samada memberi perbezaan dari sudut nilai seretan dan angkatan apabila diuji menggunakan terowong angin. Model ini telah dikecilkan skalanya kepada 1:25 dan diuji dalam keadaan atmosfera. Biasanya, bagi ujian terowong angin, model yang digunakan telah dipermudahkan atas sebab tertentu, sebab utamanya serana pada model yang kecil perbezaannya tidaklah ketara. Ini adalah untuk pembuktian samada pengabaianakan mengganggu eksperimen atau mempunyai kesan terus kepada daya seretan dan daya angkatan dan pada masa yang sama member kesan terhadap pekali seretan dan angkatan.

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Re	=	Reynolds Number
ρ	=	Pressure
υ_s	=	Mean Fluid Velocity
L	=	Characteristic Length
μ	=	Dynamic Viscosity
Cd	=	Coefficient of Drag
Cl	=	Coefficient of Lift
A	=	Frontal area

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CHAPTER 1

INTRODUCTION

1.1 Problem Statement

Normally, in wind tunnel testing, the model that's been tested is a reduced detail model of the real prototype. Although the profile and basic shape remains the same but lots of bits have been removed such as side mirror, windscreen wiper, windscreen washer nozzle, panorama glass roof, headlight washing system and the antenna. This brings a question to whether those reduced detail would gave any different to the drag and lift value for the tested model. For the naked eye, these details will cause drag to the model especially can be seen clearly at side mirror and under wheel arch. This paper will proof the truth while the researchers keep reducing the detail on their model.

The reason for that is, for such a small model, this little detail would not bring much different to the drag value. The more important factor for the researcher for the model at this size is the shape and profile. As long as the profile is the same the drag value doesn't differ much. Furthermore the strength of the model will be compromise if such small detail included, as an example the antenna, side mirror and windscreen wiper. In wind tunnel testing with air speed exceeding 140km/h, the model should be stable and tough enough to hold itself on place without dismantling itself. A less likely reason is in the designing process where the researcher did not include the detail as it is troublesome and fussy. Designing process isn't the main process in doing paperwork for wind tunnel testing but still compulsory for building the model.

One of the problems is the sizing and the maximum speed of the wind tunnel. For this paperwork, a wind tunnel with test section area of 300mm x 300mm will be used. The maximum speed for this wind tunnel is more than 25m/sec(as stated by the manufacturer), translated to approximately 90km/h. the test area will only accept a model reduced in size reaching to 1:24 in ratio. This is base on real size SUV model, BMW X5 in this case, which is a huge vehicle. A bigger ratio prototype to model, especially more than 1:10 in size will not cause much different in drag when it comes to detailing. The same goes to the wind tunnel speed, as 90km/h wasn't enough to attain constant drag value or Cd. It is well known that drag came into effect when the vehicle is travelling more than 60miles/h about 97km/h. As the test suggest, 90km/h is not sufficient to make the drag force the main force acting on the vehicle. To make it worse, when the model has been scaled down to 1:24, the need for speed to match the prototype is 24 times more. As an example, a prototype vehicle moving 60km/h through air can be matched in wind tunnel by flowing air through the model at speed of 1440km/h, which is impossible to replicate in wind tunnel.

1.2 Objective

The objectives of the research are stated below:-

1) To measure the value of drag and lift for simplified BMW X5 model
2) To measure the value of drag and lift for detailed BMW X5 model
3) To compare both value of drag and lift for detailed and simplified model
4) To determine whether the simplified model shows reduce value of drag

1.3 Scopes

The type of vehicle used for this research is BMW X5, an SUV. The reason for the choosing is the size of the vehicle which is bigger and has more details than most vehicles on the road to make the research which is around drag, more effective. At the same time it is smaller than, say a truck, which when scaled down to wind tunnel test section size will raise the ratio to a huge number, which will affect the ability to match the similarity of the model and the prototype. Out of the technical side, BMW X5 is quite a popular model, so gaining data and specification from internet are easy as the information are enormous. For the purpose of designing and building the model, the dimension and a figure showing the detail on the vehicle were needed.

The wind tunnel that will be used is Essom model MP 130D Subsonic Wind Tunnel. With 300mm x 300mm test section, a model tested should be approximately 90mm x 90mm, to get around 9% of blockage. This limits the model of the SUV to be around 1:24 scale maximum. As the air used is the same in both real and model condition, the pressure and its dynamic viscosity is the same. To get the matching Reynolds Number for 1:24 scale model, we have calculated that, for 60km/h in real situation of an SUV, the wind tunnel needed to move air at speed up to 1440km/h @ 400m/s. The Essom wind tunnel model MP 130D capable of providing air at speed up to 30m/sec (108km/h) by two downstream fans.

Both drag and lift value will be taken during the test session for both of the model. The model will be set with zero angles of attack and tilt for pure drag force direct from the front of the model and flows straight to the back. It will be tested on multiple wind speed ranging from 15m/s to 35m/s, with the air in atmosphere condition.

Rapid prototyping machine will be used to build both of the models while the designing process will be done using Solid Works software. The different for the model is the detailed version has an added detail such as hollow for front windscreen, side windows and sunroof. Apart from that, there’s side mirror and under wheel arch room for the detailed model.

CHAPTER 2

LITERATURE REVIEW

2.1 Drag Force

Drag is a mechanical force. It is generated by the interaction and contact of a solid body with a fluid (liquid or gas). It is not generated by a force field, in the sense of a gravitational field or an electromagnetic field, where one object can affect another object without being in physical contact. For drag to be generated, the solid body must be in contact with the fluid. If there is no fluid, there is no drag. Drag is generated by the difference in velocity between the solid object and the fluid. There must be motion between the object and the fluid. If there is no motion, there is no drag. It makes no difference whether the object moves through a static fluid or whether the fluid moves past a static solid object.

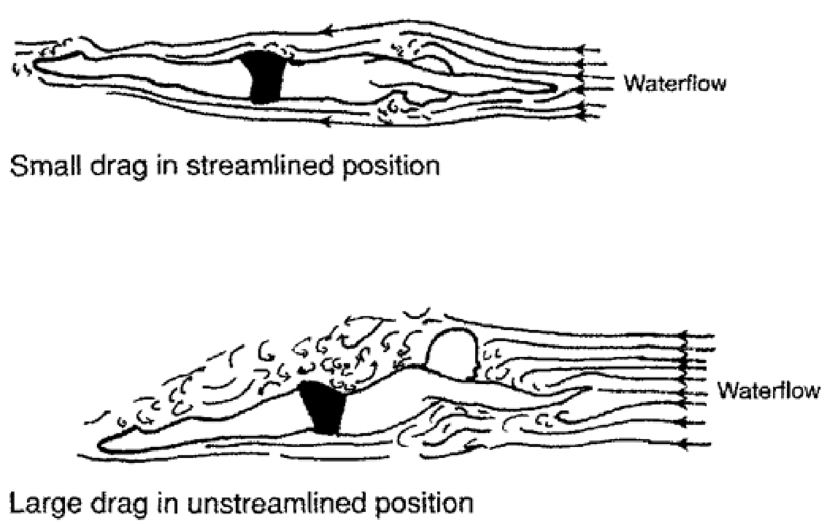

Fig 2.1 Causes of Drag

Drag is a force and is therefore a vector quantity having both a magnitude and a direction. Drag acts in a direction that is opposite to the motion of the aircraft. Lift acts perpendicular to the motion. There are many factors that affect the magnitude of the drag. Many of the factors also affect lift but there are some factors that are unique to aircraft drag.

Think of drag as aerodynamic friction, and one of the sources of drag is the skin friction between the molecules of the air and the solid surface of the aircraft. Because the skin friction is an interaction between a solid and a gas, the magnitude of the skin friction depends on properties of both solid and gas. For the solid, a smooth, waxed surface produces less skin friction than a roughened surface. For the gas, the magnitude depends on the viscosity of the air and the relative magnitude of the viscous forces to the motion of the flow, expressed as the Reynolds number. Along the solid surface, a boundary layer of low energy flow is generated and the magnitude of the skin friction depends on conditions in the boundary layer.

Think of drag as aerodynamic resistance to the motion of the object through the fluid. This source of drag depends on the shape of the aircraft and is called form drag. As air flows around a body, the local velocity and pressure are changed. Since pressure is a measure of the momentum of the gas molecules and a change in momentum produces a force, a varying pressure distribution will produce a force on the body. We can determine the magnitude of the force by integrating (or adding up) the local pressure times the surface area around the entire body. The component of the aerodynamic force that is opposed to the motion is the drag; the component perpendicular to the motion is the lift. Both the lift and drag force act through the center of pressure of the object.

2.2 Lift Force

The force that pushes an object up against the weight is lift. On an airplane or a bird, the lift is created by the movement of the air around the wings (the lift created by the body or tail is small). The figure below shows two streamlines about a typical airfoil (or wing); one travels over the top of the airfoil, the other moves underneath it.

If two particles were released from the same point at the same time, one on each streamline, they would start out moving together. As they approach the front of the airfoil, however, their velocity will start to change. Due to the shape of the airfoil, the air moves faster over the top of the airfoil than it does on the lower surface. The faster air leads to a lower pressure (from Bernoulli's Law) on the upper surface.

A smaller force, on top, will be pointed downward, and a larger force (underneath) will be pointing upwards. When the two forces are combined, the net force is lift, which is directed upwards.

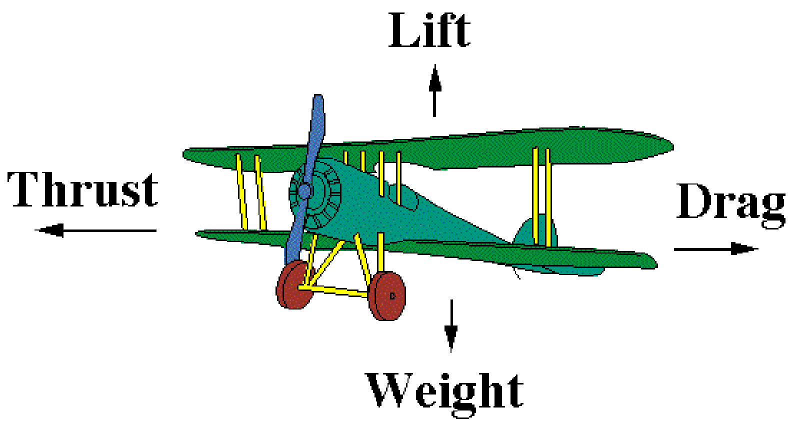

Fig 2.2 Lift and Drag on Airplane

In order to generate lift with a symmetric airfoil, the airfoil must be turned (tilted) with respect to the flow, so that the upper surface is "lengthened" and the lower surface is "shortened".

This "tilting against the airflow" is called angle of attack. It can be used for either cambered or symmetric wings. This is why an airplane rotates slightly at takeoff; the pilot is increasing the angle of attack to generate more lift. If the angle of attack is doubled, the lift doubles. There is a limit to how much lift can be generated, however. The angle of attack can be increased to a point where the net lift force drops drastically.

Airflow deflection is another way to explain lift. To understand the deflection of air by an airfoil let's apply Newton's Third Law of Motion. The airfoil deflects the air going over the upper surface downward as it leaves the trailing edge of the wing. According to Newton's Third Law, for every action there is an equal, but opposite reaction. Therefore, if the airfoil deflects the air down, the resulting opposite reaction is an upward push. Deflection is an important source of lift. Planes with flat wings, rather than cambered, or curved wings must tilt their wings to get deflection.

Another way to increase lift on a wing is to extend the flaps downward. This again lengthens the upper surface and shortens the lower surface to generate more lift.

The velocity of the freestream air (actually of the airplane) is the most important element in producing lift. If the velocity of the ariplane is increased, the lift will increase dramatically. If the velocity is doubled, the lift will be four times as large.

The generation of lift can be found elsewhere. Race car designers use airfoil-like surfaces to generate negative lift, or downward-directed force. This force, combined with the weight of the race car, helps the driver maintain stability in the high-speed turns on the race track.

2.3 Reynold Number

In fluid mechanics, the Reynolds number may be described as the ratio of inertial forces ($v_s\rho$) to viscous forces (μ/L) and, consequently, it quantifies the relative importance of these two types of forces for given flow conditions.

$$Re = \frac{\rho v_s^2/L}{\mu v_s/L^2} = \frac{\rho v_s L}{\mu} = \frac{v_s L}{\nu} = \frac{\text{Inertial forces}}{\text{Viscous forces}}$$

It is one of the most important dimensionless numbers in fluid dynamics and is used, usually along with other dimensionless numbers, to provide a criterion for determining dynamic similitude. When two geometrically similar flow patterns, in perhaps different fluids with possibly different flowrates, have the same values for the relevant dimensionless numbers, they are said to be dynamically similar, and will have similar flow geometry.

It is also used to identify and predict different flow regimes, such as laminar or turbulent flow. Laminar flow occurs at low Reynolds numbers, where viscous forces are dominant, and is characterized by smooth, constant fluid motion, while turbulent flow, on the other hand, occurs at high Reynolds numbers and is dominated by inertial forces, which tend to produce random eddies, vortices and other flow fluctuations.

CHAPTER 3

METHODOLOGY

3.1 Designing and Building the Model

Using the real dimension from BMW X5 broacher, the vehicle outline is duplicated by printing it on a graph paper to measure the dimension on scale. The reason for this is, not every dimension on the X5 body are given, such as the maximum width of the car including the side mirror when opened, the size of the wheel arch, and the detail of the roof spoiler. The method with measuring the dimension individually and in more detail, will get the best transition of real/prototype to model detail with much less difference between them. Then it’s up to scaling process where every square on the graph paper is calculated to give the exact measurement as on the prototype. The overall profile for the vehicle is sketch roughly to get the idea of flowing curve on the body of the vehicle.

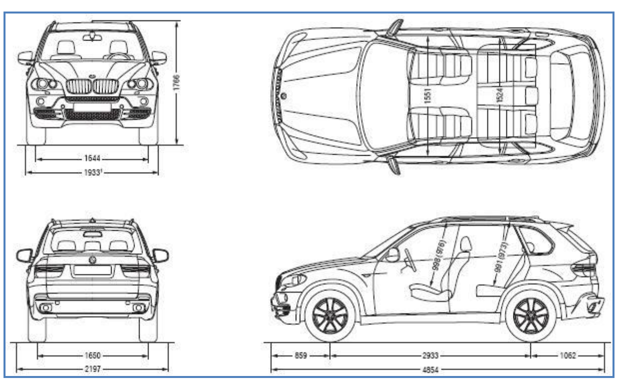

Fig. 3.1 BMW X5 dimension

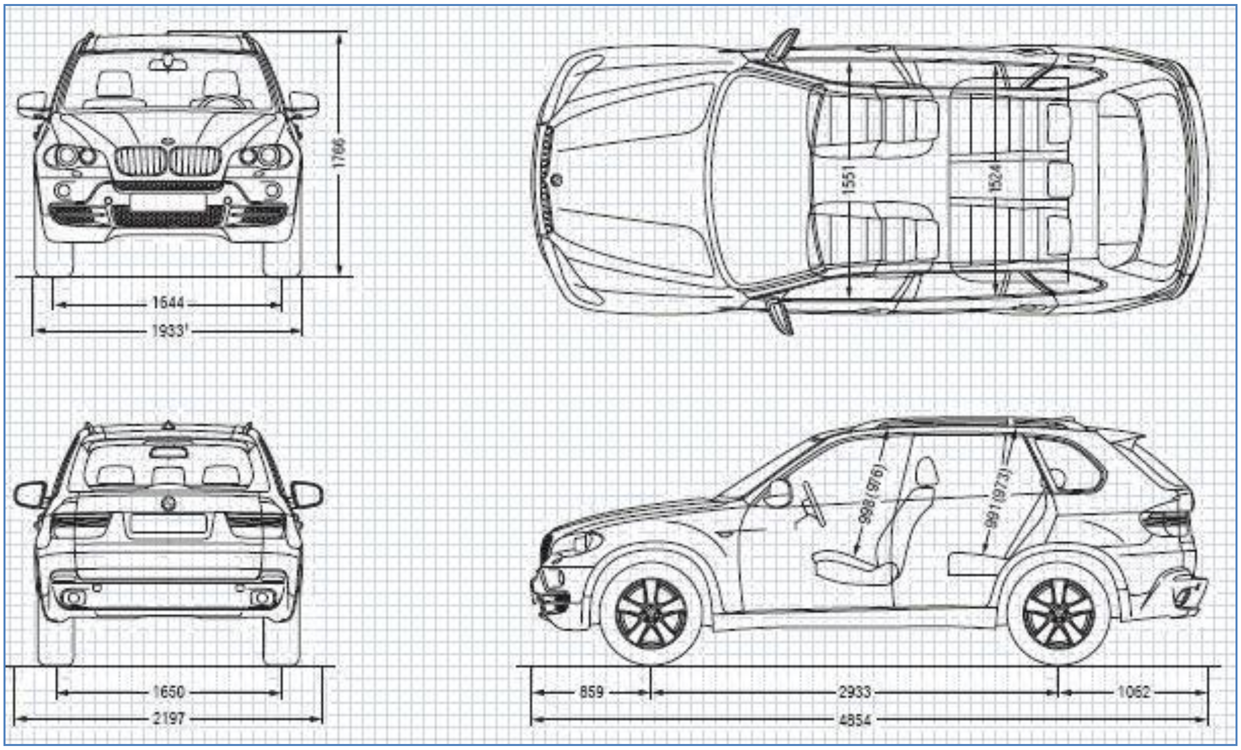

Fig. 3.2 BMW X5 dimension on graph paper

After obtaining the entire required dimension, Solid Works 2003 software will be used to design it from a 2D picture into a 3D model. Solid Works have a simple interface for 3D modeling suitable for beginners in building 3D design. Every square estimated for the size and shape of the vehicle body, and then transferred carefully to the program. The shape of the front profile such as bonnet, windscreen, tyre size, and front bumper were designed as similar as possible as this is the crucial part in wind tunnel testing. For both of the model, small curve such as on the fender and rear portion of the vehicle have been eliminated. The detailed model receives extra stuff such as wheel arch, side mirror, windscreen, and side windows. This design later will be transferred to a prototyping machine which will be used to building the solid model.

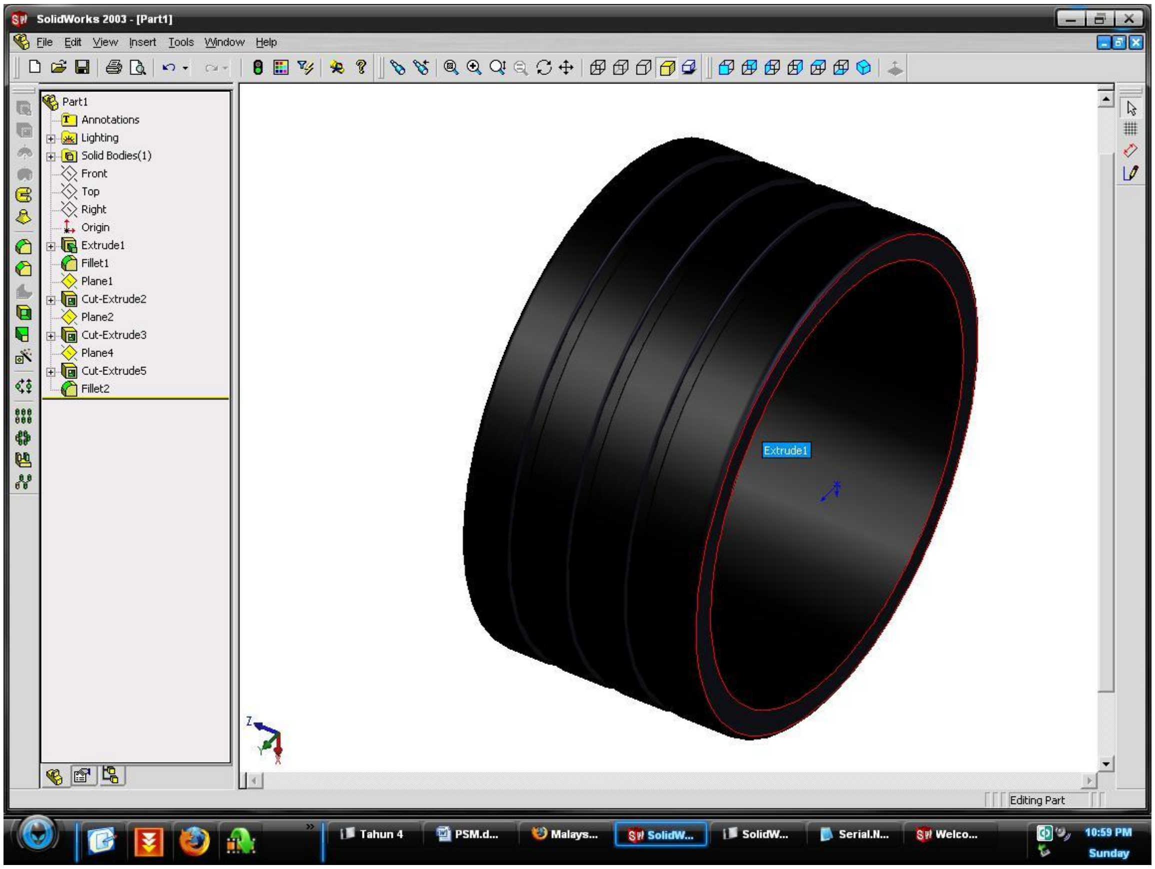

Fig. 3.3 Solid Works 2003

Building the solid model requires some sort of a prototyping machine which will convert the data from a designing program into a convertor which will send the information to the prototyping machine. It is called the Rapid Prototyping Machine manufactured by Stratasys. The model will be made from ABS resin. This is a type of thermoplastic is hugely used for manufacturing a model where the advantage of the material is no warpage, shrinkage, or moisture absorption.

Fig 3.4 A model tested in wind tunnel

To mount the models onto wind tunnel, a screw needs to be attached to the bottom of the model. The thread on this screw will be mounted on the pillar in the test section of the wind tunnel. The models need to be drilled for the screw to go through and will be fixed in place using epoxy and glue.

3.2 Testing and Collecting Data

The method of testing the model for this research is using wind tunnel facilities produced by Essom called the MP 130D Subsonic Wind Tunnel, capable of providing air at speed up to 30m/sec (108km/h) by two downstream fans. It comes with three electric components to measure lift and drag. The value of drag and lift shows directly