DESIGN AND ANALYSIS A NEW SPOILER FOR UMP HEV USING CFD

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ABSTRACT

This thesis presents the design and develops new rear spoilers to overcome a drag force that is created because of low pressure zone at the rear back. With the new design of rear spoiler for the Proton Iswara Hybrid Electrical Vehicle (HEV) UMP, the performance of the car had increased from the aspect of acceleration and also from the aspect of handling of the car, the controlled speed of this research is from 80 km/hr to 110 km/hr. The design of rear spoiler is based on the type of the car used, therefore aerodynamic shape of the body and the point of the rear spoiler is important in this research. In this research 2 spoilers have been choosing that are squareback and fastback rear spoilers. According to that reason, low pressure zone will be annihilated slowly if one of the rear spoilers is put at the rear back of the car. Refer to data testing obtained, using squareback spoiler will reduce more low pressure zone than using fastback spoiler. Based on the analysis, the suitable place to mount the rear spoiler is at the point where squareback spoiler is mounted and it synchronized with the shape of the Proton Iswara HEV. It will give additional information to the performance car researcher to continue on this research thoroughly about the effect of spoiler on any HEV car and eventually to Malaysia's first HEV race car. In the future, this factor will give benefit to the Malaysia car developer especially HEV car developer.

ABSTRAK

Tesis ini telah merekabentuk spoiler belakang baru bagi mengatasi masalah kewujudan daya tarikan yang wujud di zon belakang kereta. Dengan adanya spoiler belakang ini juga prestasi kereta Proton Iswara jenis Hybrid Electrical Vehicle (HEV) UMP ini akan meningkat dari segi kelajuan dan pemanduan semasa berada di dalam kelajuan 80 km/sejam hingga 110 km/sejam. Rekabentuk spoiler belakang ini berpandukan jenis kereta dan faktor-faktor seperti bentuk yang aerodinamik dan kedudukan spoiler belakang itu. Di dalam kajian ini dua buah spoiler belakang telah dibentuk iaitu jenis 'squareback' dan jenis 'fastback'. Menurut kajian ini, dengan kehadiran salah satu spoiler belakang ini masalah kewujudan zon tekanan tinggi di belakang kereta dapat dikurangkan dengan banyaknya. Daripada data ujikaji baru ini, dengan kehadiran spoiler jenis 'squareback' dapat mengurangkan zon tekanan tinggi lebih banyak berbanding spoiler jenis 'fastback'. Berpandu kepada analisa, kedudukan spoiler yang strategik adalah pada kedudukan spoiler jenis 'squareback' berbanding spoiler jenis 'fastback'. Ini adalah disebabkan rekabentuk kereta Proton Iswara HEV yang sesuai dengan spoiler jenis 'squareback' ini. Ini memberikan satu isyarat kepada para pengkaji berkaitan prestasi kereta untuk meneruskan kajian dengan lebih mendalam terhadap kesan spoiler belakang pada kereta jenis HEV di Malaysia seterusnya untuk kereta lumba jenis HEV keluaran Malaysia. Semoga pada masa akan datang, faktor ini akan mendatangkan nilai yang mendalam terhadap bidang kenderaan terutamanya jenis HEV.

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LIST OF SYMBOLS

C_d	Drag Coefficient
V	Velocity
Re	Reynold Number
v	Viscosity
τ	Shear Stress
u	Gradient
τS	Surface Shear Stress
F_D	Surface Drag Force
S	Cross Sectional Area
W	Watt
V	Volt

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CHAPTER 1

INTRODUCTION

1.1 Spoiler

A spoiler is an aerodynamic device attached to an automobile whose intended design function is to 'spoil' unfavorable air movement across a body of a car in motion. This can result in improved vehicle stability by decreasing lift or decreasing drag that may cause unpredictable handling in a car at high speed. Spoilers are often fitted to race and high-performance sports cars, although they have become common on passenger vehicles, as well. Some spoilers are added to cars primarily for styling purposes and have either little aerodynamic benefit or even make the aerodynamics worse.

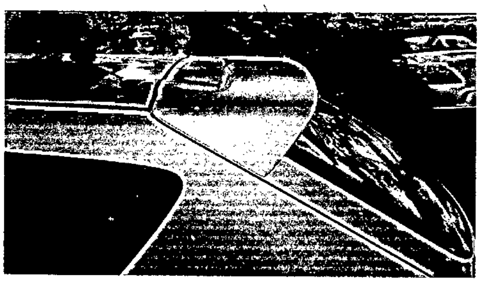

Figure 1.1: The rear spoiler

Spoilers are often incorrectly confused with, or even used interchangeably with wings. Automotive wings are devices whose intended design is to actually generate downforce as air passes around them, not simply disrupt existing airflow patterns.

Spoilers generally work by disrupting the airflow going over a car. This disruption has the primary purpose of reducing the amount of lift naturally generated by the shape of the car. The result is negative force occurred at the below part of the car and it will increase the contact between the tire and the road surface, thereby increasing traction. This increase in traction allows a vehicle in motion to brake, turn, and accelerate with more stability. Additionally, this is accompanied by an increase in aerodynamic drag like in Figure 1.2.

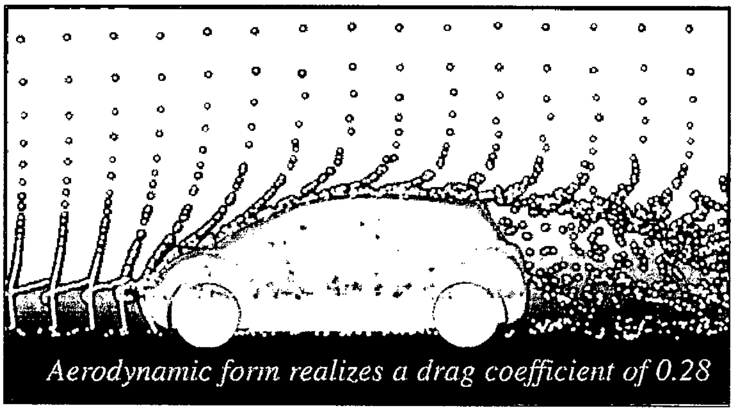

Figure 1.2: Aerodynamic flow around the car

In nearly all cases, drag increases as the speed of the vehicle increases. Thus, some spoilers that are effective at very low speeds often generate excessive drag at high speeds, and spoilers that work well at high speeds are often ineffective while moving slowly.

However, modern passenger vehicles, which are mostly front-wheel drive, have debatable gains from any theoretical increase in traction that might be provided by a rear spoiler simply because of the low speeds the vehicle reaches on public roads. Some spoilers are of a purely cosmetic design & are used only to enhance the vehicles appearance.

Sports cars are most commonly seen with spoilers, such as Ford Mustang, Subaru Impreza WRX, and Chevrolet Corvette. Even though these vehicles typically have a more rigid chassis and a stiffer suspension to aid in high speed maneuverability, a spoiler can still be beneficial. This is because, at high speed, the airflow over the top of the car tends to create a low pressure area towards the rear which literally lifts the back end of the car; reducing traction and increasing instability (see Bernoulli Effect).

The spoilers on what are viewed as "serious" sports cars, designed to different requirements than more pedestrian cars, are designed to reduce lift and in a few cases even providing a modest amount of downforce.

Another design goal of a spoiler is to reduce drag and increase fuel efficiency. Many vehicles have a fairly steep downward angle going from the rear edge of the roof down to the trunk or tail of the car. Air flowing across the roof tumbles over this edge at higher speeds, causing flow separation. The flow of air becomes turbulent and a low-pressure zone is created, increasing drag. Adding a spoiler at the very rear of the vehicle makes the air "see" a longer, gentler slope from the roof to the spoiler, which helps to eliminate flow separation. This decreases drag, increases fuel economy, and helps keep the rear window clear.

1.2 Problem Statement

- The problem for UMP Hybrid Electrical Vehicle (HEV) Proton Iswara car is when it is at speed at the range of 80-110 km/hr the airflow across the roof will shear and create flow separation. Then low pressured zone will created and increase drag. Thus, the rear spoiler is to eliminate flow separation and decreases drag.
- Determine the suitable point for the spoiler which will reduce more low pressure zone to get effective car performance.

1.3 Project Objectives

- To design a spoiler to reduce drag force at car rear
- To analyze the spoilers using CFD simulation

1.4 Project Scopes

- This project is to design the prototype spoiler
- The spoiler is for UMP HEV rear windscreen area only
- Analysis of the air flow at the spoiler using CFD simulation
- Visualize the simulation result compared to the without the spoiler

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The purpose of this chapter is to explain about the principles of aerodynamics especially on road vehicle. Chapter 2 also discusses about principle of the road vehicle's aerodynamic which can be understand through fluids dynamics studies and the previous researches on effect of rear spoiler aerodynamic flow . In addition, there is also some information about Hybrid Electrical Vehicle (HEV), it is about types of HEV and some requirements to build HEV.

Beside that, there is also some information about Computational Fluid Dynamics (CFD) and it focuses more on the CFD software. There is also information about rear spoiler and some research about rear spoiler effect the aerodynamic flow at rear back region. This mechanism will be discussing details in Chapter 2. Figure 2.1 shows the overview diagram for Chapter 2

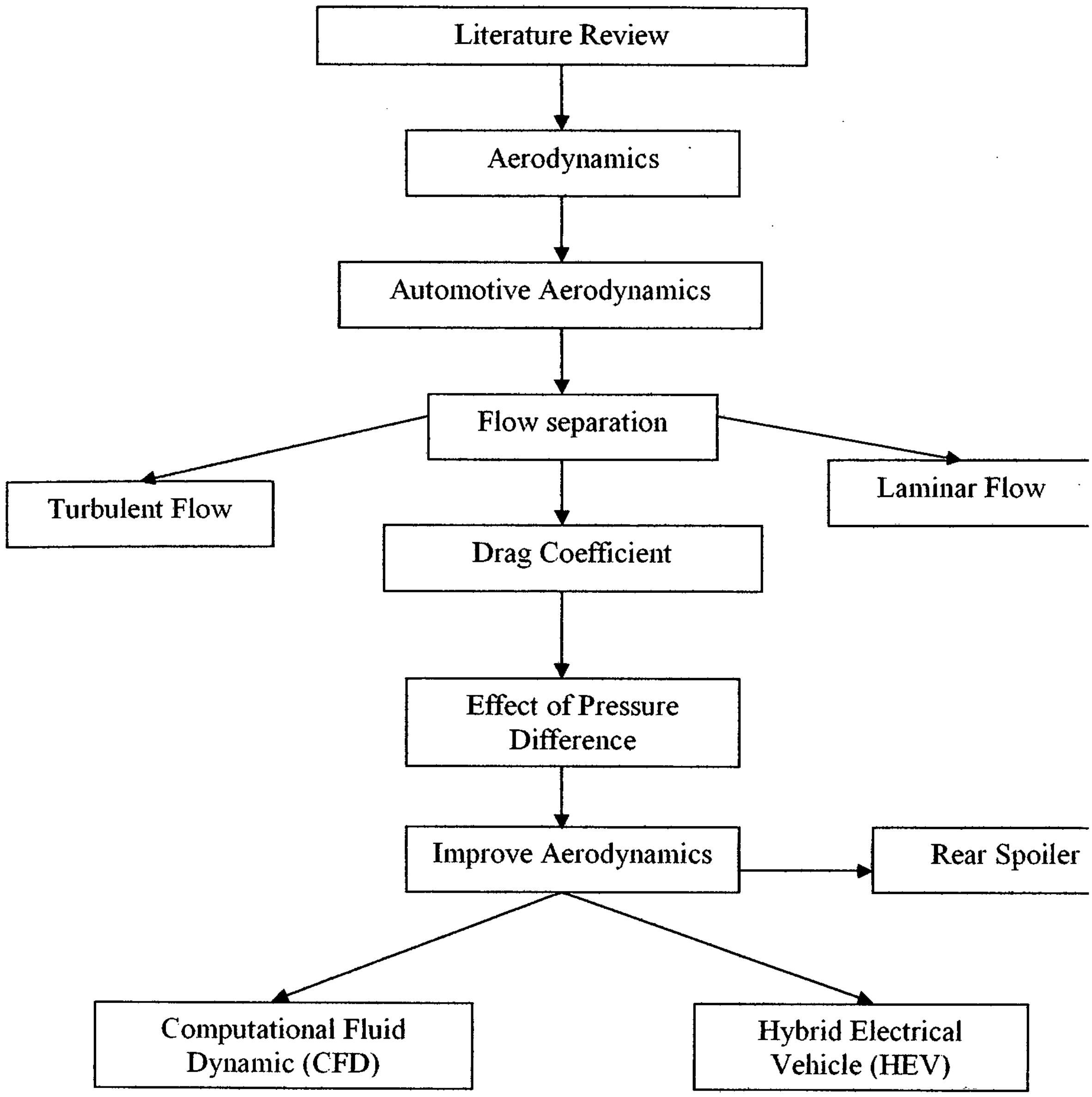

Figure 2.1: Overview diagram for literature review

2.2 Aerodynamics

2.2.1 Definition

Aerodynamics is a branch of fluids mechanics which study about the forces generated on a body in a flow [10]. The aerodynamics usually involves calculation in the properties of the flow such as pressure, velocity, temperature, density as a function of space and time. In order to calculate or approximate the forces and moments acting on the bodies in the flow, we must understand the pattern of the flows.

2.2.2 Classes of Aerodynamics Problems

Aerodynamic problem occur in many classes. The studies of flow around solid objects of various shapes is called the External Aerodynamics, for example evaluating the lift and drag on an airplane and the shock waves that form in front of the nose of a rocket. The Internal Aerodynamic then is the studies about the flow through passages in solid objects such as study of the airflow through a jet engine or through an air conditioning pipe.

The second classification of aerodynamic is the ratio of the characteristic flow speed to the speed of sound. A problem is called subsonic if all the speeds in the problem are less than the speed of sound, transonic if speeds both below and above the speed of sound are present, supersonic when the characteristic flow speed is greater than the speed of sound, and hypersonic when the flow speed is much greater than the speed of sound.

The third classification is concerned about the influence of viscosity. Some problem involve only negligible viscous effects mean that the viscous can be considered not exist. This problem called inviscid flows meanwhile the flows which viscosity cannot be neglected called viscous flows.

2.2.3 The Dynamics of Air Flow and Its Effects on Automobiles

What actually causes lift? To some degree, body panel shape and to a larger extent, air that passes through the opening of the grille and under the front end sheet metal. At speed, this massive air stream builds up tremendous pressure under the hood where it is forced to exit rearward, below the chassis, resulting in body lift.

We can effectively counter lift by limiting the amount of air flowing under the front sheet metal with the use of "dams" and by down-sizing the opening in the grille. Any remaining lift may be countered by applying down force using additional aerodynamic "spoiler" devices at the front and rear of the vehicle.

2.2.4 Automotive Aerodynamics

Automotive aerodynamics is the study of the aerodynamics of road vehicles [9]. This study involves reducing drag, reducing wind noise and preventing undesired lift forces at high speed. It is also important to produce required downwards aerodynamics force to improve traction and cornering abilities in some class of racing car.

To have a small surface, the aerodynamic automotive will integrate the wheel and lights. To be streamlined, it does not have shape edge crossing the wind stream and feature a sort tail called fastback. The aerodynamic design will have a flat and smooth to produce desirable downwards forces. The air rams into the engine bay for used of cooling, combustion, passengers, reaccelerated by a nozzle and then ejected under the floor.

Automotive aerodynamic is much different from the aircraft aerodynamic such as road vehicle shapes is bluff, vehicle operates very close to the ground, operating speed lower, the ground vehicle has fewer degrees of freedom and its motion is less affected by aerodynamic forces.

Total Aerodynamic drag = Cd multiplied by the frontal area. The width and height of curvy cars lead to gross overestimations of frontal area [9].

2.3 Flow Separation through a Road Vehicle

2.3.1 Introduction

In determining and observe the aerodynamic of road vehicles it is important to know the air flows through the vehicle's body. Basically, air flows around car's body can be divided into two simple type which are laminar and turbulent flows. Both layers can be describing in the boundary layer development on car's surface.

2.3.2 Flow Separation Process

In addition to turbulence boundary layer also has another phenomenon called flow separation Figure 2.2 that induces pressure drag to a body. It is caused when the pressure at the rear surface is smaller than the forward surface and the imbalance of the pressure causes the drag due to separation. This can be seen on an aerofoil surface again by considering flow from leading edge to trailing edge

Flow separation is bad because it leads to a larger wake and less pressure on the rear surface which reducing pressure recovery. To avoid bad flow separation, the transitions of the airflows from roof to the rear window need to be smoothen. The bad separation also can create more drag. The aerodynamic will be much effective if the flows working in clean air (laminar flow). By improving the aerodynamic of the car can reduce the boundary layer thickness thus avoids worst flow separations.

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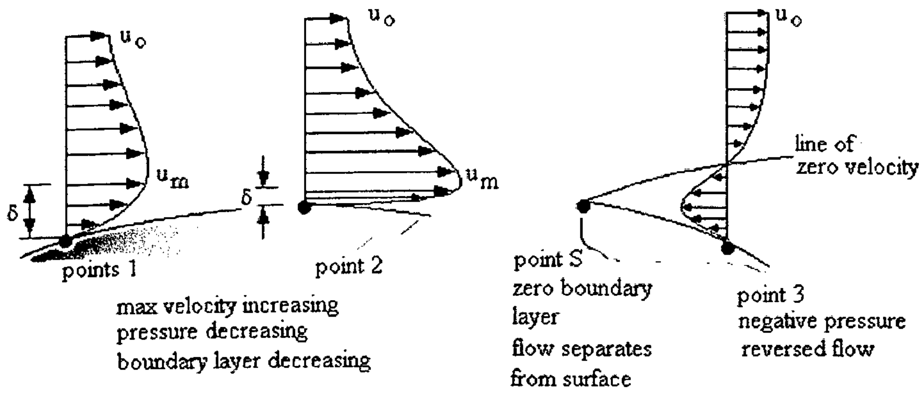

Figure 2.2: Flow separation process

2.3.3 External Flow

The external flow around a vehicle is shown in Figure 2.4. In still air, the undisturbed velocity V: is the road speed of the car. Provided no flow separation takes place, the viscous effects in the fluid are restricted to a thin layer of a few millimeters thickness, called the *boundary layer* Figure 2.3, beyond this layer the flow can be regarded as inviscid, and its pressure is imposed on the boundary layer.

Within the boundary layer the velocity decreases from the value of the inviscid external flow at the outer edge of the boundary layer to zero at the wall, where the fluid fulfills a no-slip condition. When the flow separates (Figure 2.4 shows separation at the rear only) the boundary layer is "dispersed" and the flow is entirely governed by viscous effects.

Such regions are quite significant as compared to the characteristic length of the vehicle. At some distance from the vehicle there exists no velocity difference between the free stream and the ground. Therefore, in vehicle-fixed coordinates, the ground plane is a stream surface with constant velocity V:, and at this surface no boundary layer is present. This fact is very important for the simulation of flows around ground vehicles in wind tunnels.

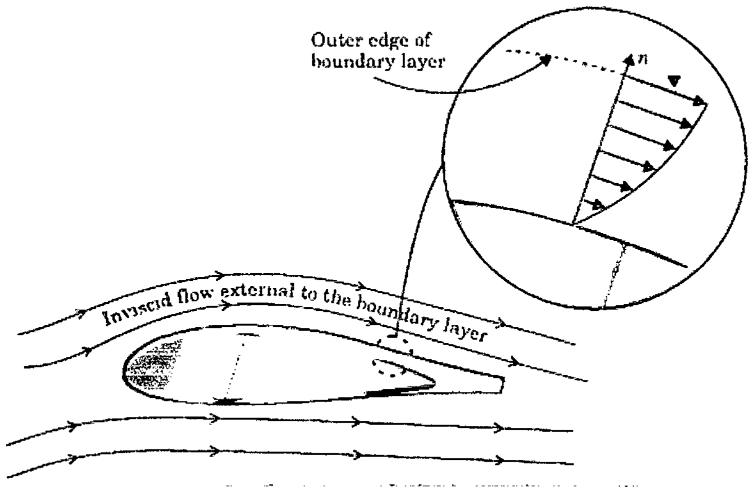

Figure 2.3: Boundary layer

The boundary layer concept is valid only for large values of

$$Re_l = (V_\infty l/\nu) > 10^4 \qquad [1]$$

This dimensionless parameter is called the Reynolds number. It is a function of the speed of the vehicle V_∞, the kinematic viscosity ν of the fluid, and a characteristic length l as defined in Fig. 2.4. The character of the viscous flow around a body depends only on the body shape and the Reynolds number. For different Reynolds numbers entirely different flows may occur for one and the same body geometry. Thus the Reynolds number is the dimensionless parameter which characterizes a viscous flow.

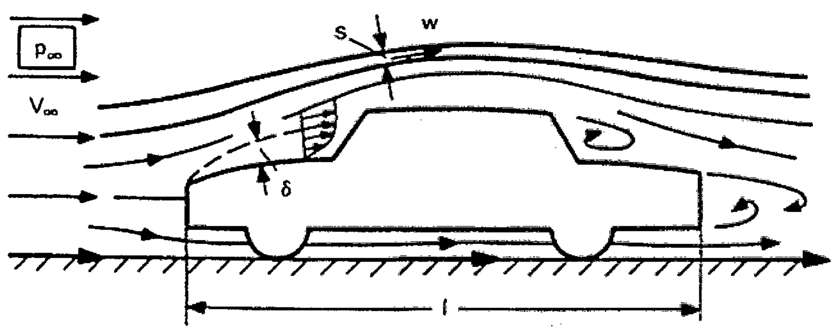

Fig. 2.4: Flow around a vehicle (schematic).

Flows around geometrically similar bodies are called "mechanically similar" if the Reynolds number according to Eq. (1) has the same value for different body lengths l, air speeds V_∞, and fluid properties ν .

Mechanical similarity is the basis for model tests. The results of the test on scale models in terms of dimensionless aerodynamic coefficients are the same as for the original vehicle if Reynolds numbers are the same.

2.3.4 Boundary Layer Development

In physics and fluid mechanics, the boundary layer is that layer of fluid in the immediate vicinity of a bounding surface [8]. For flow over any surface, there will always exist a velocity boundary layer and hence surface friction [4]. On a body of a car, this surface friction could create drag force that could effect the aerodynamic of the car. To introduce the concept of boundary layer, consider a flow through a plate in Figure 2.5.

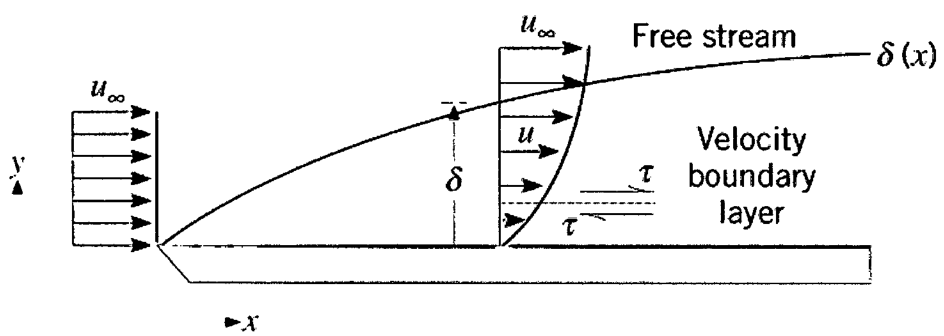

Figure 2.5: Flow through a plate

Boundary layer velocity occurs when a consequence of viscous effects associated with relative motion between a fluid and a surface. A region of the flow characterized by shear stresses, τ and velocity, u gradients. A region between the surface and the free stream whose thickness increases in the flow direction. The surface shear stress, τs provides the surface drag force, F_D. The surface friction is strongly depending on the flows condition weather laminar or turbulent flows. On car's surface, the boundary layer becomes thicker towards the rear of the car. The thicker the boundary layer, the more easily airflow will separate from the body, leading to turbulent flow [4].