THE STUDY OF AERODYNAMIC EFFECT ON SPOILER

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ABSTRACT

A spoiler is an aerodynamic device attached to an automobile to increase down force, or in other word improving road holding. In this study, an external flow analysis on a 1:5 scale model Formula One (F1) spoiler was carried out using wind tunnel facility. Several important features can be found on the model such as balance mounting (for force measurement), pressure tapping (for pressure measurement) and wool turf (for flow observation). The results from wind tunnel test can be divided into two, quantitative and qualitative. Quantitative values refer to the coefficient of drag, C_D, coefficient of lift, C_L and coefficient of pressure, C_P around the model. While qualitative values refer to the flow visualization through the wool turf observation during the test. Other than that, the relationship between those values was revealed to give better understanding of the aerodynamic effect on the spoiler.

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ABSTRAK

'Spoiler' atau pengacau merupakan satu alat aerodinamik yang dipasang pada sesebuah kenderaan untuk mengurangkan daya angkatan, atau dengan kata lain menambahkan pegangan tayar pada jalan raya. Dalam kajian ini, analisis aliran angin telah diakukan pada model spoiler kereta formula satu (F1) berskala 1:5 dengan menggunakan kemudahan terowong angin. Terdapat beberapa ciri penting pada model tersebut antaranya 'balance mouting' (untuk pengukuran daya), ' pressure tapping' (untuk pengukuran tekanan) dan 'wool turf' (untuk pemerhatian aliran angin). Keputusan yang didapati pada terowong udara dapat dibahagikan kepada dua iaitu kuantitatif dan kualitatif. Nilai kuantitatif mewakili pakali daya seret, pekali daya angkat dan pekali daya tekanan. Manakala, nilai kualitatif merujuk kepada gambaran aliran angin dalam pemerhatian aliran angin semasa ujian terowong angin dijalankan. Selain itu, hubungan antara kedua – dua nilai kuantitatif dan kualitatif dinyatakan untuk memberi kefahaman terhadap kesan aerodinamik pada model spoiler yang digunakan.

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LIST OF SYMBOLS

SYMBOL	DEFINITION
F	Force, N
D	Drag, N
L	Lift, N
ρ	Density, kg/m^3
A	Area, m^2
Re	Reynolds number
V	Velocity, m/s
L	Characteristic length, m
M	Mach number
μ	Viscosity,
C_D	Drag coefficient
A_F	Characteristic area of vehicle, m^2
V_r	Speed of the vehicle relative to the wind, m/s
C_L	Lift coefficient

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R_d	Drag resistance
R_L	Lift resistance
α	Angle of attack
C_P	Pressure coefficient
α	Flow coefficient depending on the Reynolds Number, Re which may be taken as equal to 0.99 approximately
ΔP	Differential pressure of the Pitot tube in relation with atmospheric, $Pa = N/m^2 = kg/ m^2s^2$

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CHAPTER 1

INTRODUCTION

In general, aerodynamics is simply how air flows over, under and sideways of a vehicle, whether it is a car, truck or airplane. The main concerns of automotive aerodynamics are reducing drag and wind noise, improving vehicle stability and preventing undesired lift forces at high speeds. For some classes of racing vehicles, it may also be important to produce desirable downwards aerodynamic forces to improve traction and thus cornering abilities.

Spoilers generally work by disrupting the airflow going over a car. This disruption has two primary effects which are reducing the amount of lift naturally generated by the shape of the car and increase the down force of the vehicle. The result of these two effects is the same: increasing the force between the tire and the road surface, thereby increasing traction. This increase in traction allows a vehicle in motion to brake, turn, and accelerate more aggressively without tire slippage. Additionally, this is accompanied by an increase in aerodynamic drag. In this study, the spoiler that has been used is rear spoiler. The rear spoiler (also known as wing spoiler) is an airfoil suspended above the body of the vehicle.

The study is based on Formula One (F1) rear spoiler. Compared to the passenger car spoiler, the Formula One car spoiler consists of three major elements which are three horizontal aerodynamic elements and two vertical elements that support these three

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aerofoils. The upper element of aerofoil will produce the upper force and left the vacuum at the rear of the aerofoil. This vacuum area (low pressure area) will produce the down force to the track. When the air moved from the lower aerofoil to the upper, the air from lower aerofoil attaches the upper wing before it become fully laminar. The process is called reattachment. The reattachment happened to two lower aerofoil and ends at the highest. The reattachment produced large down force to the wing. The rear spoiler produced to 1/3 from the total force of the down force. The larger surface area produced bigger down force and bigger drag. The surface area can be added with adding the elements of aerofoil.

This Thesis report is concerned with an investigation in the aerodynamic effect of spoiler in high speed. A clear definition of the aims and objectives will be provided and in the context of this definition and an explanation of the design methodology will begin.

The investigation will start by focusing upon the basic concept of aerodynamic and the effects of spoiler (rear wing). The wind tunnel testing and application to the spoiler model (1:5) will be considered and this will form the basis for the rest of the information provided in the literature review. Conclusions will then be drawn from the investigation and recommendations will be made for future work that could be carried out in support of this work.

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1.1 OBJECTIVE

Develop a scale model (1:5) and carry out the aerodynamic study using wind tunnel testing. Several important features can be found on the model such as balance mounting (for force measurement), pressure tapping (for pressure measurement) and wool turf (for flow observation). The results from wind tunnel test are divided into two, quantitative and qualitative.

1.2 SCOPE OF STUDY

1. Produce of Formula One (F1) rear spoiler scale model.
2. Carry out the external force analysis of drag and lift coefficient, pressure distribution and flow visualization
3. Come out with design improvement of the spoiler on its aerodynamic effect

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CHAPTER 2

LITERATURE REVIEW

2.1 Aerodynamic

The aerodynamics resistance is generated by two sources; one is the air flow over the exterior body of the vehicle and the other is the flow through the engine radiator system and the interior of the vehicle for purposes of cooling, heating and ventilating. The external air flow generates normal pressure and shear stress on the vehicle body. According to the aerodynamic nature, the external aerodynamic resistance comprises two components, commonly known as the pressure drag and skin friction. The pressure drag arises from the component of the normal pressure on the vehicle body acting against the motion of the vehicle, while the skin friction is due to the shear stress in the boundary layer adjacent to the external surface of the vehicle body.

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2.2 The Air Flows (Airfoil)

Airfoil

An airfoil is the shape of a wing as seen in cross-section. It is passed through a fluid in order to provide either lift or down force, depending on its application. An inverted airfoil will create a downward pressure on an automobile or other motor vehicle, improving its traction and keeping it on the ground. The term "lift" can mean a force generated in any direction in any medium. Any thin object with a positive angle of attack, such as a flat plate or the deck of a bridge, will generate lift. Airfoils though are more efficient, generating lift with the least drag and maintaining lift at higher angle of attack. A lift and drag curve obtained in wind tunnel testing is shown on the right.

Airfoil design is a major facet of aerodynamics. Various airfoils serve different flight regimes. A supercritical airfoil, with its low camber, reduces transonic drag divergence, while a symmetric airfoil may better suit frequent inverted flight. Supersonic airfoils are much more angular in shape and can have a very sharp leading edge. Moveable high-lift devices, flaps and slats are fitted to airfoils on most aircraft. New airfoil design techniques continue to develop.

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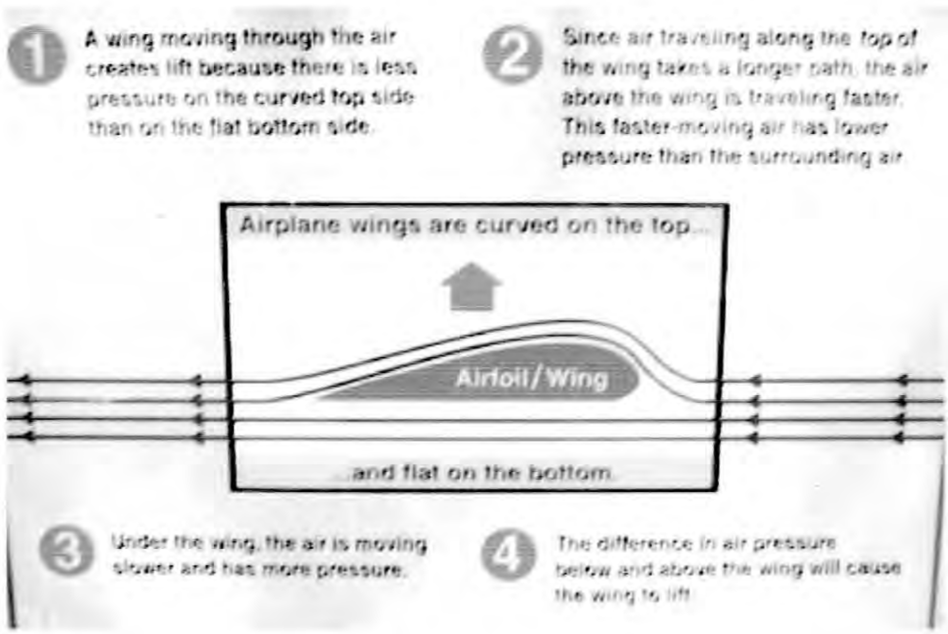

Figure 2.1: Violates the law of conservation of momentum

Merging flows at the rear should maintain downward momentum. Also the principle of action-reaction, which would require upward lift to be equaled by downward accelerative force on the air, is not evidenced in departing air which has no net deflection. In order to have the same transit time, flow at a more curved upper wing surface, having a longer path is said to be of greater velocity than that at a less curved lower surface, making upper surface pressure less than that at the lower.

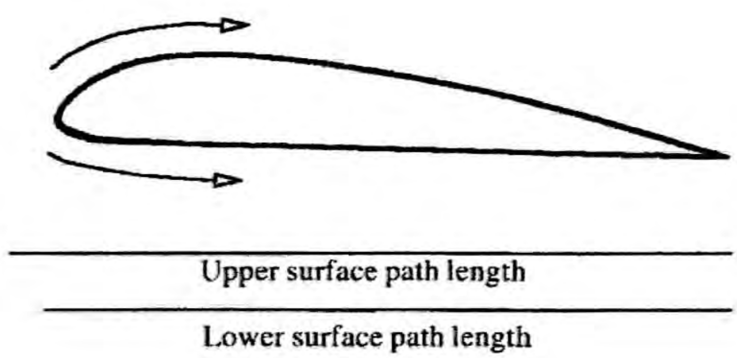

Figure 2.2: Wing air flow

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Upper surface flow is indeed faster than the lower, so much so that transit time at the upper surface in typical normal flight is always less than at the lower. Upper surface flow is indeed faster than the lower, so much so that upper surface transit time is normally less than the lower, as indicated here:

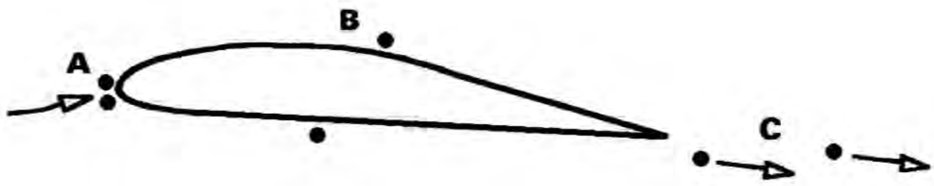

Figure 2.3: Wing air flow

The basic facts of aerodynamic lift and propulsion are:

1. Lift is derived by accelerating air mass downward.

2. Forward propulsion is gained by accelerating air mass rearward.

3. Drag is incurred through accelerating air mass forward, as by viscous coupling. For the most part this is undesirable but unavoidable.

These phenomena are in accordance with Newton's laws of action and reaction. Higher level theory involves Bernoulli, but attributes difference in velocity between above-wing and below-wing flows to "circulation," rather than equal transit time. All air movements are circulatory. Circulation begins to develop when a wing is started into forward motion, as indicated in the next figure, as air following the surfaces is accelerated downward at the rear. Because of downward air acceleration, pressure below the airfoil is increased and pressure above it is decreased. In response to pressure difference, air recirculates upward around the leading and trailing edges.

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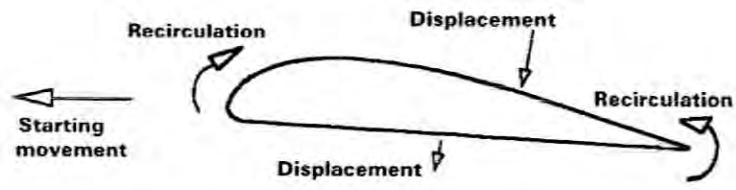

Figure 2.4: Circulation at wing

As forward airfoil movement continues, downward movement left behind the trailing edge recirculates upward around the leading edge and around the center of a receding aft vortex. Forward recirculation around the airfoil is known as "circulation" while the recirculation pattern left behind is known as the "starting vortex." The principle of conservation of angular momentum demands angular momentum of the two rotational patterns is equal and opposite.

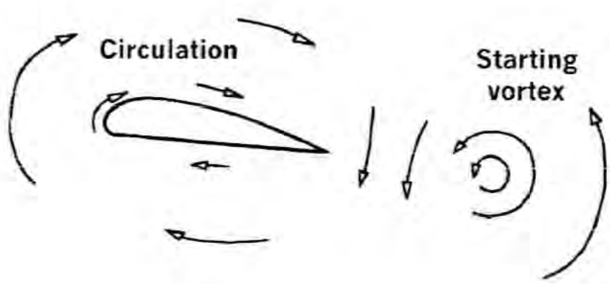

Figure 2.5: Air circulation and starting vortex

Circulation is regenerative. Pressure difference produces circulation, and as circulation upward momentum is intercepted by the forward-moving airfoil or wing, more pressure difference is produced. Thus circulation increases regeneratively, but is limited to the level at which it provides downward movement at the trailing edge for flow to depart in the pointed direction. Circulation in excess of this would be opposed by airfoil direction. With circulation providing the downward demand at the trailing edge, contribution from the starting vortex is no longer needed and growth of the starting vortex ceases as circulation growth ceases.

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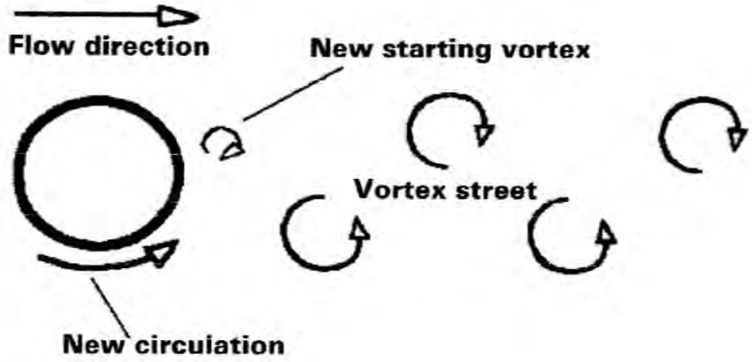

Figure 2.6: New circulation and starting vortex

Circulation is sometimes described as a circular movement superimposed on passing flow, as indicated here. Alternatively it can be considered as a transitory rotation of air which travels with the airfoil through relatively still air, in a manner somewhat analogous to movement of water as it is parted by a ship bow and rejoins at the stern. In this case water movement travels with the ship even though the water does not.

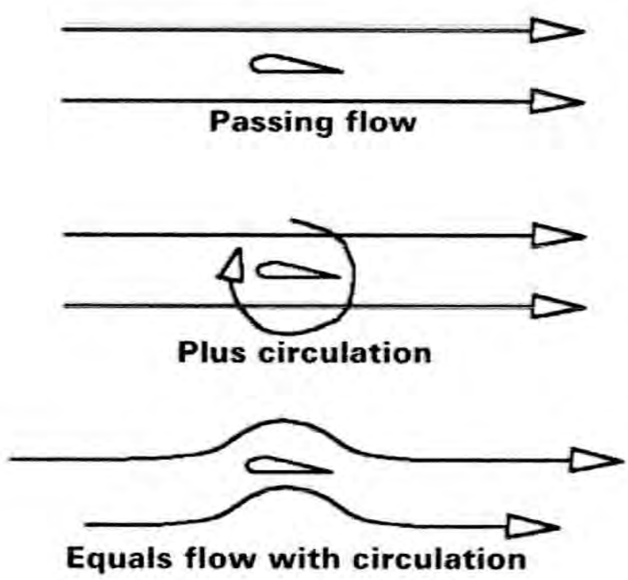

Figure 2.7: Passing flow with circulation

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