AN AERODYNAMIC STUDY OF CAR SPOILER USING CFD

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DECLARATION

I declare that this thesis entitled “An Aerodynamic Study of Car Spoiler Using CFD” is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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Name : Muhammad Zaid Bin Nawam

Date : .....

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 with Honours.

Signature : .....

Supervisor's Name : Dr. Mohd Afzanizam Bin Mohd Rosli

Date : .....

DEDICATION

To those who have been supporting me throughout my 4 years of study.

Thank you.

ABSTRACT

Aerodynamic design of an automotive vehicle influences the performance, safety, and maneuverability of the vehicle. The factor of rising price of the fuel besides the world vision on reducing the greenhouse effect are some of the aspects that boost the needs of refining the vehicle aerodynamics. There is a fact that the design of the vehicle affects 11% of fuel to overcome the drag force on a high-speed driving. Furthermore, the shape of the vehicle especially sedan type has greatly affected by the lift force. Undesirable high value of lift force on an automotive vehicle could cause lack of stability and safety. In this study, the improvisation of the aerodynamic characteristics of a vehicle is discussed in term of rear- wing spoiler design. Four spoiler designs are proposed, analyzed and compared to each other. The drag and lift coefficient value of the vehicle with attached spoiler, the pressure and velocity distribution are evaluated in determining the best spoiler design. The flow characteristics were analyzed using ANSYS FLUENT®. The CFD technique used is validated by using the Ahmed body as a benchmark as the experimental result on the model is available. Grid independence study is conducted in determining best mesh resolution and turbulence model for this study. The generic sedan car as a base model and the spoilers are created in CATIA®. The base model is attached with various spoiler designs and tested to gather its data and result. The finding of the study shows that without a spoiler, the drag and lift coefficient of the car are 0.19230 and 0.03957. While when attached with spoiler, there is an increment in the drag coefficient of the car in range of 26.68% to 150.89%. However, the lift coefficient value shows a declination in range of 1.39% to 1992.87%. The best spoiler design is spoiler 3. The best spoiler design should have the least drag coefficient increment and considerably higher negative lift coefficient.

ABSTRAK

Rekabentuk kenderaan automotif mempengaruhi prestasi dan keselamatan kenderaan. Faktor kenaikan harga minyak dan visi untuk mengurangkan kesan rumah hijau menyebabkan perlunya penambahbaikan aerodinamik kenderaan. Terdapat satu fakta bahawa reka bentuk kenderaan memberi kesan kepada 11% bahan bakar untuk mengatasi daya seret pada kelajuan tinggi. Selain itu, bentuk kenderaan terutamanya jenis sedan banyak dipengaruhi oleh daya angkat. Nilai angkat yang tinggi pada kenderaan automotif boleh menyebabkan kekurangan kestabilan dan keselamatan. Dalam kajian ini, penambahbaikan ciri-ciri aerodinamik kenderaan dibincangkan dari segi reka bentuk spoiler sayap belakang. Empat reka bentuk spoiler dicadangkan, dianalisis dan dibandingkan. Nilai pekali seretan dan angkat kenderaan dengan spoiler, pengagihan tekanan dan kelajuan dinilai dalam menentukan reka bentuk spoiler terbaik. Kajian kebergantungan grid dijalankan dalam menentukan resolusi mesh dan model aliran terbaik untuk kajian ini. Ciri-ciri aliran dianalisis menggunakan ANSYS FLUENT®. Teknik CFD yang digunakan disahkan dengan menggunakan model Ahmed sebagai rujukan. Kereta sedan sebagai model asas dan spoiler dihasilkan menggunakan CATIA®. Model asas dipasang dengan pelbagai reka bentuk spoiler dan diuji untuk mengumpulkan data dan hasilnya. Dapatan kajian menunjukkan bahawa tanpa spoiler, pekali seret dan angkat kereta adalah 0.19230 dan 0.03957. Manakala, dengan spoiler yang dilampirkan, terdapat peningkatan dalam pekali seret kereta di antara 26.68% hingga 150.89%. Walau bagaimanapun, nilai pekali angkat menunjukkan penurunan sebanyak 1.39% hingga 1992.87%. Spoiler 3 telah dipilih sebagai bentuk spoiler terbaik .Rekabentuk spoiler yang terbaik sepatutnya mempunyai peningkatan pekali seret paling rendah dan penguranagan pekali angkat yang berpatutan.

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LIST OF ABBREVIATION

2D	-	2 Dimension
3D	-	3 Dimension
CFD	-	Computational Fluid Dynamics
C_D	-	Drag Coefficient
C_L	-	Lift Coefficient
Eq.	-	Equation
JK PSM	-	Jawatankuasa Projek Sarjana Muda
k-ε	-	k-epsilon
k-ω	-	k-omega
SST	-	Shear Stress Transport
UTeM	-	Universiti Teknikal Malaysia Melaka

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CHAPTER 1

1 INTRODUCTION

This chapter covers the introduction of the project entitled “Simulation Study of Aerodynamic in Car Spoiler”. In this chapter it will cover project background which consists of introduction of aerodynamic and spoiler development, the problem statement, objective and scope of the project.

1.1.1 Project Background

The present car industry has provided the users with many types of cars ranging from sports, sedan, and truck to a luxury car. Back to the old days, where the aerodynamic design of a car is not a crucial thing, the common shape of the car is like a box. In the country of Malaysia, the trend of a box-like shaped car could be seen in the production of the first national car in the mid-1980s that is Proton Saga (Jomo K. S., 2003). This trend of a box-shaped car has continued for several years and several models in Proton production. However, in the present car industry, aerodynamic design and shape have become a very important aspect. The old box-shaped cars could be hardly seen in the new-production car nowadays. The development in the car industry has led to a more economical and efficient vehicle. The factors of the development are due to the advancing technologies besides the factor of energy-efficiency.

In this project, the main discussion is mainly focusing on the aerodynamic. According to (Sandra May, 2015), aerodynamics is the way of air moves and flows through

things. Aerodynamic forces including drag and lift forces are the important aspects and values that determine the quality of the aerodynamic design of the vehicle. The drag force is a sort of force that is trying to stop or slows down the vehicle movement. It may be in term of tire friction with the road or may be in term of air drag. Drag forces play an important role in affecting the value of the car drag's coefficient. Drag coefficient as referred to (Sandra May, 2015) is a value that engineers and aerodynamicists use to model all of the complex dependencies of body shape or design and flow condition on car drag. These values of drag in term of force or coefficient give a big impact on the car economy and efficiency. Lift force, on the other hand, is a force that acts perpendicularly to the motion of the vehicle. It is a sort of forces that potentially lift the vehicle upward. Lift coefficient is described as a value that is used to simulate all the complexity of dependencies of the flow behavior and condition and its design that contributed and affected the lift. While the drag coefficient gives impact in efficiencies, the lift values affect the stability of the vehicle. Thus, these two values must be in the best range to produce a good design of a vehicle.

Aerodynamic of the car has now been in the top priority for the car designer. There are abundance of study and research in the automotive industry that found the advantages and cruciality of the aerodynamic. (Mazyan, 2013) has discussed the effect of attaching rear spoiler in order to improve the aerodynamic design of the Ahmed body. The finding of the simulation clearly shows that there is an improvement in the aerodynamic drag behavior acting on the car. The result of 10% decrement in the aerodynamic drag could give a big impact on the performance and efficiency of the car. A study by (G, Mukkamala, & Kulkarni, 2014) found that 50% of the vehicle fuel consumption on a standard highway speed is contributed by the aerodynamic performance of the vehicle.

The development in the car industry and technology also has produced a more high-performance car that can achieve a speed as high as 457.86km/h such as produced by Koenigsegg Agera RS. As we know, there are many factors involved in achieving this record. However, a good aerodynamic design must be a crucial factor that contributed to the achievement. Without a good aerodynamic design of the car, the high speed as that could be nearly impossible. In the other hand, a car with that speed without proper aerodynamic design could be dangerous and impractical to be driven.

In today's car design development, designers and engineers have come out with many ideas and solution to the aerodynamic matters. Some of them are by changing car's design in term of body frame as seen in the evolution of car chassis and body from the tear-drop car until the streamline design. In addition, other than changing the body shape, the other alternative done by the engineers are by adding a device to improve the aerodynamic properties of the car. There are many types of these aerodynamic devices such as bumpers, side skirt and spoilers. In this paper, none of the car chassis and body design will be discussed. The main thing that will be focused is about the aerodynamic device that is the rear-wing spoiler.

The rear-wing spoiler is a device that is added to the rear of the car to improve the car's aerodynamic and stability by adding more pressure on the rear of the car. (Cheng & Mansor, 2017) states that generally there are two types of common rear spoiler equipped in most of the vehicle especially car. The type of the spoilers are free-standing wing spoiler and the other type is strips. In both sedan and hatchback car type, the common spoiler used is strips. Sometimes they are factory standard equipped and sometimes it could be purchased aftermarket. While the free–standing wing spoiler is commonly used for a sedan car as it requires a sufficient area to be attached to a car. In the early 20s, many car users install the

rear spoiler for the purpose of decoration. However, the rear spoiler today is not only for that purpose. The adding of the rear spoiler could affect the lap time for a race car. Besides, the stability of road car could have a big difference with a rear spoiler.

1.2 Problem Statement

When a vehicle is moving, it is cutting through an air. By imagining walking in the swimming pool, it is the same thing happens when we move or walk in the air, just the effect is not so significant compared to moving in water. But when saying about a high-speed movement even in the air, for example, 100km/h that is an average speed of today's car, the design of the car plays an important role for the efficiency and stability of the movement. Too many drag forces on the car body could cause high waste in engine energy consumption while too much lift forces could cause the car lacks in stability and dangerous to be driven.

Usually, the lift force affects most on the rear of the car especially a sedan car because of its shape. Moving at high speed causes the high-speed air to move following the body shape of the car causing high pressure on the front hood follows by front windshield. But arriving at the rear of the car, the air suddenly loses its track and causing the air flow to be turbulence and producing a low-pressure region at the car's rear. This low-pressure region is undesired as it could cause an undesired drag and lift and the tires could lose its traction to the road and causing an accident.

In conclusion, the problem statement for this research are as follows:

1. How to obtain C_D and C_L?
2. What is the effect of attaching a rear spoiler?
3. What is the best spoiler design?

1.3 Objectives

The objectives of the project are:

i. To design a spoiler for a sedan car.

ii. To predict the C_D and C_L of the car without attaching rear spoiler using ANSYS-Fluent®.

iii. To predict the C_D and C_L of the car with rear spoiler using ANSYS-Fluent®.

1.4 Scope of Project

Aerodynamic characteristic depends on many factors, this study focuses on external devices that is rear-wing spoiler on a sedan car. The flow of this project mainly based on the design, development and numerical simulation of the effects of rear-wing spoiler. There are four spoiler designs will be considered by modifying the shape of the spoiler. The finding of this study is discussed in term of C_D and C_L value, pressure and velocity distribution.

CHAPTER 2

2 LITERATURE REVIEW

This chapter will give a generic view about the background and development of car spoiler along with the concept and theories of aerodynamics that relate with this study.

2.1 Introduction

Car spoilers, vortex generator, tail plate and similar functioning devices were once a mere product. However, in today scenarios, spoilers had become a must equipped device in a most performance car.

In 1899, a Belgium race car driver, Camille Jenatzy breaks the records on 100km/h barrier for the first time in a race car (Katz, 2006). As shown in the Figure 2-1, the car that Jenatzy drives is the car that is described as the pioneer of the streamlined car in the automotive industry. This electro-powered race car has a torpedo shape to reduce the total drag acting on the car.

Figure 2-1: Jenatzy's car (La Jamais Contente) (Adam Lohonyai, 2014)

The post-world war era shows a great development in car industry focusing on the aerodynamic design of the car. This era has produced a most significant design of a teardrop design car shape. In 1921, Edmund Rumpler surprised visitors at the Berliner Automobile Ausstellung with his revolutionary car design named 'Tropfenwagen' or a 'Teardrop Vehicle' as shown in Figure 2-2. This car could achieve a markable speed of 185km/h that was pretty fast in that era. Besides, the efforts in reducing the drag acting on the car had shown a great achievement with its tested drag coefficient in 1979, which resulted in only 0.28 of C_D value (Li Yanlong Yang Zhigang, 2013) which is quite impressive comparing with today's technology and achievement.

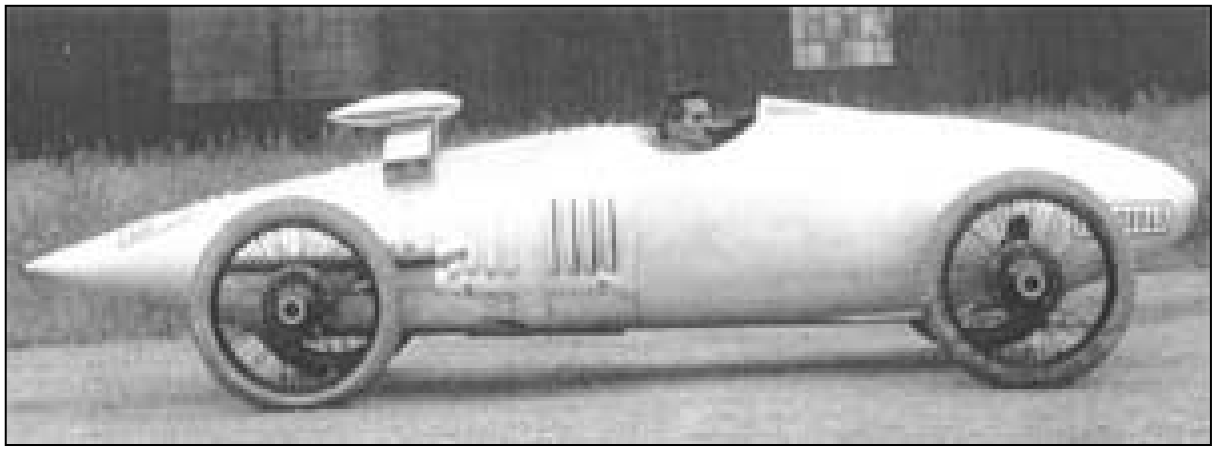

Figure 2-2: Benz-Tropfenwagen (Mattijs Diepraam, 2005)

Edmund Rumpler, the designer of the Tropfenwagen held the first aerodynamic testing in a wind tunnel. The Tropfenwagen showed an impressive result in the test. Few years later, in 1929 a grandson of Opel founder, Fritz Von Opel has come out with a new concept of rocket race car that utilizes jet engine and employ inverted wings (Katz, 2006) as shown in Figure 2-3. The wings equipped at the side of the car are in a negative angle of attack in order to create a large down force. However, this aggressive innovation is totally ignored. In the same era, a Hungarian engineer, Paul Jaray has developed an innovation of smooth surfaces of the car's body, headlamps, tapered rear end and cambered windshields as shown in Figure 2-4. It is to be admitted that his innovation managed to achieved a low value of drag coefficient that are ranging from 0.29 to 0.30 (Katz, 2006). However, (Syon, 2008) states that due to the conflicts of political and economic turmoil in the 1930s causing the idea being just a short-lived experiment. Still, it inspires others to follow his steps. Due to the great achievement, much of Paul's innovations were adopted by many car manufacturers such as Audi and BMW.

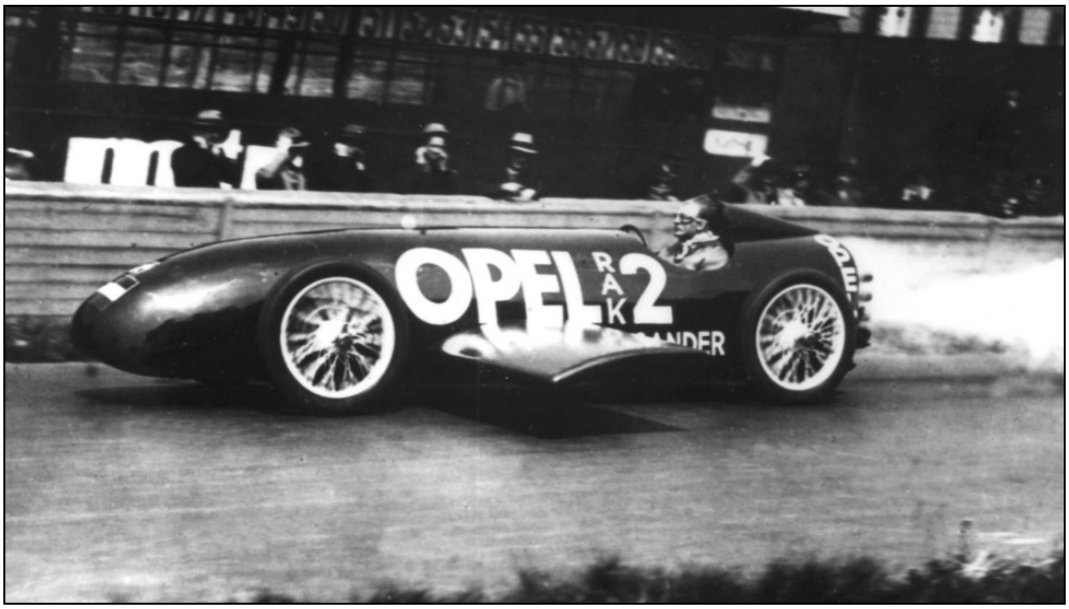

Figure 2-3: Opel-RAK (Michael Ballaban, 2014)

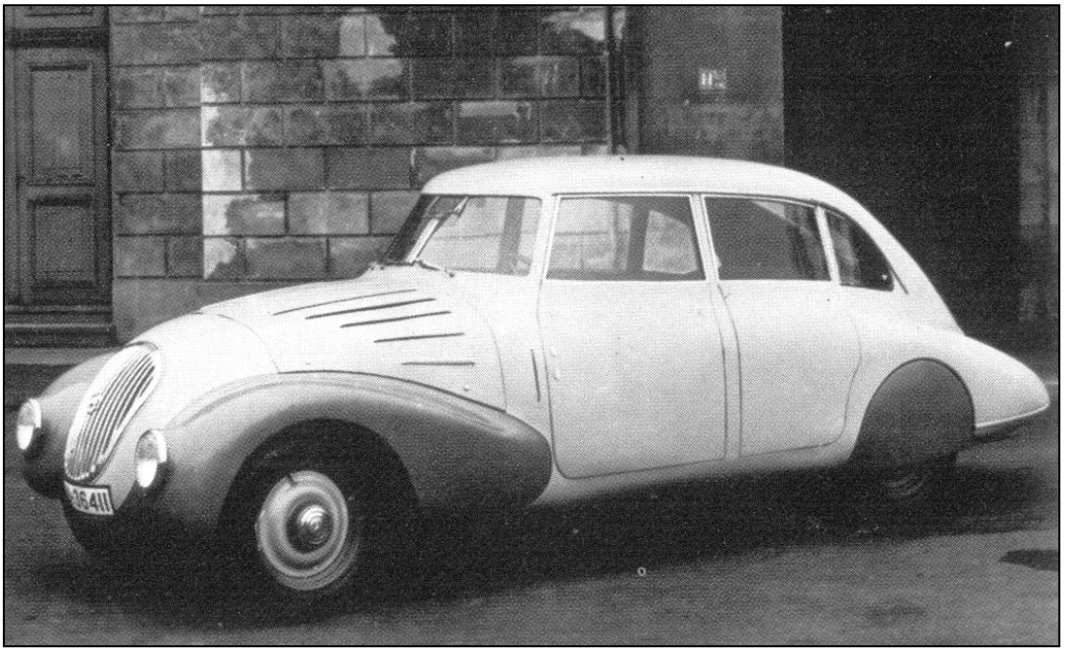

Figure 2-4: Paul Jaray's Streamline Car (Alex Oagana, 2010)

In the early years of 1930s, a German aerodynamicist Wunibald Kamm brought the concept of aerodynamics in cars, with the use of airfoils resulted in Kammback cars. One of the car that applied Kammback design is Ford GT as shown in Figure 2-5. Kammback is designed based on the streamline shape but only its back is slightly truncated. Kammback