UNIVERSITI TEKNIKAL MALAYSIA MELAKA

DESIGN AND SIMULATION OF GO-KART ACTIVE REAR SPOILER AIR FOIL SHAPE USING COMPUTATIONAL FLUID DYNAMICS (CFD) SIMULATION

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor's Degree in Mechanical Engineering (Automotive Technology) (Hons.)

by

CARLA REGINA YALING

B071210374

930122-13-6338

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APPROVAL

This report is submitted to the Faculty of Engineering Technology of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Engineering Technology (Automotive Technology) (Hons.). The member of the supervisory is as follow:

………………………………..

(Project Supervisor)

ABSTRAK

Tesis ini berkaitan dengan kajian aerodinamik Go-Kart. Tujuan utama aerodinamik kereta lumba adalah untuk mencapai daya bawah diingini dan seret kurang yang menyumbang kepada prestasi yang lebih baik dan pengendalian dalam perlumbaan. Dalam usaha untuk meningkatkan aerodinamik ini, alat aerodinamik seperti sayap belakang diperlukan. Objektif projek ini adalah untuk mereka bentuk dan simulasi spoiler belakang Go- Kart untuk prestasi dan pengendalian yang lebih baik. Fokus penyelidikan tertumpu kepada sudut yang sesuai untuk spoiler belakang Go- Kart bagi mencapai daya bawah yang lebih baik. Reka bentuk spoiler direka menggunakan perisian Computer Aided Design (CAD) berdasarkan kajian literature dan menganalisis dengan pelbagai sudut serang menggunakan perisian Computational Fluid Dynamics (CFD).

ABSTRACT

This thesis deals with the study of Go-Kart aerodynamics. The primary aim of race car aerodynamics is to achieve desired downforce and less drag which contribute to better performance and handling in racing. In order to improve this aerodynamics requirement, an aerodynamic device such as the rear wing is needed. The objective of this project is to design and simulation the rear spoiler for Go-Kart for better performance and handling. This research focus on the suitable angle of attack of the rear spoiler for the Go-Kart achieving better downforce. The rear spoiler is design based on the literature research using the Computer Aided Design (CAD) software and analyse it with various angle of attack using the Computational Fluid Dynamics (CFD) software.

DEDICATION

I would like to dedicate this to my father, Mr Yaling Chuanteck and my mother, Mrs Rosnah Yehat, my two lovely brothers, Hans De Rieviera Yaling and Ferdinand De Franco Yaling, my supervisor, Mr Mohd Faruq bin Abdul Latif, co-supervisor, Mr Mohd Suffian bin Ab Razak and my friends for supporting me from the beginning until the end of this project.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATION, SYMBOLS AND NOMENCLATURE

A	-	Area
AOA	-	Angle of attack
CAD	-	Computer Aided Design
CFD	-	Computational Fluid Dynamics

DoE	-	Design of Experiment
D	-	Drag
d	-	Diameter
H	-	Height
ICG	-	Interactive Computer Graphic
L	-	Lift force
M	-	Mach number
NASA	-	National Aeronautics & Space Administration
PIV	-	Particle Image Velocity
V	-	Velocity
VWT	-	Virtual Wind Tunnel
WS	-	Wingspan
α	-	Angle of attack
C_D	-	Coefficient of drag
C_L	-	Coefficient of lift
C_p	-	Pressure coefficient
C_s	-	Side force coefficient
D_f	-	Downforce
l	-	Length
P_∞	-	Barometric pressure
R_e	-	Reynolds number
u_s	-	Speed of sound
v_m	-	Mean velocity
v_s	-	Flow velocity
ε	-	Epsilon
ρ	-	Density
K_{us}	-	Understeer coefficient
μ	-	Viscosity

CHAPTER 1

INTRODUCTION

1.0 Background

Go–kart or kart is a small four wheeled vehicle without a traditional suspension. It was considered as a non-life threatening and a very safe motorsport with rare risk of injuries. Go-karts come in various forms and shapes start from the motorless models to high-powered racing machines such as the Superkarts which has the ability to beat other racing cars on long circuits. Karting is commonly perceived as the stepping stone to the higher ranks of motorsport (Aberdeen Lim Jian Rong,2011)

Karts vary widely in speed and some can reach speeds exceeding 260 kilometres per hour. The advance in aerodynamics is partly reflected in the increase in speed. Aerodynamics, particularly ground effect aerodynamics, as applied to open wheeled race cars is still mainly an experimental science and will remain so for some time to come. The primary aim of race car aerodynamics is to generate a desired level of downforce negative lift for the least possible drag. However, the balance of the downforce under all conditions of speed and acceleration is equally important (Katz, 2006).

Adding active rear spoiler on Go-Kart can generate the downforce at high speed as the grip mostly generated by aerodynamic downforce and help improve traction in an effort to prevent sliding while cornering. Computer Aided Design (CAD) model can be tested without any prototypes and computational fluid dynamics to analyse the design effectively in order to achieve better aerodynamic performance (Pakkam & Gopalarathnam, n.d. 2011).

1.1 Problem Statement

In the last decade, manufactures and teams has make several effort in advanced design and setup procedure as their support in addressed the aerodynamic drag forces in Go-Kart competition (Biancolini, 2004). About 50 to 60% of total fuel energy is lost due to the burning fuel in accelerating a racing car or road vehicle to overcome the aerodynamic drag. Faster acceleration is needed in winning a race and drag reduction is the goal that need to be achieve(Hassan, Islam, Ali, & Islam, 2014). Besides that, aerodynamic downforce has been a greater value in reducing lap times than low drag on high powered race cars. The purpose of downforce is allowing a car to travel faster through a corner by increase the vertical forces on tires, thus create more grip (Kieffer, Moujaes, & Armbya, 2006). By adding rear wing to Go-Kart, it can provide enough downforce, minimum aerodynamic drag and good directional stability (Yang, Gu, & Li, 2011).

Current research suggested the installation of rear wing with an appropriate angle of attack can reduce aerodynamic lift coefficient (Breu, Guggenbichler, & Wollmann, 2008) and improve the wake structure of vehicle (Jiang & Kang, 2005). The wake effect can be estimated using particle image velocity (PIV) to analyse the flow behind a vehicle with or without spoiler (Kim, Kim, Sung, Kim, & Choi, 2006).Computational fluid dynamic is feasible for the numerical simulation of automobile airflow which it provides the reference for the automotive development with spoiler (Hai-Tao, 2011). The turbulent simulation (using a $k–\varepsilon$ model) of the airflow on the front and rear wings can performed using computational fluid dynamics with different angles of attack and effect of the ground on the front wing (Kieffer et al., 2006). Computer Aided Design used in design model and create meshes for CFD simulation with the recommendation of angle of attack (Chandra, 2011).

By designing an aerodynamic spoiler for Go-Kart with variable downforce and analyse the suitable angle of attack using the suggested method, the performance goal of Go-Kart can be achieved. Thus, the optimization in a competition Go-Kart aerodynamic hopefully can establish a world speed record for Go-Kart industry (Tor, n.d. 2006).

1.2 Objectives

The objectives of this project are:

1. To design aerodynamic rear spoiler for Go-Kart with variable downforce.
2. To analyse the suitable angle of attack for the Go-Kart active rear spoiler using the computational fluid dynamic simulation.

1.3 Scope of Study

In order to reach the objectives, a few scopes have been drawn. The fully body of Go-Kart is drawn back using the Computer Aided design (CAD). By designing the model using CAD software, the use to build a real prototype is not required due to the time limitation and cost production. With the model create by the CAD, the model can be a benchmark in analyse the coefficient of drag (C_D) and coefficient of lift (C_L) by generating the mesh using the computational fluid dynamic (CFD) simulation without adding the rear spoiler on the Go-Kart model. The rear spoiler is design and model using the CAD based on the shape and parameters chosen. Then, the model is evaluate by using CFD to determine the suitable angle of attack for better downforce. Lastly, the suitable angle of attack can be finalize after the evaluation of CFD. This project only covered and focused on rear spoiler of Go-Kart. The data will be use as analysis by other resource such as the mechanical linkage in achieving the best results for the Go-Kart better handling performance.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

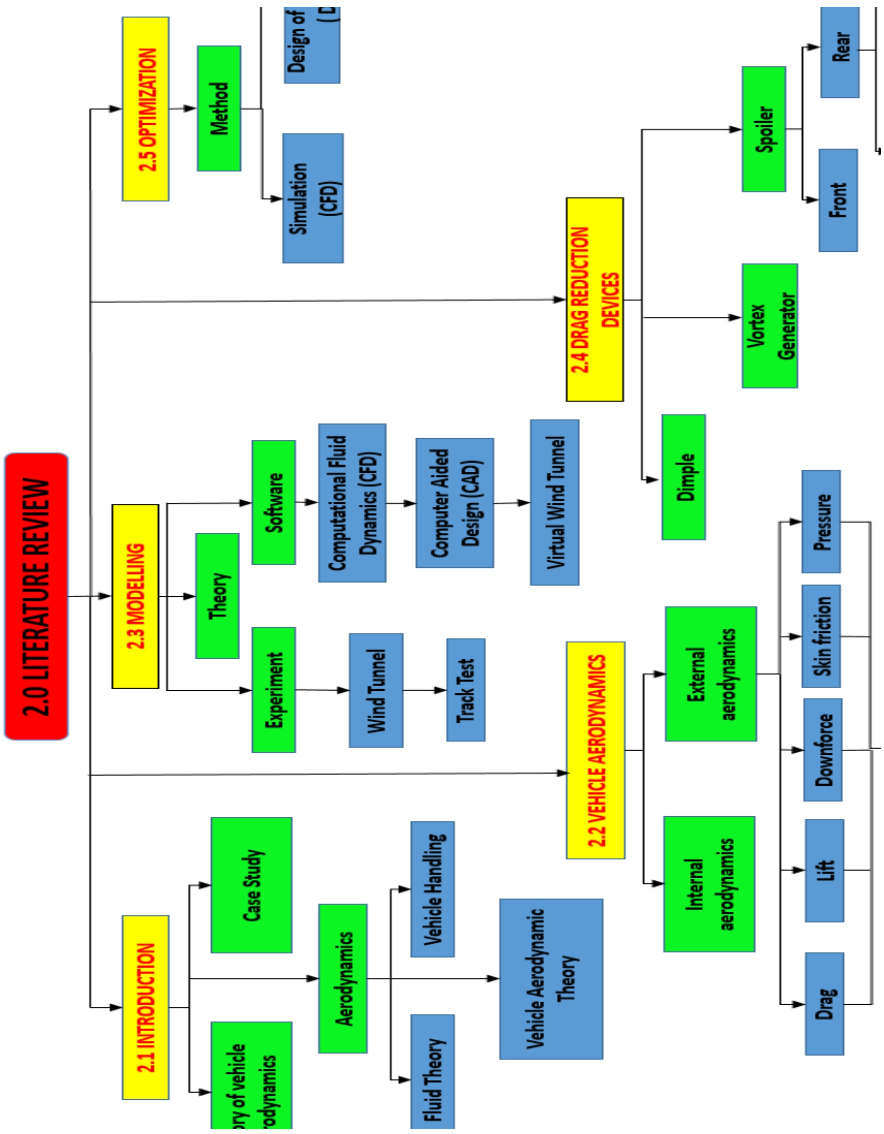

Figure 2.1 Flow of K-Chart for Literature Review

In this chapter, the definitions and theories shall be defined and explained. This chapter discuss the literature based on the flow of K-Chart as shown in Figure 2.1. K-Chart has been used for research planning and monitoring because of the systematically organizing research in the form of Tree Diagram which enable better flow in writing the literature review. This literature review has been divided into five topics. The first topic deals with introduction that explained more about the developments and history of aerodynamics and also the current research which related to this thesis. Second topic explained more about the overall scopes of vehicle aerodynamics that affect to the vehicle handling. The third topic discussed on the methodology and applications used for this thesis project. The fourth topic explained the devices that were used for drag reduction and downforce. From this topics, the theory and design of active rear spoiler has been elaborated more which related to this thesis project. Lastly, the fifth topic deals with the method involved in optimizing the design of the model project.

2.1.1 History of vehicle aerodynamic

The interaction between the air flow and the ground, and the complicated geometrical shapes that are involved in motor vehicle aerodynamics has make it a complex subject. The road of vehicle aerodynamics has been treated by Barnard (1996) and Hucho (1998a) who gives very readable account and particularly comprehensive treatment. In the 1980s, the main developments with vehicle aerodynamics occurred and the use of low-drag vehicles has become common until now. Vehicles are still designed by body stylist and aerodynamicist then refinements the shape for giving drag reduction and other aerodynamic improvements. Aerodynamic makes it major impact through the contribution to road load on vehicles (Richard Stone & Jeffrey K. Ball, 2004)

The historical development of automobile aerodynamics has developed in the early of 19^{th} century which occupies four chronologically indistinct phases of basics shapes, streamlined cars, detail optimization and shape optimization as shown in Figure 2.2. To show which work contributed to the development of automobile aerodynamics and illustrate how this knowledge applied to automobile design are the two aims of the historical development of automobile aerodynamics (Wolf-Heinrich Hucho,1998).

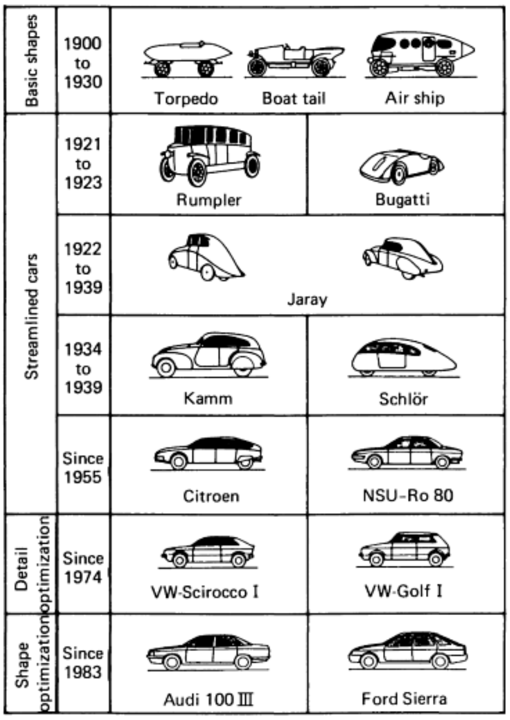

Figure 2.2 : The four primary phases of cars aerodynamics (Wolf-Heinrich Hucho,1998).

Torpedo shape car built by Camille Jenatzy was the oldest vehicle developed according to aerodynamic principle as the exposed wheel and driver which were not integrated had led to a considerable drag increase. Alfa Romeo built in 1913 with body shape of an airship, which were little suited in automobile aerodynamics. However, due to poor roads and low engine power, it contribute to low speed and subordinate role of aerodynamic drag (Wolf-Heinrich Hucho,1998).

The streamlined bodies design started simultaneously after the First World War which has the shape of aerofoil viewed on the top, streamlined roof and uncovered wheels that result to an increase of drag and more significant to vehicle body improvement of aerodynamic quality. Hucho, Janssen and Emmelmann represent one approach of method in optimize body details. Styling, safety, comfort and production were the requirement to practical automotive engineering in adapting aerodynamics.(Wolf-Heinrich Hucho,1998).

Engineering energy went into invention and design that would yield faster, more reliable and more comfortable vehicles in the early 1900.As year passes, designers had succeeded in building cars with low drag coefficient and achieved a shape of a car with the concept of aerodynamics (Thomas D. Gillespie, 1992).

2.1.2 Aerodynamics

Aerodynamics is the branch of dynamics that treats of the motion of air and other gaseous fluids and of the forces acting on the bodies in motion relative to such fluids (Webster's Third New International Dictionary).Aerodynamics is the science of the motion of gases and the effect of those motions on various bodies or surfaces in the flow (John David Anderson,1997). Aerodynamics is closely related to hydrodynamics and gas dynamics, which represent the motion of liquid and compressible-gas flows respectively (Gary A. Flandro, Howard M. McMahon & Robert L. Roach, 2012).Aerodynamics can be classified in a number of ways which are the external aerodynamics and internal aerodynamics. External aerodynamics deal with external flow over a body. It is the prediction of forces, moments, and aerodynamic heating associated with a body. Internal aerodynamics deals with flows internally within ducts. It study the flow through passage in solid objects respectively (John David Anderson,1997).

2.1.2.1 Fluid Theory

Bernoulli Equations deals with pressure and velocity of air that flow smoothly around a body. It describes the conditions existing in the free stream, outside the boundary layer. It is possible in prediction of the surface pressures and lift for various types of shapes (William F. Milliken & Douglas L. Miliken, 1995).

Bernoulli's Equation states the sum of static pressure and dynamic pressure of the air will be constant as it approaches the vehicle. The equation is as below:

$$P_{static} + P_{dynamic} = P_{total} \tag{1}$$

$$P_s + {}^{1}/_{2}\, \rho\, V^2 = P_t \quad (2)$$

Where:

P = Density of air

V= Velocity of air (relative to car)

Streamlines is the air streams along line and a bundle of streamlines forms a streamtube. Streamtube can be visualized from the smoke streams used in a wind tunnel as shown in Figure 2.3 (Thomas D. Gillespie, 1992).

Figure 2.3 : Streamtubes flowing over an aerodynamic body (Wolf-Heinrich Hucho)

A streamtubes is composed of a frictionless and incompressible fluid and is an isolated system. The path of successive air particles in a steady flow is called a streamline. Static pressure is the pressure in the airstream (William F. Milliken & Douglas L. Miliken, 1995).The streamtubes split as the flow approaches the vehicle with some going above vehicle and others below the vehicle. One streamline must go straight to the body and stagnate. At that point the relative velocity gone to zero and the static pressure observed will be P_t (Thomas D. Gillespie,1992).

The streamlines turn in the upward and curvature concave upward as it flowing above the hood. The static pressure must be higher than ambient to provide force to turn the air flow in order for the air stream to be curved upward. The pressure must below the ambient in order for bending the flow and increase the velocity as the flow turns to follow the hood (Thomas D. Gillespie,1992). This is because the higher velocity of the flow over the vehicle roof resulting to a lower pressure than under the lower body, where the flow velocity is low (Richard Stone & Jeffrey K. Ball, 2004).

Bernoulli's Equation explain how the pressure and velocity vary in the gross air flow over a car body. The air simply flow up over the roof and down the car the back side of the vehicle and exchange the pressure for velocity at the front with the absence of friction. However, drag is produced due to the air friction on the surface of the vehicle and main flow down back side of the vehicle. This can be explained from the understanding the action of boundary layers in the flow over an object (Thomas D. Gillespie,1992).

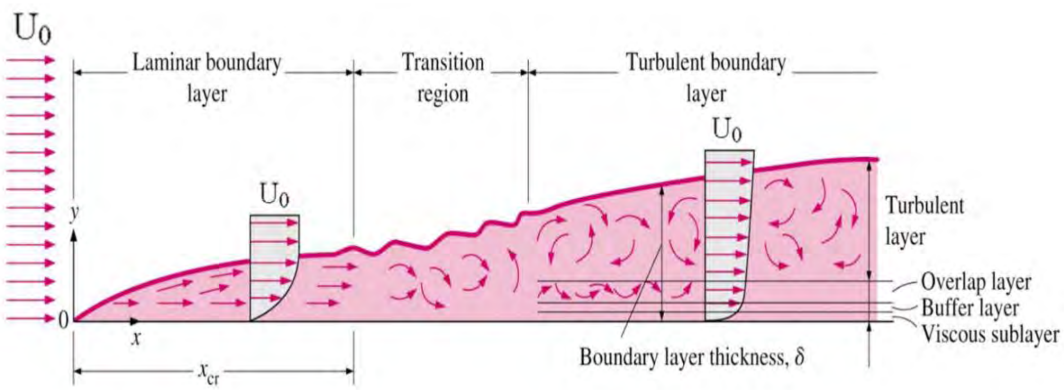

Figure 2.4 : Development of a boundary layer (Ganesh Visavale,2014)

The development of a boundary layer can be illustrated from Figure 2.4. The boundary layer thicken as the air continues to move along the surface and thus loses energy due to skin friction. The increase in pressure and the lack of energy create the reversed flow at the surface. This condition is known as flow separation (William F. Milliken & Douglas L. Miliken, 1995).