UNIVERSITI TEKNIKAL MALAYSIA MELAKA

DESIGN OF AERODYNAMICALLY EFFICIENT SHELL ECO-MARATHON URBAN CAR THROUGH FRONT FACE DESIGN OPTIMIZATION

This report is submitted in accordance with the requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor of Mechanical Engineering Technology (Technology Automotive) with Honours.

by

MOHD SYAHFENDY BIN SULAIMAN

B071610575

970813125597

FACULTY OF MECHANICAL AND MANUFACTURING ENGINEERING TECHNOLOGY

2019

UTeM

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA

TAJUK: Design of Aerodynamically Efficient Shell Eco-Marathon Urban Car Through Front Face Design Optimization

SESI PENGAJIAN: Semester 1 2019/2020

Saya **MOHD SYAHFENDY BIN SULAIMAN**

mengaku membenarkan Laporan PSM ini disimpan di Perpustakaan Universiti Teknikal Malaysia Melaka (UTeM) dengan syarat-syarat kegunaan seperti berikut:

1. Laporan PSM adalah hak milik Universiti Teknikal Malaysia Melaka dan penulis.
2. Perpustakaan Universiti Teknikal Malaysia Melaka dibenarkan membuat salinan untuk tujuan pengajian sahaja dengan izin penulis.
3. Perpustakaan dibenarkan membuat salinan laporan PSM ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. **Sila tandakan (✓)

☐	SULIT	(Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia sebagaimana yang termaktub dalam AKTA RAHSIA RASMI 1972)
☐	TERHAD	(Mengandungi maklumat TERHAD yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan)
☐	TIDAK TERHAD	

Disahkan oleh:

_____________________________ _____________________________

Alamat Tetap:

Kampung Binai, Peti Surat 312,

89908, Tenom, Sabah.

Cop Rasmi:

Tarikh: _____________________________

Tarikh: _____________________________

** Jika Laporan PSM ini SULIT atau TERHAD, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan dengan menyatakan sekali sebab dan tempoh laporan PSM ini perlu dikelaskan sebagai SULIT atau TERHAD.

DECLARATION

I hereby, declared this report entitled “PSM Title” is the results of my own research except as cited in references.

Signature	:	……………………………………………
Author’s Name	:	MOHD SYAHFENDY BIN SULAIMAN
Date	:	……………………………………………

APPROVAL

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

……………………………………..

MOHD SUFFIAN BIN ABD. RAZAK

ABSTRAK

Reka bentuk aerodinamik kenderaan adalah salah satu unsur penting untuk penggunaan bahan bakar dan prestasi kenderaan. Pada masa kini, peningkatan penggunaan bahan bakar kereta telah menjadi faktor penting dalam pengeluaran kereta. Ini disebabkan kenaikan harga bahan api dan pengurangan pengeluaran bahan api fosil. Matlamat utama aerodinamik adalah untuk mengurangkan daya seret dan bunyi angin. Perubahan kecil kepada reka bentuk badan kenderaan boleh menjejaskan "*Drag Coefficient* (C_d)" kereta terutamanya dengan mengubah bentuk bahagian depan kerana ia menyumbangkan kesan sehingga 65% untuk bahagian depan. Oleh itu, projek ini memberi tumpuan kepada pengoptimuman bentuk di bahagian hadapan kereta Urban Shell Eco-Marathon untuk mendapatkan reka bentuk yang paling aerodinamik tanpa menjejaskan pandangan estetiknya. Objektif utama kajian ini adalah untuk menganalisis dan mengkaji kesan pengubahsuaian di bahagian depan kereta kepada ciri aerodinamik. Reka bentuk tiga dimensi kereta Mercedes Benz CLA 2013 telah dihasilkan dengan menggunakan perisian CATIA V5 sebagai model rujukan. Tiga jenis pengubahsuaian dibuat pada model ini dan digunakan untuk menentukan sifat aerodinamiknya. Perisian ACU Solve daripada Altair digunakan untuk menjalankan analisis CFD. hasil daripada pengubahsuaian yang dilakukan menunjukkan hasil yang baik apabila "*drag coefficient*" menunjukkan pengurangan sebanyak 14.18%. Adalah jelas dilihat bahawa dengan hanya meningkatkan sudut cermin hadapan, dan ketinggian penutup enjin kereta dapat mengurangkan "*drag coefficient*" serta mempunyai pengedaran tekanan dan aliran udara yang lebih baik.

ABSTRACT

Aerodynamic design of a vehicle is one of the crucial elements for fuel consumption and its performance. Nowadays, the improvement of the fuel consumption of a car has become a significant factor in car production. This is due to the rising of fuel pricing and declination on the fossil fuel production. The main goal of aerodynamics is to reduce drag and wind noise. A small change to the body design can affect the drag coefficient of the car especially by changing the shape of front face since it contributes the effect up to 65% for the front face. Thus, this project is focusing on shape optimization on the front portion of the Shell Eco-Marathon urban car to get the most aerodynamic design without compromising its aesthetic look. The major objective of this study is to analyse and examine the effect of purpose modification on frontal area of a car to the aerodynamics characteristic. A three-dimensional design of Mercedes Benz CLA 2013 car was carried out by using CATIA V5 software as a benchmarking model. Three type of modification is made on this model and used to determine its aerodynamics characteristic. ACU Solve software from Altair is used for the computational fluid dynamics (CFD) analysis. The result shows an excellent optimization for the benchmarking model as the drag coefficient is reduce by 14.18% for the final model. From the CFD result, it is clear to see that by only increasing the windshield angle, and the height of the hood has a significant influenced on reducing the drag coefficient as well as have a better pressure distribution and better streamline airflow.

DEDICATION

I am dedicating this thesis to my beloved parents, Mr Sulaiman Bin Yunus and Mrs Syahqirah Lasah Abdullah who has always be a positive role model in my life and continually provide their moral, spiritual emotional and financial support. Thank you for being my source of inspiration and gives me strength when I am on my weakness point.

ACKNOWLEDGEMENT

First and foremost, I would like to express my biggest appreciation to those who provided me the possibility to complete this report. A special thanks to my Supervisor, Mr Mohd Suffian Bin Abd. Razak for giving me a chances and opportunity to get involved in this project. I am thankful to him for his ideas, guidance, supports, and encouragements in making this research possible.

Besides, special thanks Co-Supervisor, Mr Muhammad Rafi Bin Omar who contributes his useful comments during discussion on using software in developing the CAD modeling. It helps me to learned and gained more useful knowledge. Without the help of my Supervisor and Co-Supervisor, it is impossible for me to complete this project on time.

Lastly, thanks to all my family, friends and people who give me support all the time throughout completing this project.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

F_d	Drag Force
C_d	Coefficient of Drag
Pa	Pascal
P_D	Wind Resistance
P_R	Rolling Resistance
P_T	Friction and Transmission Resistance
G	Fuel Used to Overcome Aerodynamic Drag

LIST OF ABBREVIATION

CFD	Computational Fluid Dynamics
CAD	Computational Aided Design
MPV	Multi-Purpose Vehicle
FEM	Finite Element Method
FVM	Finite Volume Method
3D	Three Dimensional
SEM	Shell Eco-Marathon

CHAPTER 1

INTRODUCTION

1.1 Background

Shell Eco-Marathon is a well-known competition around the world that challenges the student to design, build and drive the most energy-efficient vehicle. Students are required to build a vehicle to compete among them to see whose vehicle goes further on the given track with the least amount of fuel. Due to that, the aerodynamic design of a vehicle is one of the crucial elements for fuel consumption and its performance. Nowadays, the improvement of the fuel consumption of a car has become a significant factor in car production. This is due to the rising of fuel pricing and declination on the fossil fuel production (Ghani, 2013). The main goal of aerodynamics is to reduce drag and wind noise. Hence, it is also used to produce the downforce for the vehicle to have suitable traction between the vehicle and road. The front face area and shape of the vehicle is playing an essential role in reducing the force drag (F_d). The bigger the front face area of the vehicle will produce a high force drag because of the high coefficient of drag. Figure 1.1 shows an example of the different basic shape and its coefficient of drag.

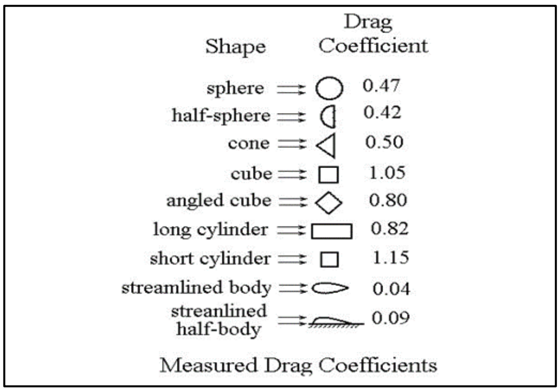


Figure 1.1: Basic shape and its drag coefficient (Foreman, 2011)

This project focuses on designing the aerodynamically efficient of the urban car through front face design optimization. The body design of the urban car needs to meet the high aerodynamics performance in order to reduce the usage of fuel. By using a systematic engineering design tools such as CATIA, Hyperworks, a few shape design variations can be tested and simulated iteratively in order to determine the lower drag coefficient. Once the best aerodynamics design is achieved, the prototype of the urban concept car can be developed.

In order to design and develop this concept car with an aerodynamically efficient, two methods usually used; either computer modelling or wind tunnel experiment. Figure 1.2 and Figure 1.3 shows an example of using wind tunnel and computer modelling to determine the aerodynamics of a vehicle.

Figure 1.2: wind tunnel testing (“Volkswagen New Polo - Car Body Design,” 2009)

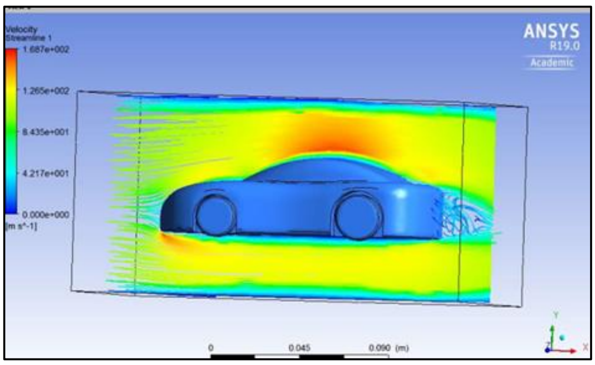


Figure 1.3: Computer Modelling testing (Qadoos, 2013)

However, wind tunnel experiment is the most accurate method to get a result. While the simple way to do testing on the aerodynamics of a vehicle is by using a Computational Fluid Dynamics (CFD). CFD is a software used to analyze the fluid flows on a vehicle by using numerical analysis and data structure. Another researcher had done research on determining the percentage of differences between using wind tunnel and CFD. It shows that the result of using simulation have a deviation of less than 15% compared to wind tunnel result (Sapian, 2009).

1.2 Problem Statement

The aerodynamic design of a car is one of the important elements in order to lower fuel consumption. A small change to the body design can affect the drag coefficient of the car especially by changing the shape of front face since it contributes the effect up to 65% for the front face (Lajos, 2002). Thus, this project is focusing on shape optimization on the front portion of the Shell Eco-Marathon urban car to get the most aerodynamic design without compromising its aesthetic look.

1.3 Objective

1. To propose and design an aerodynamically efficient design of the urban car.
2. To examine the effect of the proposed modification on the aerodynamic drag.

1.4 Work scope and limitation

This study focuses on the exterior design of an urban car with simulation on its aerodynamics performance using systematic engineering design tools. The main priority of this focus design is the front face of the urban car. A shape design on the front face of the car needs to be tested and simulated in order to make a comparison between the result to determine the best design.

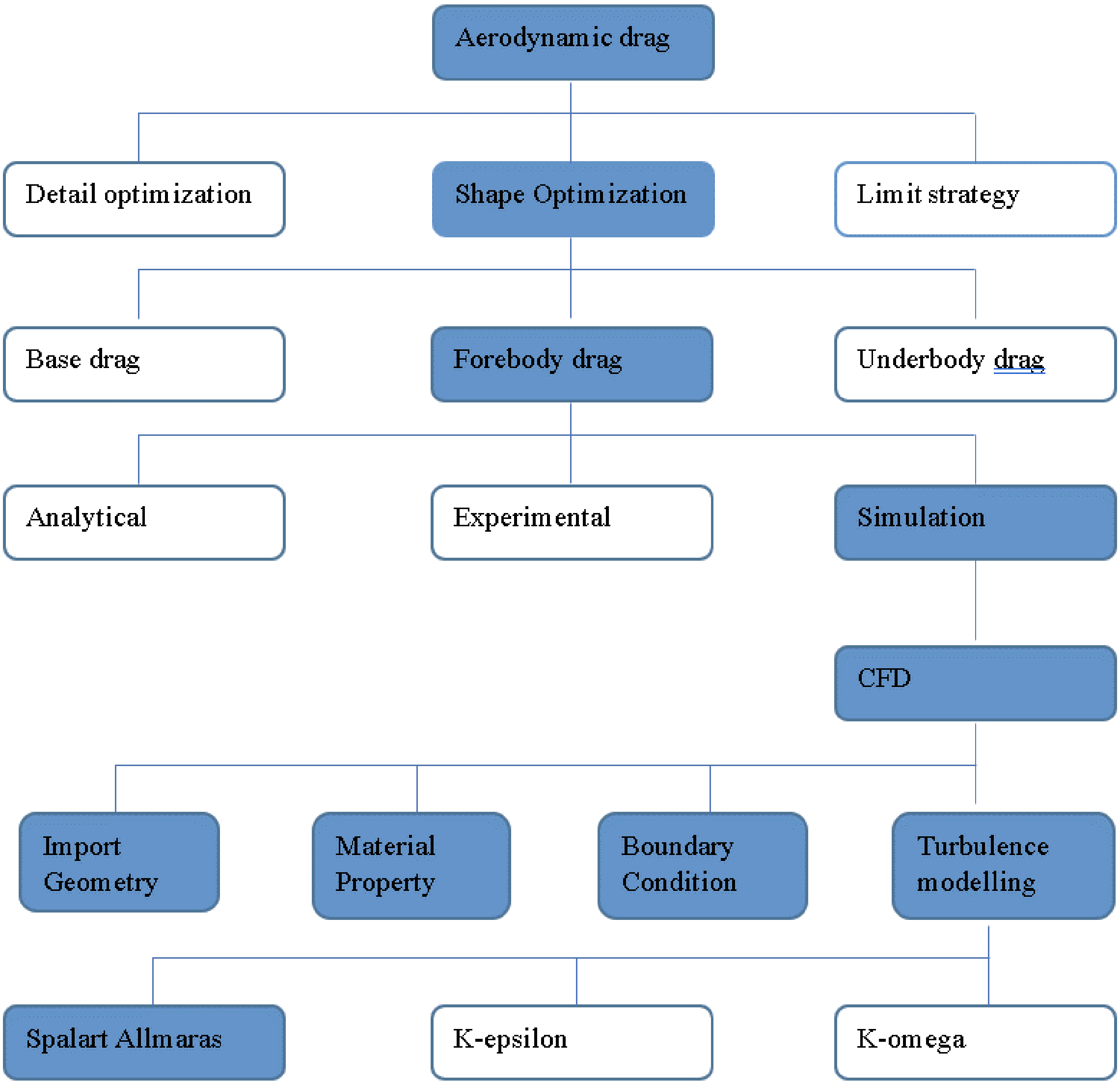
The limitations of this project are shown below;

1. To study the effect of shape optimization on the front face of the car. The front exterior of the car will be covered in this project.
2. The interior and engine modification will not be included in this project
3. CAD data will be generated from conceptual drawing for analysis and optimization.
4. The simulation is using CFD solver, Hyperworks Acusolve on half car body in steady state analysis. Turbulent equation Spalart-Allmaras is to be used for turbulence modelling.

1.5 Expected result

With all the planning and preparation that have made for this project, there is nothing else need to be expected rather than to design an urban concept car with an efficient aerodynamic. The drag coefficient of the urban concept car is expected to be at the minimum value to achieve efficient aerodynamic.

1.6 K-Chart


Aerodynamic drag
Detail optimization
Shape Optimization
Limit strategy
Base drag
Forebody drag
Underbody drag
Analytical
Experimental
Simulation
CFD
Import Geometry
Material Property
Boundary Condition
Turbulence modelling
Spalart Allmaras
K-epsilon
K-omega

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter, a brief review of literature is provided on the following topics: introduction to aerodynamics drag, development strategy of a vehicle, area of optimization, method of finding result and Computational Fluid Dynamic (CFD). All the discussion is based on the previous study from other researchers, books, articles, and other sources.

2.2 Aerodynamic drag

Research on efficiency aerodynamics properties on a vehicle road has captured more attention in the automotive industry nowadays since they aim on developing a vehicle with low fuel consumption. Besides that, aerodynamics also contributes to many elements such as minimize wind noise, prevent droplet of rainwater from accumulating on the windshield, to cool the engine compartment, control the directional stability of the vehicle and so on. Anyhow, while discussing on a fuel economy and consumption, this category is determined by aerodynamic drag.

Aerodynamics drag of automotive is mean by a drag force that acts on the body of moving vehicle when the vehicle is trying to move through the air. Having a high aerodynamic drag on a vehicle will increase the fuel consumption as the pressure that act on the vehicle is high. It means that the engine needs more power to overcome the pressure between air and the body of the vehicle. Reducing a aerodynamics drag may lead the vehicle having a low fuel consumption. Howell, J., & Gaylard (2006) state that 10% of improvement in aerodynamics drag can lead to almost 3% improvement in fuel consumption. So far, there are three strategies that can be used on a car development which is detail optimization, shape optimization, and limit strategy. Details on those three development strategies will be discussed in the section.

2.2.1 Detail optimization

During the late of the 1960s, detail optimization strategy of aerodynamics has been used in the development of a vehicle. Details optimization is the optimization that can be done on some aspects of the car without impairing the styling on the car. Figure 2.1 offer an insight to the strategy called detail optimization.

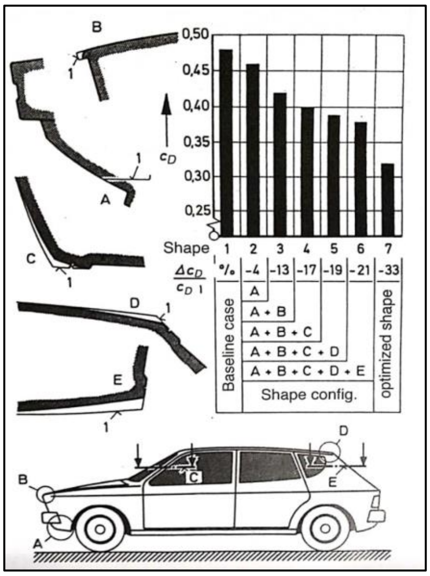


Figure 2.1: Detail optimization of a hatchback car (Schuetz, 2016)

Those five elements shown in the figure above are the example of the component that can be optimized without changing the styling of the car model. Overall, the drag coefficient can be reduced by up to 21% (Schuetz, 2016). However, the detail optimization strategy has its limitations that the coefficient of drag below 0.40 is hardly be realized due to the rules of "no change in styling" (Schuetz, 2016).

2.2.2 Shape optimization

After realized the limit of the coefficient of drag below 0.40 is hard to get, the industry of automotive came out with a new strategy called shape optimization. To get started with this strategy, a low drag basic body must be developed. The shape of the basic body was formed with a rough sketching body of revolution. Then, a concept design of a car can be designed from the basic body by adding the real vehicle shape. This steps of this development from a basic body are lined up in Figure 2.2.

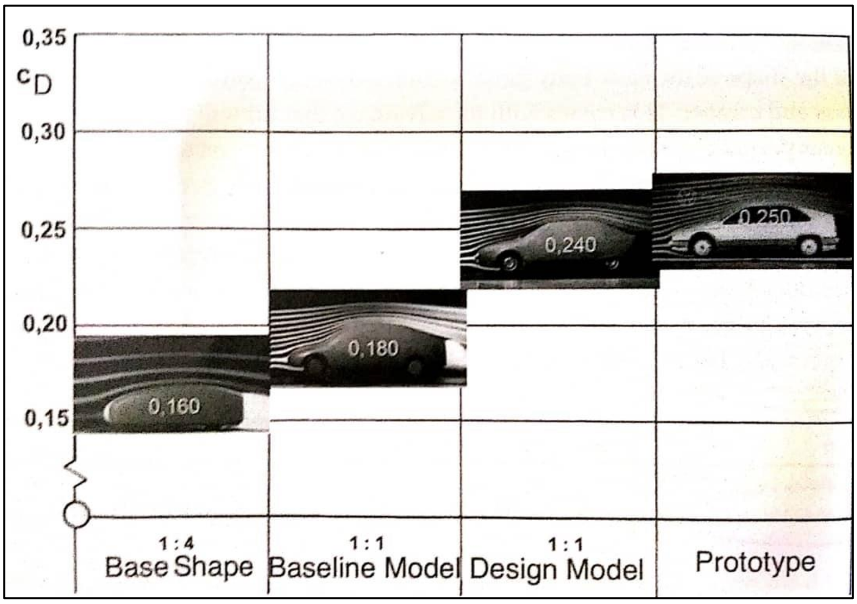


Figure 2.2: Shape development of body (Schuetz, 2016)

Numerous studies on shape optimization have shown a significant improvement on the aerodynamics of the vehicle by adding some devices such as vortex generator, spoiler, and others. According to Srinivas (2015), 25% of the aerodynamics could be reduced by adding a vortex generator on the roof of a car. Furthermore, another researcher had researched on the effect of adding a spoiler to the aerodynamics. It shows that by adding a spoiler on a car had an average of 15% drag reduction when the spoiler is placed (Ramya, Moturi, Kumar, & Ramanaiah, 2016).