UNIVERSITI TEKNIKAL MALAYSIA MELAKA

INTRODUCTORY OF DIMPLE TO AHMED BODY TOP SURFACE AS A DRAG REDUCTION DEVICE BY USING DOE APPRAOCHES

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

By

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APPROVAL

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

……………………………………..

(Project Supervisor)

ABSTRACT

Buses are one of the important public transport for nowadays. The large size of the bus experienced a large aerodynamics drag when travelling in long distance at high speed. The objectives of this research is to optimize the introductory of dimple on the top surface of Ahmed Body to decrease the drag coefficient by using Design of Experiment (DoE) approaches and to investigate fuel consumption reduction using the parameter analyzed from the optimized drag coefficient. First, a geometry design called Ahmed Body was chosen to simulate in this research because it is a simple 3D bluff body representing a very simplified car (Beaudoin & Aider, 2008). A benchmark model of Ahmed Body with some changes of no back slant angle was developed in order to represent the actual geometry of bus and it was simulated in virtual wind tunnel test to obtain the benchmark drag coefficient. In the part of DoE, four factors with each factor has two parameters were listed down. By applying two level factorial design, 16 possible combinations of the matrix design were developed and simulated in virtual wind tunnel. The results obtained was been carried out the optimization process in order to determine the best combination design that has the least drag coefficient. The design model with the dimension of dimple shifting of 104.4mm, 39.7mm diameter of dimple, 4.06m^2 dimple coverage area and the depth of 2mm for the dimple was been selected as the optimized model. The optimized model of Ahmed Body was simulated in virtual wind tunnel and it showed that about 36.5% drag coefficient was reduced and this helped to reduce 18.54% of fuel consumption if the optimized design was applied to real bluff vehicle such as bus. Finally, this research has successful achieved the objectives through adding dimple on the top surface of Ahmed Body.

ABSTRAK

Pengankutan bas mempermainkan pernanan yang penting dalam masa kini. Bas yang bersiaz besar mengalami rintangan aerodinamik yang kuat apabila bergerak dalam kelajuan cepat. Oleh itu, objektif-objektif kajian ini adalah untuk mengoptimalkan pengenalan “dimple” pada permukaan atas Ahmed Body untuk mengurangkan pekali rintangan aerodinamik dengan menggunakan cara Design of Experiment (DoE). Selain itu, tujuan kajian ini adalah untuk menyiasat pengurangan penggunaan minyak petrol dengan menggunakan parameter yang dianalisis dari pekali rintangan aerodinamik yang dioptimumkan. Berdasarkan Beaudoin dan Aider (2008) bahawa Ahmed Body merupakan salah satu model yang biasa dipilih untuk menujikan ciri-ciri aerodinamik. Jadi, model Ahmed Body telah dipilih sebagai model disimulasikan dalam kajian ini. Satu piawaian model Ahmed Body dengan ketiadaan sudut condong bahagian belakang telah dicipta untuk mewakili geometri bas sebenar dan model ini telah disimulasikan dalam ujian terowong angin untuk mendapatkan piawai pekali rintangan aerodinamik. Selain itu, dalam bahagian DoE, empat faktor telah disenaraikan dengan setiap faktor mempunyai dua parameter masing-masing. Dengan menggunakan dua tahap reka bentuk faktorial, sebanyak 16 kombinasi reka bentuk matriks telah diciptakan dan disimulasikan dalam ujian terowong angin. Keputusan yang diperolehi telah dioptimalkan untuk mendapat kombinasi reka bentuk yang optimum deangan mempunyai pekali rintangan aerodinamik yang paling rendah. Kombinasi reka bentuk itu menunjukan bahawa dimensi pergerakan “dimple” daripada 104.4mm, “dimple” diameter 39.7mm, kawasan liputan dimple 4.06m^2 dan 2mm kedalaman “dimple” itu telah dipilih sebagai model optimum. Selepas itu, model Ahmed Body yang dioptimumkan telah diuji sekali lagi dalam ujian terowong angin dan keputusan-keputusan diperolehi menunjukkan bahawa sekira-kira 36.5% pekali rintangan aerodinamik dikurangkan dan ini membantu kenderaan-kenderaan menjimatkan sebanyak 18.54% penggunaan

minyak petrol jika reka bentuk dioptimumkan itu diaplikasikan dalam kenderaan sebenar seperti bas. Akhir sekali, kajian ini telah berjaya mencapai objektif-objektif kajian ini dengan melalui menambah “dimple” pada permukaan atas Ahmed Body.

DEDICATION

This report is dedicated to my beloved family, friends and my supervisor who always encourage and guide me during this final year project research. Lastly, my final report group mates and supervisor who were always been there when I need help and guide for my final year project research.

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LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

DoE	-	Design of Experiment
UAV	-	Unmanned Aerial Vehicle
HPV	-	Human Powered Vehicle
C_DA	-	Aerodynamic Drag Area
CFD	-	Computational Fluid Dynamics
VG	-	Vortex Generators
Θ	-	Angle
H	-	Height
L	-	Length
W	-	Width
E	-	Length of Back Slant
R	-	Radius
k	-	The Number of Factors to Be Investigated
L	-	Liter
G	-	Fuel Consumption
C_D	-	*Drag Coefficient*
C_r	-	*Rolling Resistance*
C_p	-	*Pressure Coefficient*
F_D	-	*Aerodynamics Drag Force*
F_R	-	*Rolling Resistances*

F_x	-	*X-Traction Force*
P_D	-	*Wind Resistance*
P_T	-	*Friction and Transmission Resistance*
P_R	-	*Rolling Resistance*
B	-	*Fuel Consumption per Unit Distance with Unit*
P_A	-	*The Accessories Power*
P_∞	-	*Freestream Static Pressure*
$A\ /A_{ref}$	-	*Cross Sectional Area of Vehicle*
$\rho\ /\rho_{air}$	-	*Density of Air*
c	-	*Unit Conversion Factor*
ρ_f	-	*Fuel Density*
b_e	-	*Brake Specific Fuel Consumption*
η_D	-	*Drivetrain Efficiency*
t	-	*Time of Travel*
m	-	*Mass of Vehicle*
g	-	*Gravitational Acceleration*
v	-	*Vehicle Velocity*
$\frac{\Delta G}{G}$	-	*Change in Fuel Consumption*

CHAPTER 1

INTRODUCTION

1.0 Background

Bus is one of the common public transport around the world serve over few decades and due to shortage of fossil fuel, the government forced to rise the fuel prices and for those bus manufacturer have to come out a design which produce a better fuel efficient buses. There is a tractive resistances need to overcome by the moving vehicle which involved rolling resistance and aerodynamics resistance. When the vehicle is travelling in low speed, the rolling resistance plays the dominant over the aerodynamics resistance. However, this condition has been changed as the vehicle's speed increase. At the higher speed, the aerodynamics resistance had dominates the rolling resistance.

Nowadays, the vehicle dimension can be categorized as bluff body shape and streamlined shape. For bluff body such as truck vehicle, about 50% of petrol was consumed to over the aerodynamic drag at high speed (McCallen et al., 1999). In order to reduce the drag coefficient, there are two categories of drag reduction device that can be applied on the vehicle which are active drag reduction device and passive drag reduction device. Due to complicate and expensive reason, active drag reduction device is impractical while compared to passive drag reduction device. The passive drag reduction devices included deflector, boat tails, fences, vortex generation, splitter plates and non-smooth surface.

Among the techniques mentioned above, by adding the non-smooth surface devices such as dimples on the vehicle can be practically reduce its drag coefficient up to 50% (Harun et al. 2016). The concept of the design is actually adapted from the concept of dimples on the golf ball. The dimples help to early induce the turbulent vortex at lower

Reynolds number and caused the smaller wake produced at the end part of the ball (Chear & Dol 2015).

1.1 Problem Statement

The large size of the bus experienced a large aerodynamics drag when travelling in long distance at high speed. Normally, drag force can be divided into 2 types which are pressure drag and friction drag. Fiction drag is related to the boundary layer is induced which the front and rear parts has a huge pressure difference and this will affected the fuel consumption (Martin Alcantara et al., 2014)， (Chear & Dol 2015). According to research obtained, when a vehicle is travelling in 100 km/h, the aerodynamics drag caused the heavy vehicle consume about 65% of the total energy consumption and for medium-size sedan it caused it to consumes around 20% of the fuel consumption (Jing et al., 2010), (Wang et al., 2016).

There are two main factors that affect drag coefficient of bluff body which are the roundness of its front corner and the flow separation at its rear end. Hence, in this research we just focus on the flow separation which are reducing the boundary layer or the wake. Based on the stimulation results showed that by adding a designed dimples on vehicle roof and engine cover able to reduce the drag coefficient up to 10.31% when the vehicle is travelling in the speed of 30 m/s (Song et al., 2011). This is due to the dimples able to create an early transition to turbulent boundary layer and this helps the flow attached to the surface and reducing the boundary (Toet 2013).

The increasing of fuel cost and environment burden on fossil fuel should widely concerned in automotive field. Based on this research, reducing the drag coefficient able to help the automotive manufacture company to design a vehicle with least fuel consumption by adding a passive drag devices without changing the exterior design which are complicated and costly. The vision of this research is to help local bus company to reduce the fuel consumption of each buses by adding the drag reduction devices.

1.2 Objective

Based on the problem statement discussed, the objectives of this study are:

- To optimize an introductory of dimples on the top surface of Ahmed body to decrease the drag coefficient by using DOE method.
- To investigate fuel consumption reduction using the parameter analyzed from the optimized drag coefficient.

1.3 Scope

The scope of this research is mainly focus on the optimization of introductory of the dimples on the top surface of the Ahmed body and we did not cover for the both side and front surface. Aerodynamic drag contained two main component which are pressure drag and skin friction drag. In this research, we just focus on the pressure drag but not skin friction drag due to the pressure drag occupy majority of the total drag when the vehicle is travelling in high speed and it can be affected by the vehicle geometry because of the boundary layer separation which form the wake region at the vehicle rear end part. Based on previous research, the middle front section of the top surface of Ahmed body showed the least drag coefficient when the dimples is added (Latif et al., 2016). Hence, in this research we just focus on the middle front section of the top surface of Ahmed body to carry out the optimization by shifting the position of dimples with certain dimension in order to get a better stimulation result for least drag coefficient and less boundary layer separation by using Design of Experiment (DoE) approach. Furthermore, before carry out the DoE, four factors are listed to test and each factor has two parameters so that the result of DoE able to show which of the factor affect the response significantly.

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

In this chapter will discuss about the previous research that related to aerodynamics drag according to the k-chart as shown in ***Figure 2.0***. Based on the k-chart, it can be categorized types of Vehicle, Drag Reduction Technique, Drag Reduction Devices, and Simulation Method. In the Simulation Method category, it is included Design of Experiment (DOE), Hypermesh, MINITAB and Vehicle Fuel Consumption. The literature review will discuss from the general term of vehicle until the objective of this project which is vehicle fuel consumption.

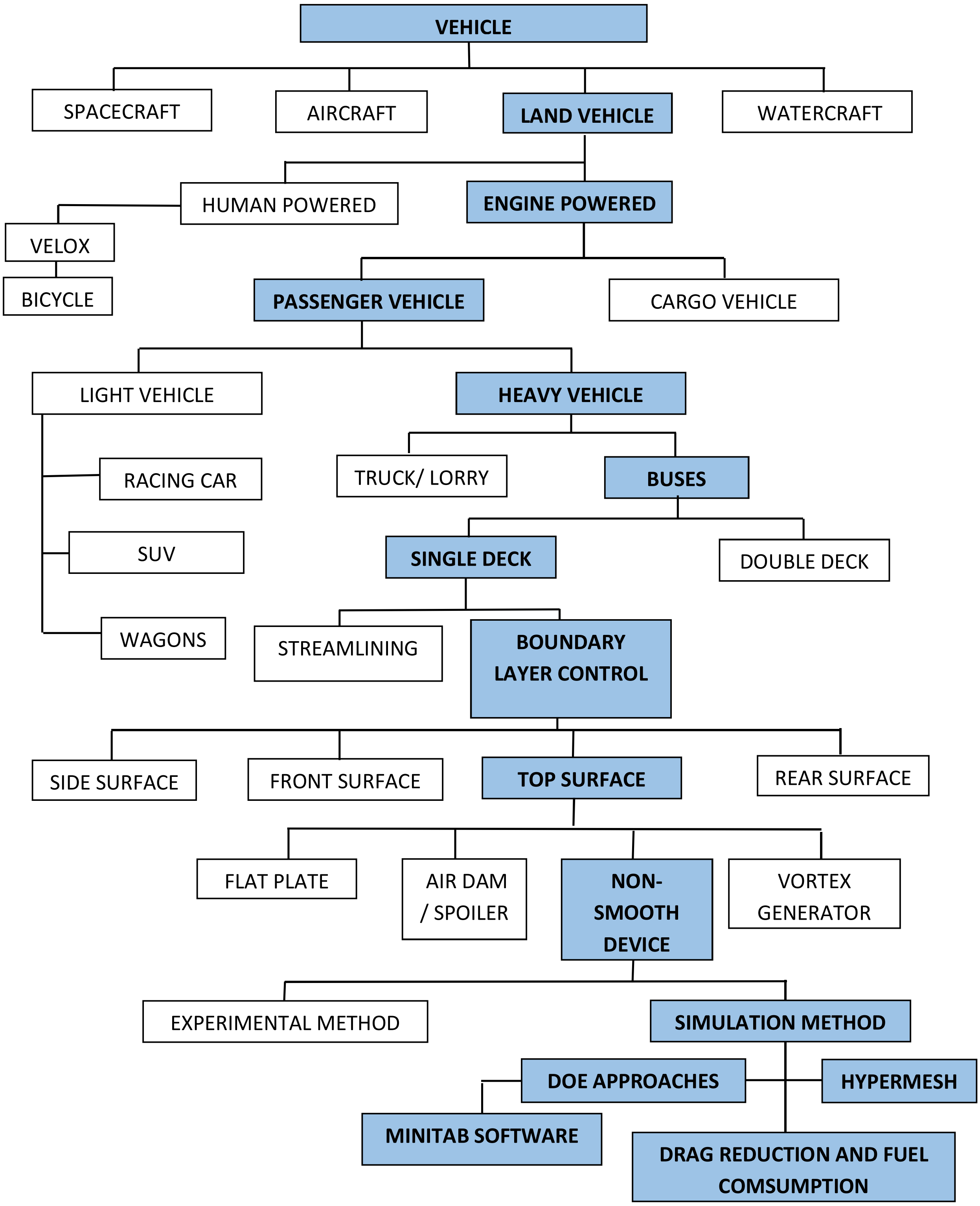

Figure 2.0: K – Chart

2.1 Vehicle

With the problem of drying up fossil fuel and increment of petrol price, the concerns of energy saving and environmentally friendly are been rose. The issue of aerodynamics had given impacts to the fuel consumption efficiency no matter in aircraft, watercraft or land vehicle.

2.1.1 Watercraft

For a vessel, it must be designed to move smoothly through the water with the minimum resistance. Hull resistance is the amount of force required by the vessel to move through the calm water at the certain speed. Recently, a device known as interceptors have been widely used catamaran for ride control and steering. A study was carried out and the results showed that interceptors that applied on the high speed yachts have high effective in reducing drag. About 10% or greater resistance reductions were found on the boat which the speed over around 8 knots, even at the low speed it has shown about 5% resistance dropped (Day & Cooper, 2011).

During the vessel travelling, around 50% of the total resistance is came from skin friction of fluid, while for submarine the ratio increased up to 70% (Gu et al., 2014). Based on the phenomena of lotus effect, the water droplet remains on top of the tip and unable infiltrate into the pits due to the surface repels the droplet and this phenomena similar with the technique of coating a superhydrophobic surface on the ship. This technique was introduced into drag reduction of watercraft. There are 50% drag reduction is achieved in laminar flow when the silicon wafers is coated with two hydrophobic nano-coating which are nanobrick and nanograss (Henoch et al. 2006). Same thing goes on with the aluminum surface which coated with a hydrophobic Al_2O_3 micro and nanoparticles coating. The dual structure roughness revealed a better drag reduction which is 77% for the turbulent flow (Taghvaei et al. 2017).

2.1.2 Aircraft

In the last 20 years, the use of riblets for viscous drag reduction has been highly concerning. For the commercial transport aircraft, the viscous drag consumed about 40% - 50% of the total drag under cruise condition. Thus, a small amount of the drag reduction, it would effectively effect the cruise condition (Ancelle et al. 1992). Riblets is the surface that are micro-grooved and aligned to the freestream direction. Viswanath found that with the optimized riblets, up to 5 – 8% of the drag is reduced and it been measured on 2D airfoils at low incidence. This is due to the riblets delaying the laminar-turbulent boundary layer transition (Viswanath, 2002).

In aerospace, there are many optimization methods have been developed and could be used in research. By designing an unmanned aerial vehicle (UAV) with a morphing wing that able independent span and chord changes, it demonstrated a drag reduction of up to 23% when compared to non-morphing model (Gamboa et al. 2009). This output is been proven by study, the wind tunnel test demonstrated that by morphing the upper surface of wing results in delay of the transition of laminar-turbulent flow (Sainmont et al. 2011).