DESIGN AND ANALYSIS OF VORTEX GENERATOR FOR UMP HEV USING CFD

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ABSTRACT

This thesis is doing vortex generator model with new high to overcome unstable airflow problem in rear car parts. So, with addition vortex generator on rear parts of proton iswara type Hybrid Electrical Vehicle (HEV) will decrease instability air movement on rear car parts. Beside that, addition of vortex generator in rear roof of car is to decrease high pressure and zero velocity area. It is because to make stability of car.Design of vortex generator is done based on shape Proton Iswara vortex generator but only with different high. The vortex generator high is determined based on this study. In this study, 3 velocities (90,100 and 110 km/h) will analyze using cosmosfloworks. Each velocity of car model will analyze with and without vortex generator. Based on this study, addition of vortex generator on rear car able to decrease total area of high pressure and low or zero velocity. This can be seen with decreasing of airflow in the rear car. It is because the vortex generator can be reduce the turbulent boundary layer flow.

ABSTRAK

Tesis ini telah membuat model vortex generator dengan ketinggian yang baru bagi mengatasi masalah pergerakan angin yang tidak stabil pada bahagian belakang kereta. Jadi penambahan vortex generator pada bahagian atas belakang kereta Proton Iswara jenis Hybrid Electrical Vehicle (HEV) akan mengurangkan ketidakstabilan pergerakan angin pada bahagian belakang kereta. Selain itu tujuan penambahan vortex generator di atas bumbung bahagian belakang kereta adalah bagi mengurangkan kawasan yang bertekanan tinggi dan berhalaju sifar. Ini bertujuan untuk meningkatkan kestabilan sesebuah kereta.Rekabentuk vortex generator ini berdasarkan bentuk vortex generator untuk Proton Iswara tetapi hanya ketinggian yang berbeza. Ketinggian vortex generator ditentukan berdasarkan kajian ini. Di dalam kajian ini, 3 kelajuan(90,100 dan 110km/h) telah dianalisis menggunakan Cosmosfloworks. Dan setiap kelajuan itu model kereta akan dianalisis dengan dan tanpa penambahan vortex generator.Berdasarkan kajian ini penambahan vortex generator pada bahagian belakang kereta dapat mengurangkan jumlah kawasan bertekanan tinggi dan berhalaju rendah atau sifar. Dan ini dapat dilihat dengan penurunan pergerakan angin dibahagian belakang kereta tersebut. Ini disebabkan penggunaan vortex generator dapat mengurangkan turbulent boundary layer.

TABLE OF CONTENTS

LIST OF FIGURE

LIST OF TABLES

LIST OF SYMBOL

CAD	-	Computer Aided Design
VG	-	Vortex generator
HEV	-	Hybrid electrical vehicle
EV	-	Electric Vehicle
CFD	-	Computational fluid dynamics
C_L	-	Lift coefficient
C_D	-	Drag coefficient
F_D	-	Drag force
F_L	-	Lift force
^0C	-	Temperature
V	-	Velocity
km/h	-	kilometer per hours
A	-	Area
L	-	Length
W	-	Width
PNGV	-	Partnership of new generation of vehicle
kg	-	Mass(kilogram)
NEDC	-	New European driving cycle
W/h	-	Watt per hour
kW	-	kilowatt
ρ	-	Density
μ	-	velocity
τ	-	Shear stress
δ	-	Displacement
dp/dy	-	Pressure gradient
$d\mu/dy$	-	Velocity distribution

Re	-	Reynolds number
u	-	Dynamics viscosity
m	-	Meter
m/s	-	meter per second

LIST OF APPENDIX

CHAPTER 1

INTRODUCTION

1.1 Introduction

Nowadays the automotive aerodynamics technology becomes well known. Every time cars are produce. There are improvements of the cars. When we look at the first model car, the design of car not like latest model car. It is because after one car was produce, the engineers will be improve the quality of car such as improve the safety for passenger or add the new technology for the car.

As an example, in vehicle body development, reduction of drag is essential for improving fuel consumptions and driving performance and if an aerodynamically refined body is also aesthetically attractive, it will contributed much to increase the vehicle appeal to potential customers.

However as the passenger car must have enough capacity to accommodate passengers and baggage in addition to minimum necessary space for its engine and others components; it is extremely difficult to realize an aerodynamics ideal body shape. The car is therefore obliged to have a body shape that is rather aerodynamics bluff not an idea streamline shape as seen on fish and birds. Such as body shape is inevitably accompanied by flow separation at the rear end. The passenger car body's aerodynamics bluffness.

In aeronautical field, it is important to measure the best drag and lift force of an airplane in order to lower the stall speed of the plane and improve the stability. To achieve that, vortex generator increases the mean stream wise momentum of the boundary layer by drawing in high momentum fluid from the free stream [1].

If the same principles applied into the sedan car, theoretically the drag coefficient can be reduce by the help of vortex generator.

1.2 Project Objective

i. To reduce flow separation for normal car by using vortex generator
ii. Decrease lift at rear end and reduce overall the drag of car.
iii. To analyze the model car with and without vortex generator.

1.3 Project Scope

i. To understand flow properties on a car
ii. To make a CAD model of the HEV
iii. To use CFD software to analysis the flow properties

1.4 Background

A simple definition of aerodynamics is the study of the flow of air around and through of vehicle, primarily if it is motion. Aerodynamics developments play a vital role in vehicle like cars, either in reducing drag or generating downforce. This downforce or negative lift generated by the car increase the vertical load on the tires, thus increasing tire friction. When a car moves at speed 90km/h and above, the space at rear window is empty and like as a "vacuum" and there have a force to upward the rear car.

So this research will be investigation and focus at rear window of Hybrid Electrical Vehicle (HEV) which turbulence boundary layer will happen at the speed 90km/h and above. So this situation will be formation the lift. And for reduce the lift and overall drag, this research will investigation how the vortex generator can be influence boundary layer and reduce the lift and overall drag of a car when the vortex generator is added at the rear roof car and near the rear window.

The function of vortex generator likes as rear spoiler but is different in shape and size. So this research considers the concept of aerodynamics of a car and boundary layer to design the vortex generator. For design the vortex generator, these researches also consider symmetrical aerofoil and the NACA0015 were choosing for this research. NACA015 was choose because it is a symmetrical aerofoil and the point of design vortex generator is suitable with it.

1.5 Problem Statement

The problem for HEV at high speed is the air flow over the top of the car tends to create a low pressure area towards the rear which literally lifts the back end of the car, reducing traction and increasing instability.

The process to improve the aerodynamics design of a vehicle required a long research and high cost to redesign the aerodynamic features. It may take many years to develop the desirable aerodynamic design.

So one of the methods to solve this problem is usage vortex generator in rear roof.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter has been covered the scope of literature review of this project. Before design the vortex generator, we should be understanding about aerodynamics of a car to know how the airflow around a car. Otherwise we should know the base of lift and drag force on a car.

Lift was defined earlier as the component of the net force (due to viscous and pressure forces) that is perpendicular to the flow direction [3]. And drag is defining the force a flowing fluid exerts on a body in the flow direction. Drag is usually an undesirable effect, like friction and we do our to minimize it [3]. So reduction of drag is closely associated with the reduction of fuel consumption in automobiles.

Drag coefficient and the lift coefficient were expressed as:

$$C_L = \frac{2F_L}{\mathrm{p}V^2 A} \qquad [2.1]$$

$$C_D = \frac{2F_D}{pV^2 A} \qquad [2.2]$$

where C_L is lift coefficient and C_D is drag coefficient F_L is refer to lift force and it generated by a small pressure differential between the upper and lower surfaces of the wing caused by the aerodynamic reaction to the wing motion through the atmosphere, F_D is refer drag force, ρ is refer the density and for this case it consider the air density at temperature 25^0 C, V is refer to velocity and this research the velocity be consider 90 km/h until 110km/h and A is normally refer the frontal area (the area projected on a plane to the direction of the flow). In other words, A is the area that would be seen by a person looking from the direction of the approaching fluid.

The frontal area of a car is $A=LW$ where L refer to length of car and W refer to width.

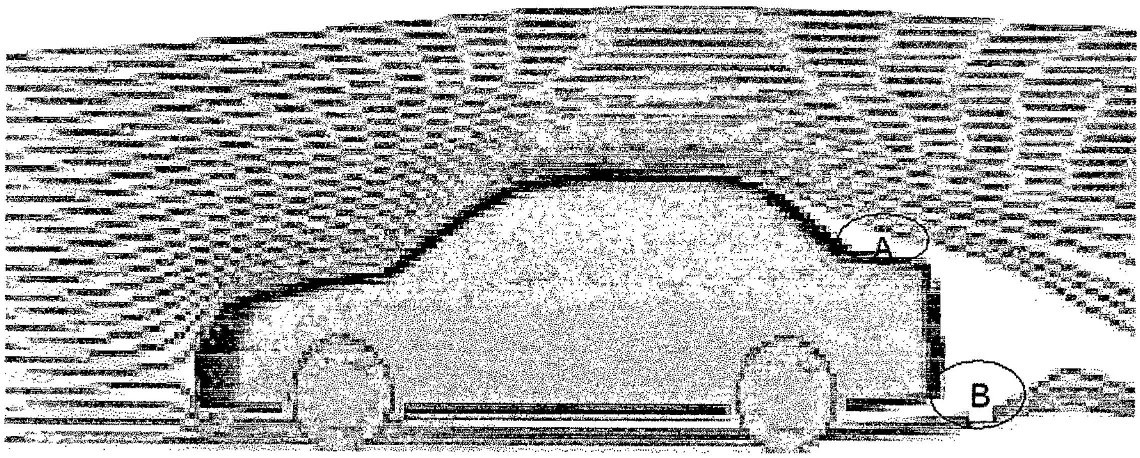

Figure 2.1 Flow around a car

If we refer at figure 2.1, we can see the flows around a car, and at point A: the flow not supported the rear body car and the flow at bottom car push the rear car. So when the car moving with the high velocity around 90km/h and above (especially 100-110km/h), the rear tires are very easy to lift and it is dangerous for passenger. Because of the presence of a trunk at the rear, the flow separates at the roof end and then spreads downward.

As a result, the flow around the car is similar to that around a streamline-shaped object with a taper at the rear. For this reason, an Iswara with a trunk tends to have smaller drag coefficient value. In other words, taper at the rear has the effect of delaying flow separation or shifting the flow separation point upstream or shifting the flow separation point upstream.

2.2 Hybrid Electrical Vehicle (Hev)

2.2.1 Definition of Hev

Hybrid electrical vehicle (HEV) combines the internal combustion engine of a conventional vehicle with the battery and electrical motor of an electric vehicle. As a result, HEVs can achieve the fuel economy of conventional vehicles. In combination, these attributes offer consumers the extended range and rapid refueling they expect from a conventional vehicle, as well as much of the energy and environmental benefits of an electrical vehicle. Other benefits of HEVs include improved fuel economy and lower emissions, in comparison with conventional vehicles. HEVs are inherently flexible, so they can be used in a wide range of applications from personal transportation to commercial hauling.

2.2.2 Development of HEV

Three ways are consider for efficient on board energy conversion of high energy liquid fuels to electric power [16].

i. Hydrogen production by a reformation process and use in a fuel cell.
ii. The direct methanol fuel cell, with less energy density of the liquid fuel, compared to gasoline.
iii. Producing electric power by an ICE-alternator unit for intermediate storage in a battery and adding to the efficiency of the drive train, combined with storage of regenerative braking energy.

From the three options above, only number three provide to the technology development requirement. The hybrid system consists of two storage units which are fuel tank and battery. This item leads two energy conservation units which are ICE and electric motor. All this item make a system knowing as hybrid drive train. All components required for the drive chain and consider the development of technology more that development of fuel development.

The potential of HEV is to reduce emissions and to increase mileage that has been demonstrated with many prototype of different kind of vehicle types. The most important thing in this system is the battery. The function is to provide energy to the engine but development of battery still need to be improving and for wide variety of usage.

2.2.3 Types of HEV

Series HEV made by adding an ICE-alternator unit to an EV to charge the battery. Battery and electrical motor provided traction power for the drive train for lead to power transmission and control. Figure 2.2 shows there are no reduction in motor and controller dimension and only minor reduction in battery capacity is possible.

In parallel HEV the electric engine and the battery are add-on is added to make a conventional drive train. Mechanical drive train assists on acceleration and regenerative the energy braking by contributes to the designed in order to define the level. Referring to Toyota designer of HEV, the ICE and electric motor are combined together for making the producing of torque is high. The combination is combining by a planetary gear which permits to select the power distribution between two branches of the power train.

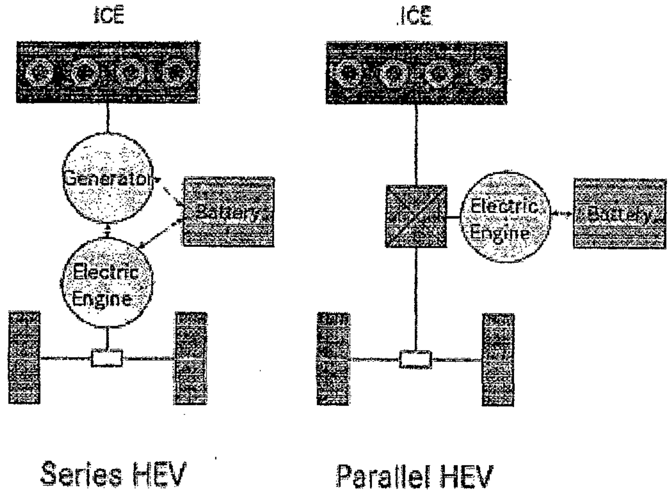

Figure 2.2 HEV Drives Train Examples

2.2.4 Battery Requirements for HEV

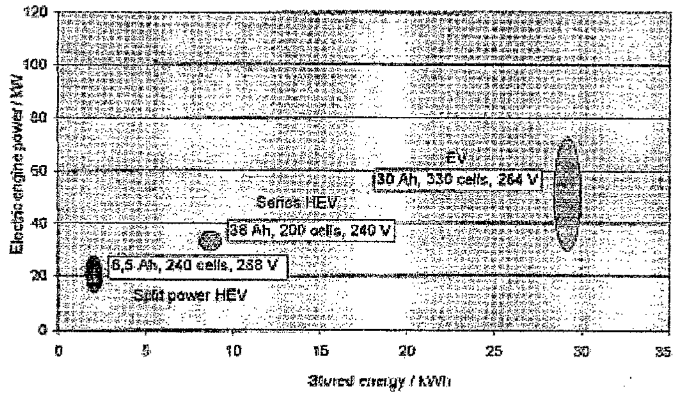

Figure 2.3 Examples for battery configurations for different EV and HEV

Figure 2.3 show the configurations of battery for different EV and HEV drive trains. The storage energy for three examples of batteries and power of the electric drive train is different according to the types of drive train. For example EV battery for Mercedes-Benz A class EV, three parallel strings of 110 cells make the different about the battery. For HEV series battery, a NiMH (Nickel oxide Metal Hybrid) system from DAUG is taken, about 30% of the EV capacity. The table below shows the specific power of the cells increasing from EV to parallel HEV batteries.

Table 2.1: PNGV definition/requirements of batteries for HEV

	Power assist, fast response engine	Power assist, slow response engine	Dual mode
Energy, kW h	0.3	3	8
Peak power, kW	25	65	65
Power to energy ratio, h^{-1}	83	22	8
Mass, kg	40	65	115

The battery requirement of HEV is define as the "partnership for a new generation of vehicles (PNGV)". Low requirement and dual batteries are demanding but the power needs to be high for make sure for the fast response battery with a power to energy ratio of 83.The main thing in HEV system and the most costly are the batteries and the electric motor. In order to overcome this problem with effective ways it is adequate to look for the minimum energy stored and increasing the power of the engine. The method can be done for maximum power handling are:

i. Regenerative braking energy and power uptake
ii. Power in the power assist mode of the electric motor to effectively slow down the response of the ICE

Figure 2.4 shows the power profile of a typical small size car. For a vehicle with 1130kg of total mass at the "new European driving cycle" (NEDC), the maximum energy to be accepted and stored during regenerative braking is about 100 W/h.

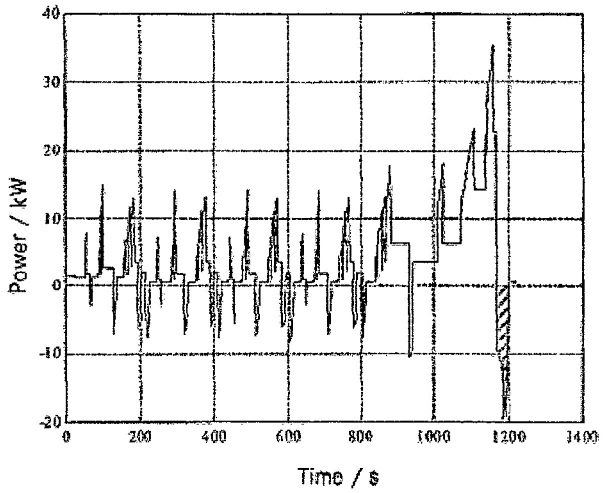

Figure2.4 Power profile of a 1130 kg car on NEDC

The exemplified of battery power assist fast response PNGV type seems to be an adequate choice with respect t the peak power(Table 2.1).

Cycle life really important to be consider in a battery. The power of 100W/h want to be stored should not constitute more than 10% of the battery capacity. This is to make sure more than 100,000 cycles can be produce during a vehicle life time. This is a very crude estimate, because few data indicating a relationship of cycle number on depth-of-discharge DOD are available with statistic significance, together with all random parameters that influence cycle life.

For a 1kW battery is recommended in PNGV requirement compare to 0.3. The power to energy ratio demanded for according to figure 2.1 would then be 20, which is at the limit of present NiMH cells.

Table 2.2: Cell size for 200-300 V, 1kW/h power assist HEV battery

	NiMH	Li-Ion
Cell number	167-250	56-84
Cell capacity, A h	5.0-3.5	5.0-3.5

For effectively electric drive trains the battery voltages is required in range of 200-300 V. NiMH and Li-Ion are more advanced battery system now and 1kW/h battery range of 200-300 V is shows below in the table 2.3. The battery is for all in series connected cells.

Table 2.3: HEV battery requirements

Specific power (discharge)	1 kW/kg
Specific power (charge)	1 kW/kg
Specific energy	40–50 W h/kg
Total energy stored	1–3 kW h
Battery voltage	200–300 V

For overall information provide above it can be summarize that the technical battery requirement for a cost saving and performance effective in HEV. From table 2.19 above the data show battery system weighing 50 to 100kg can be anticipated according to the car types and model. These considerations follow by the sufficient cycle life to perform adequately during operation and lifetime of the battery.

2.3 Aerodynamics

2.3.1 Definition

Aerodynamics is a branch of fluids mechanics and it concerned with the flow of air around objects. The flow processes to which vehicle is subjected falls into three categories [1]. The first categories is flow of air around the vehicle, second is flow of air around the vehicle's body and lastly is flow processes within the vehicle's machinery.

The first two flow fields are closely related [1]. For the example, the flow of air through the engine compartment depends on the flow field around the vehicle. Both flow fields must be considered together. On the other hand, the flow processes within the engine and transmission are not directly connected with the first two categories. They are not called aerodynamics and are not treated here.

Aerodynamics is one of the most important design criteria in cars. But this is no doubt that road vehicle aerodynamics has its roots in the aerodynamics of aeronautic. The importance of aerodynamics is not the same for a road vehicle as for an aero plane. The latter cannot 'live' without aerodynamics but vehicle can[1]. It's a very important concept as refining a car's aerodynamics can significantly increase road holding and cornering, increase top speeds and increase fuel efficiency. Some cars also take advantages of the airflow over them to aid in other function of the cars not linked directly with drag or downforce such as air intake to the engine.

2.3.2 Automotive Aerodynamics

Automotive aerodynamics is the study of the aerodynamics of road vehicles [14]. This study involves reducing drag, reducing wind noise and preventing undesired lift forces at high speed. It is also important to produce required downwards aerodynamics force to improve traction and cornering abilities in some class of racing car.

To have a small surface, the aerodynamics automotive will integrate the wheel and lights. To be streamlined, it does not have shape edge crossing the wind stream and feature a sort tail called fastback. The aerodynamics design will have a flat and smooth to produce desirable downwards forces. The air rams into the engine bay for used of cooling, combustion, passengers, reaccelerated by a nozzle and then ejected under the floor.

Automotive aerodynamic is much different from the aircraft aerodynamic such as road vehicle shapes is bluff, vehicle operates very close to the ground, operating speed lower, the ground vehicle has fever degrees of freedom and its motion is less affected by aerodynamic forces.

Total aerodynamic drag = C_d multiplied by the frontal area. The width and height of curvy cars lead to gross overestimations of frontal area [2].

The main considerations in aerodynamics of road vehicle are reducing drag, to increase top speed and fuel efficiency, and increasing downforce, so that the cars has more grip when cornering.