DESIGN AND ANALYSIS OF VORTEX GENERATOR
FOR A HEV MODEL

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A report is submitted in partial fulfillment
of the requirements for the award of the degree of
Bachelor of Mechanical Engineering with Automotive Engineering

Faculty of Mechanical Engineering
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SUPERVISOR DECLARATION

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering with Automotive.

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I declare that this thesis entitled “Design and Analysis of Vortex Generator for a HEV Model” is the result of my own research except as cited in the reference. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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DEDICATION

I would like to show my expression and gratitude to Allah Subhanahu wa Ta’ala whose guidance, help and grace was instrumental in making this humble work become a reality. Thanks to my beloved parent, Mr Ismail Bin Che Samad and Pn. Rohani Bte Mat Adam and to all by sibling and friends. Thanks also to all staff in Faculty of Mechanical Engineering from University Malaysia Pahang especially to my supervisor.
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ABSTRACT

Design and analysis of vortex generator by using Computational Fluid Dynamic (CFD) on Hybrid Electrical Vehicle (HEV) model was carried out on this project. One of the main causes of aerodynamic drag for vehicle is the separation of flow near the vehicle’s rear end. To control the flow separation, delta wing shaped vortex generator is test for application to the roof end of vehicle. A vortex generator (VG) is an aerodynamic surface, consisting of a small vane that creates a vortex. The model of vehicle that can be used to conduct this project is HEV model for Proton Iswara. The objective of the project is to determine the percentage of drag reduction by using VG, ranging from 60 km/h to 120 km/h that designed by Computational Aided Design (CAD) in SolidWorks software. Vortex generator themselves create drag, but they also reduce drag by preventing flow separation at downstream. The overall effect of vortex generators can be calculated by totaling the positive and negative effects. Drag coefficient can be obtained by using output of CFD then export into FEM analysis to find the value of drag force to be applied into aerodynamic drag coefficient equation. Besides that, CFD simulation results such as contour plot also used to analyze the characteristic of streamline flow at the rear end of HEV model. Comparison of drag coefficient between the model of HEV vehicle with and without vortex generator must be done to achieve the project objectives. The application of VG had shown that 6.61 percent reduction in aerodynamic drag coefficient.
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LIST OF SYMBOL

\( C_D \) Drag Coefficient
\( \rho \) Air Density
\( A \) Frontal Area
\( V \) Speed
\( F_D \) Drag Force
\( P \) Aero power
\( V_o \) wind velocity

LIST OF ABBREVIATION

HEV Hybrid Electrical Vehicle
CFD Computational Fluid Dynamic
VG Vortex Generator
CHAPTER 1

INTRODUCTION

1.1 Introduction to Vortex Generator

A vortex generator (VG) is an aerodynamic surface, consisting of a small vane that creates a vortex. Some surfaces on an airplane can result in air flow separation from the surface or skin. A vortex generator creates a tip vortex which draws energetic, rapidly-moving air from outside the slow-moving boundary layer into contact with the aircraft skin. This keeps the flow close to the aircraft surfaces. Vortex generators can be found on many devices, but the term is most often used in aircraft design. Vortex generators are also being used in automotive vehicles. In one form they are used as in aircraft to influence the boundary layer of air flow primarily for drag reduction. Vortex generators are likely to be found the external surfaces of vehicles where flow separation is a potential problem because VGs delay flow separation. The vortex is oriented by appropriate placement of the vortex generator in order to redirect airflow in the flow field so that adverse interactions are prevented or delayed. With this mechanism, the generators act as a flow deflector.
1.2 **Project Objectives:**

1) Design a vortex generator of HEV model.
2) To determine the percentage of drag coefficient reduction by Vortex Generator.

1.3 **Project Background**

Purpose of this project is to make vortex generator (VG) to develop HEV Model for Proton Iswara in UMP Mechanical Lab. This project involves designing and simulating a model of VG based on boundary layer theory. To select the appropriate shape and size of the VG which generate streamwise vortex, the most efficient shape is important to achieve the objectives. The thickness of the boundary layer is measured based on the assumption that the optimum height of VG would be nearly equal to the boundary layer thickness. Overall this project will acquire the skill of design and analysis using simulation software.

1.4 **Problem Statement**

There are two types of flow that occur on all vehicles, attached flow and separated flow. Separated airflow at the rear end of sedan vehicle is turbulent air and turbulent air increase drag. When separated flow is created it effectively expands the size of the hole and vehicle needs to punch a larger hole through the air as moving. This requires more energy and increase the drag. Now, this project must be continued to reduce the drag by adding the vortex generator at the rear end of vehicle in order to control flow separation.
1.5 Project Scopes

1) Study on aerodynamic drag reduction by Vortex Generator.
2) Design the model of VG with SolidWorks.
3) Model analysis using CFD in COSMOSFloWorks software.
4) Interpret result of drag force in FEM analysis by using COSMOSWork software.
CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter will provide detail description of literature review done regarding the project title of design and develop HEV model vortex generator based on boundary layer theory. In this literature review, it starts with the introduction to the vortex generator, external flow, boundary layer theory, drag coefficient, flow separation, optimum height vortex generator for vehicle and function of the vortex generators have been analyze and shown. These information are been used and been referring when develop the Vortex Generators (VG). This information is being got from the books, journals, websites and market survey.
2.2 Introduction to Vortex Generator

A vortex generator is an aerodynamic surface, consisting of a small vane that creates a vortex. Vortex generators can be found on many devices, but the term is most often used in aircraft design. Vortex generators are likely to be found on the external surfaces of vehicles where flow separation is a potential problem because VGs delay flow separation [4]. On aircraft they are installed on the leading edge of a wing in order to maintain steady airflow over the control surfaces at the rear of the wing. They are typically rectangular or triangular, tall enough to protrude above the boundary layer, and run in span wise lines near the thickest part of the wing. They can be seen on the wings and vertical tails of many airliners.

![Vortex Generator at rear end of vehicle](image)

Figure 2.1 Vortex Generator at rear end of vehicle

Vortex generators are positioned in such a way that they have an angle of attack with respect to the local airflow. A vortex generator creates a tip vortex which draws energetic, rapidly-moving air from outside the slow-moving boundary layer into contact with the aircraft skin. The boundary layer normally thickens as it moves along the aircraft surface, reducing the effectiveness of trailing-edge control surfaces; vortex generators can be used to remedy this problem, among others, by re-energizing the boundary layer. Vortex generators delay flow separation and aerodynamic stalling; they improve the effectiveness of control surfaces.
2.3 **External Flow**

External flows involving air are often termed aerodynamics in response to the important external flows produced when an object such as an airplane flies through the atmosphere. Figure below show the external flow around sedan vehicle for passenger car [1].

![External Flows over the Car](image)

**Figure 2.2 External Flows over the Car**

A streamline is a line that is parallel to the direction of flow of a fluid at a given instant or the path a given particle follows in a flowing fluid. A streamlined shape, therefore, is one that is constructed with a shape that offers a minimum resistance to fluid flow. Prime examples of streamlining are modern aircraft and just about any fish or sea mammal.

There are two types of airflow that occur on all vehicles; Attached Flow and Separated Flow. As far as is practical, vehicle designers strive to keep the flow of air as close to the vehicle skin as possible. This is attached flow, and from an aerodynamic streamlining viewpoint, it is much more preferable than separated flow [10].
2.4 Boundary Layer Theory

A boundary layer is that layer of fluid in the immediate vicinity of a bounding surface. In the Earth's atmosphere, the planetary boundary layer is the air layer near the ground affected by diurnal heat, moisture or momentum transfer to or from the surface. On an aircraft wing the boundary layer is the part of the flow close to the wing. The boundary layer effects occur at the field region in which all changes occur in the flow pattern. The boundary layer distorts surrounding nonviscous flow. It is a phenomenon of viscous forces. This effect is related to the Reynolds number. The character of the viscous flow around a body depends only on the body shape and the Reynolds number [2].

There are two types of viscous flow, laminar flow and turbulent flow. Laminar flow sometimes known as streamline flow occurs when a fluid flows in parallel layers, with no disruption between the layers. Turbulent flow is a fluid regime characterized by chaotic, stochastic property changes and unstable boundary layer [3].

2.5 Drag Coefficient

In a moving common car there are constantly forces acting to the car in which causes drag to overcome the resistance. It is dependent on the geometry of the body, motion of the body and the fluid in which it is traveling. Aerodynamic drag depends on the size of the vehicle (which characterized by its frontal area), the drag coefficient $c_D$ (which is a measure of the flow quality around the vehicle), and the square of the road speed $V$ [3].
\[ F_D = C_D \frac{1}{2} \rho V^2 A \quad (2.1) \]

\[ C_D = \frac{F_D}{\frac{1}{2} \rho V^2 A} \quad (2.2) \]

\( C_D \) = Drag Coefficient
\( \rho \) = Air Density
\( A \) = Frontal Area
\( V \) = Speed
\( F_D \) = Drag Force

Aerodynamic drag on vehicles can be reduced by streamline the body or by controlling boundary layer separation [12].

### 2.6 Flow Separation

Flow separation is one of the major problems in external flow [1]. Separated Airflow is turbulent air and turbulent air increases drag. When Separated Flow is created it effectively expands the size of the hole the vehicle makes as it passes through the air by adding to the dimensions of the sides, the top and the undercarriage so that aerodynamically, it is larger than it physically is. The vehicle punches a larger hole through the air.