

**FV MALAYSIA RACE CAR - BODYWORK DESIGN AND ANALYSIS**

**NAQUIDDIN BIN NASIRIN**

**B041210193**

**BMCA**

**Email: quedean149@gmail.com**

**Draft Final Report**

**Projek Sarjana Muda II**

**Supervisor: DR. MOHD AZMAN BIN ABDULLAH**

**2<sup>nd</sup> Examiner: DR. MUSTHAFAH BIN MOHD TAHIR**

**Faculty of Mechanical Engineering**

**Universiti Teknikal Malaysia Melaka**

**JUNE 2016**

## DECLARATION

I declare that this project report entitled “FV MALAYSIA RACE CAR – BODYWORK DESIGN AND ANALYSIS” is the result of my own work except as cited in the references

Signature : .....

Name : NAQUIDDIN BIN NASIRIN

Date : .....

## **APPROVAL**

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

Signature                   : .....

Name of Supervisor : DR. MOHD AZMAN BIN ABDULLAH

Date                         : .....

## **DEDICATION**

In the name (of) Allah, The Most Gracious, The Most Merciful.

Dedicated to my beloved mother and father.

## **ABSTRACT**

The purpose of this study is to identify aerodynamics properties of the race car. Aerodynamic is the main factor on how well performance of the car itself. Car with good aerodynamics properties will have better fuel economy and performance. Failure to have better aerodynamics properties will make the vehicle lose stability during high speed maneuvering. The aerodynamics properties include coefficient of drag, coefficient of lift, and effect on different speed travelling. This study use Formula Varsity race car model that designed by using CATIA software. Then, it was been analyzed by using ANSYS Fluent software. Result from the analysis can be used to find the coefficient of drag and coefficient of lift. It is also shown that coefficient of lift and drags on vehicle may be difference on different meshing size. The experiment is repeated by using several different speeds in order to see difference performance of vehicle. The finding may be useful in optimizing the aerodynamic properties of bodywork for future use.

## ABSTRAK

Tujuan utama kajian ini adalah untuk mencari ciri-ciri Aerodinamik pada sesebuah jentera perlumbaan. Aerodinamik merupakan salah satu faktor yang penting dalam mengukur prestasi sesebuah kenderaan tersebut. Kenderaan yang mempunyai ciri-ciri aerodinamik baik mampu mempunyai kadar ekonomi bahan api dan prestasi yang bagus. Kegagalan mempunyai kadar aerodinamik yang bagus mampu menyebabkan hilang kestabilan semasa pemanduan di kelajuan yang tinggi. Ciri-ciri aerodinamik yang termasuk adalah pekali daya seretan, pekali daya angkatan dan kesannya terhadap kelajuan yang berbeza. Kajian ini telah menggunakan model jentera perlumbaan FV Malaysia yang direka menggunakan perisian CATIA. Kemudian, model tersebut telah dianalisa menggunakan perisian ANSYS Fluent. Keputusan kajian dapat digunakan untuk mencari pekali daya seretan dan angkatan. Selain itu, ia daya pekali seretan dan angkat akan berubah apabila mempunyai saiz meshing yang berbeza. Kajian ini diulang menggunakan kelajuan yang berbeza dalam mencari perbezaan prestasi jentera. Hasil kajian amat berguna dalam mengoptimumkan ciri-ciri aerodinamik pada jentera masa hadapan.

## ACKNOWLEDGEMENT

I would like to express my deepest appreciation to my supervisor Dr. Mohd Azman bin Abdullah for giving me this opportunity to do final year project with him. He never hesitated to give me advice and guidance whenever I confronted problems. I am thankful for his patience and advice while leading me in this project.

Secondly, I would like to thank an assistant engineer En Mohd Firdaus bin Md Razali for spending his time to guide me and provide access to CAE Lab. He would share his knowledge in respective field with me and guide me to do a research. Also, I would like to their kindness in suggesting me the suitable time to use laboratory equipment for his action saved me a lot of time.

I would like to thank my sponsor through this research, Perbadanan Tabung Pendidikan Tinggi Malaysia for providing financial fund and also my parents who constantly provide financial support and moral support through studies. Other than that, I would like to thanks my fellow friends for giving me their support, patience and encouragement.

## CONTENT

CHAPTER	CONTENT	PAGE
	<b>SUPERVISOR'S DECLARATION</b>	iii
	<b>TABLE OF CONTENT</b>	viii
	<b>LIST OF FIGURES</b>	xi
	<b>LIST OF TABLES</b>	xiii
	<b>LIST OF ABBREVIATIONS</b>	xiv
	<b>LIST OF SYMBOLS</b>	xv
<b>CHAPTER 1</b>	<b>INTRODUCTION</b>	1
	1.1 Background	1
	1.2 Problem Statement	3
	1.3 Objective	3
	1.4 Scope Of Project	4
	1.5 General Methodology	4
<b>CHAPTER 2</b>	<b>LITERATURE REVIEW</b>	7
	2.1 Introduction	7
	2.2 Previous Study	7
	2.3 Aerodynamic Theory	11
	2.3.1 Drag Force	11
	2.3.2 Lift Force and Downforce	13
	2.3.3 Coefficient of Drag and Lift	15
	2.3.4 Boundary Layer	16
	2.3.5 Bernoulli Principle	17
	2.3.6 Reynolds Number	19
	2.3.7 Density of Gas	19



<b>CHAPTER 3</b>	<b>METHODOLOGY</b>	20
3.1	Introduction	20
3.2	General Experimenting Setup	20
3.3	Computer Aided Design	22
	3.3.1 Bodywork	23
	3.3.2 Tire	24
	3.3.3 Front Spoiler	25
	3.3.4 Rear Spoiler	26
3.4	ANSYS Software For Fluent Analysis	26
	3.4.1 Design Modelar	27
	3.4.1.1 Preparing Design	27
	3.4.1.2 Importing Geometry File	27
	3.4.1.3 Unit Change	27
	3.4.1.4 Connectivity Inspection	28
	3.4.1.5 Repairing Holes	29
	3.4.1.6 Boundary Layers	29
	3.4.1.7 Removing Body FV	30
	3.4.2 Meshing	31
	3.4.2.1 Meshing Size	31
	3.4.2.2 Defeaturing and Inflation	32
	3.4.2.3 Named Selection	33
	3.4.2..4 Prismatic Layer	34
	3.4.3 Solution	35
	3.4.3.1 Model	35
	3.4.3.2 Materials	36
	3.4.3.3 Boundary Condition	36
	3.4.3.4 Reference Value	38
	3.4.3.5 Frontal Area	39
	3.4.3.6 Solution Method	40
	3.4.3.7 Monitoring Coefficient of Drag and Lift	41
	3.4.3.8 Run Calculations	43

<b>CHAPTER 4</b>	<b>RESULTS AND DISCUSSION</b>	46
4.1	Coefficient of Drag	46
4.2	Coefficient of Lift	49
4.3	Comparison of Coefficient of Drag	51
4.4	Comparison of Coefficient of Lift	53
4.5	Comparison of Coefficient of Drag at Different Speed	54
4.6	Comparison of Coefficient of Lift at Different Speed	55
4.7	Comparison of Coefficient of Drag for Different mesh size at 25m/s	56
4.8	Comparison of Coefficient of Drag for Different mesh size at 25m/s	57
<b>CHAPTER 5</b>	<b>CONCLUSION</b>	59
5.1	Introduction	59
5.2	Achievement of Project Objectives	59
5.2	Suggestion for Improvement and Future Work	61
<b>REFERENCE</b>		62
<b>APPENDIX</b>		63

## LIST OF FIGURES

<b>Figure 1.1:</b> Flow chart of the methodology	5
<b>Figure 2.1:</b> T-1 Model on early Henry Ford's design	7
<b>Figure 2.2:</b> Velocity vectors around separation point	8
<b>Figure 2.3:</b> Aerodynamics force that reacts on open wheel race car	13
<b>Figure 2.4:</b> Boundary Layers on flat plate	15
<b>Figure 2.5:</b> Bernoulli Principles	16
<b>Figure 2.6:</b> Aerofoil lift	17
<b>Figure 3.1:</b> General Procedure for analysis	20
<b>Figure 3.2:</b> Bodywork with cockpit covered	21
<b>Figure 3.3:</b> Bodywork Design	22
<b>Figure 3.4:</b> Tire Design	23
<b>Figure 3.5:</b> Front Spoiler	24
<b>Figure 3.6:</b> Rear Spoiler	25
<b>Figure 3.7:</b> Project Schematic	26
<b>Figure 3.8:</b> Units Changing	28
<b>Figure 3.9:</b> Edge colouring by connection	28
<b>Figure 3.10:</b> Repairs Hole	29
<b>Figure 3.11:</b> Enclosure	30
<b>Figure 3.12:</b> Boolean Function	30
<b>Figure 3.13:</b> Sizing	31
<b>Figure 3.14:</b> Inflation	32
<b>Figure 3.15:</b> Named Selection: symmetry-side	33
<b>Figure 3.16:</b> Inflation for Prism Layer	34
<b>Figure 3.17:</b> Prism Layer	34

<b>Figure 3.18:</b> Models	35
<b>Figure 3.19:</b> Pressure Outlet	37
<b>Figure 3.20:</b> Velocity Inlet	38
<b>Figure 3.21:</b> Reference Values	39
<b>Figure 3.22:</b> Projected Surface Area	40
<b>Figure 3.23:</b> Solution Method	41
<b>Figure 3.24:</b> Lift Monitor	42
<b>Figure 3.25:</b> Drag Monitor	43
<b>Figure 3.26:</b> Drag Monitor	44
<b>Figure 4.1:</b> Graph Coefficient of Drag vs. No of Iteration	46
<b>Figure 4.2:</b> Pressure Distribution on Surface Body	46
<b>Figure 4.3:</b> Pressure Distribution from Front View	47
<b>Figure 4.4:</b> Graph Coefficient of Lift vs. No of Iteration	49
<b>Figure 4.5:</b> Velocity Streamline	49
<b>Figure 4.6:</b> Graph of Comparison between Coefficients of Drag	51
<b>Figure 4.7:</b> Graph Comparison of Coefficient of lift	52
<b>Figure 4.8:</b> Coefficient of Drag at Different Speed	53
<b>Figure 4.9:</b> Coefficient of Lift	54
<b>Figure 4.10:</b> Comparison of CD at different Mesh Size	56
<b>Figure 4.11:</b> Comparison of CL at different mesh size	57

## LIST OF TABLES

<b>Table 1:</b>	Type of Drag Force with their percentage of influence	11
<b>Table 2:</b>	Coefficient of Drag and Lift at different Speed	59

## LIST OF ABBEREVATIONS

ANSYS	American Computer-aided engineering software
CFD	Computational Fluid Dynamic
CATIA	Computer Aided Three-dimensional Interactive Application
FV	Formula Varsity
FSAE	Formula Society of Automotive Engineers

## LIST OF SYMBOL

$C_D$	= Coefficient of Drag
$C_L$	= Coefficient of Lift
$A$	= Frontal Area of Vehicle ( $m^2$ )
$\rho$	= Density of Air ( $kg/m^3$ )
$V$	= Velocity of vehicle ( $ms^{-2}$ )
$T$	= Temperature ( $^{\circ}C$ )
$P$	= Pressure (kPa)
$R$	= Gas Constant Value

# CHAPTER 1

## INTRODUCTION

### 1.1 BACKGROUND

The numerical analysis on aerodynamic properties using Computational Fluid Dynamic has become more effective way compare to conventional way. Ability to have major changing on design during fundamental designing can save time used in constructing prototype thus, reduces cost for prototyping. Analysis using wind tunnels are very expensive and demand large amount of equipment and skilled personnel.

The aim of this study is to increase the performance of open-wheel race car of FV Malaysia by manipulating several aerodynamic factors on the bodywork. The coefficient of drag and the coefficient of lift are being analyzed using fluid analysis. This project conducted by using ANSYS, CATIA and CFD software that provided by the faculty of mechanical engineering.

Aerodynamic is the main factor when designing an open-wheel race car. The shape of the vehicle is often the main factor that contributes to aerodynamic performance. Aerodynamic can be defined as the study on how fluid or air properties move whenever interact with solid object. To have the stability on open-wheel race car, aerodynamic drag



and aerodynamic lift need to be considered during design processes. During high-speed maneuver, open-wheel race car has significant effect on aerodynamic behavior.

Lower value of drag force will increase the top speeds and increase the stability of the open-wheel race car. However, the drag force can be compensated by manipulating drag force into down force. As a result, it will push car downward and provide higher traction force on tire.

Traction force is defined as a force used to generate motion between a body and tangential surface. Traction force on tire is needed to deliver full power of engine to tire without any tire slip. As a result, it provides better tire grip and better acceleration. Traction force also needed to provide better traction during taking corner or overtaking maneuver during high speed. Appropriate traction force can provide better grip and stability during cornering; too much traction force can slow down the car, lack traction force can lead to spin tire during acceleration and under steer during cornering.

On open-wheel race car, aerodynamic factor can be highly influence by shape of side port and open cockpit shape. The occurrence is due to larger frontal area that generates drag force. Improper shape can cause the open-wheel race car to be unbalance due to turbulent flow. Air flow can be directed and shaped in order to have the best aerodynamic properties. It can be shaped by modifying the front spoiler, fuselage, and side port and rear spoiler shape. Down force can be obtained by manipulating drag force. The use of spoiler on front and rear race car body can change direction of air flowing through bodywork.

## **1.2 PROBLEM STATEMENT**

FV Malaysia challenged the students to build a formula 1 style car. UTeM Racing Team has participated in FV Malaysia Race at Sepang International Circuit. Designing processes conducted by students in order to have the best design on aerodynamic factor. The computational Fluid Dynamics (CFD) has played important role to analyze bodywork recently. In order to get higher efficiency on aerodynamic factor, the drag force should be fully eliminated as it slows down the race car. The down force should be generated in order to maintain car on ground and has better traction control when taking corner.

## **1.3 OBJECTIVE**

The objectives of this project are as follows:

1. To design the bodywork of FV race car by using CATIA
2. To Analysis aerodynamics properties of bodywork by using ANSYS

## **1.4 SCOPE OF PROJECT**

The scopes of this project are:

1. To design model of bodywork using computer aided software
2. To analyze to several properties using ANSYS software:
  - 2.1 Coefficient of drag
  - 2.2 Coefficient of lift
3. Design modification to improve the area that has low aerodynamic properties.

## 1.5 GENERAL METHODOLOGY

The actions that need to be carried out to achieve the objectives in this project are listed below.

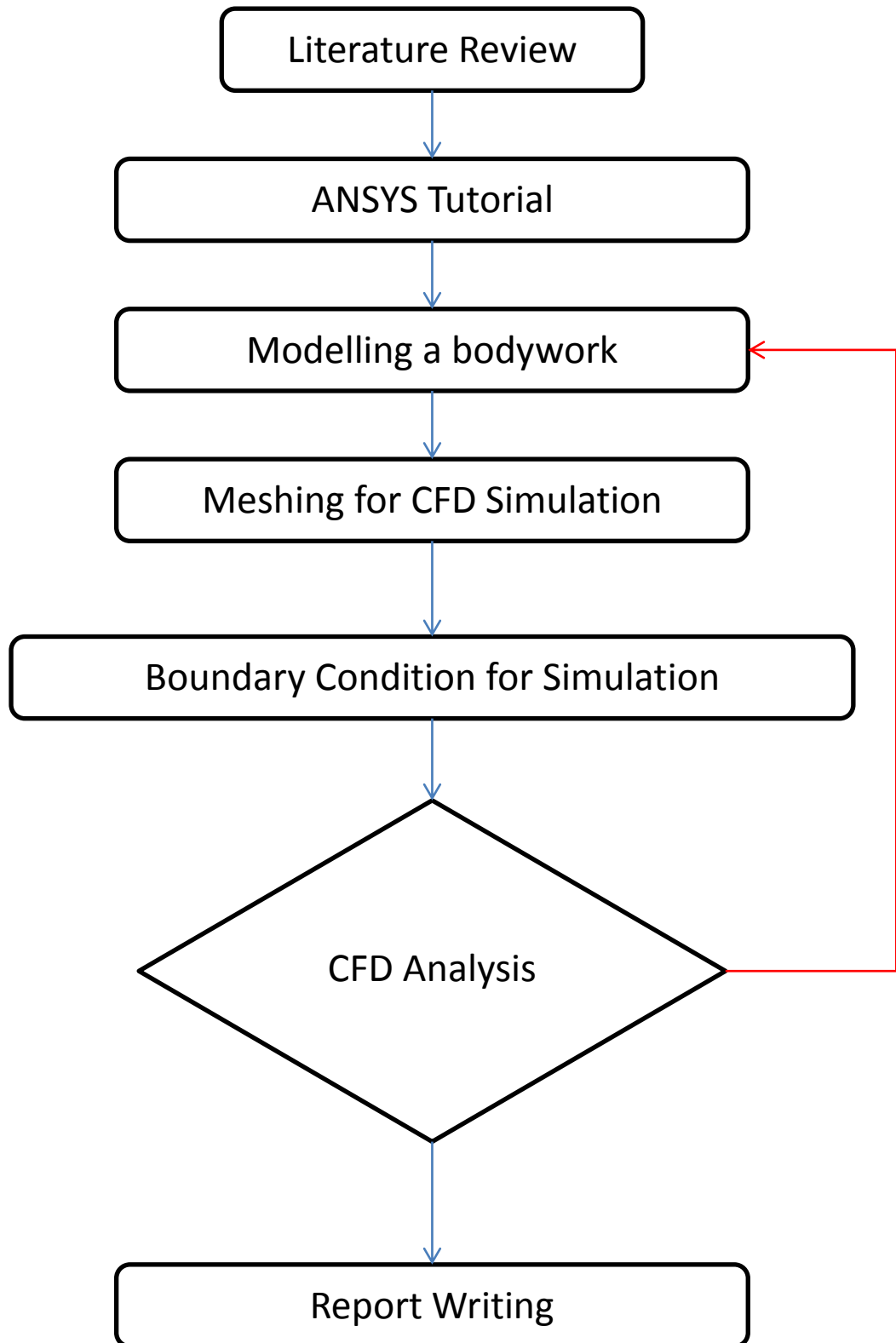
1. Design the Bodywork

Journals, articles, or any materials regarding the project will be reviewed.

2. Computational Fluid Dynamics using ANSYS

ANSYS tutorial conducted in order to expose initial stage for analysis.

The methodology of this study is summarized in the flow chart as shown below. The research start with the literature review to gather as much as possible previous data and research that have been done. Since ANSYS software is not in compulsory subject, tutorial have been conducted in order to provide knowledge on how to use ANSYS software. Modeling a car using CATIA V5 software, during design stage generative surface design and part volume function has been used. The design consist several parts which is front spoiler, bodywork, and tire and rear spoiler. Model of the car will be transfer to ANSYS software, meshing is being included at different size in order to see difference. Boundary condition has been set up as realistic as possible with real world. Analysis has been conducted to retrieved coefficient of drag and lift for the car. By referring previous study, if the coefficient of drag and lift are not near to previous study, the design should have slight modification.



**Figure 1.1:** Flow chart of the methodology

## **CHAPTER 2**

### **LITERATURE REVIEW**

#### **2.1 INTRODUCTION**

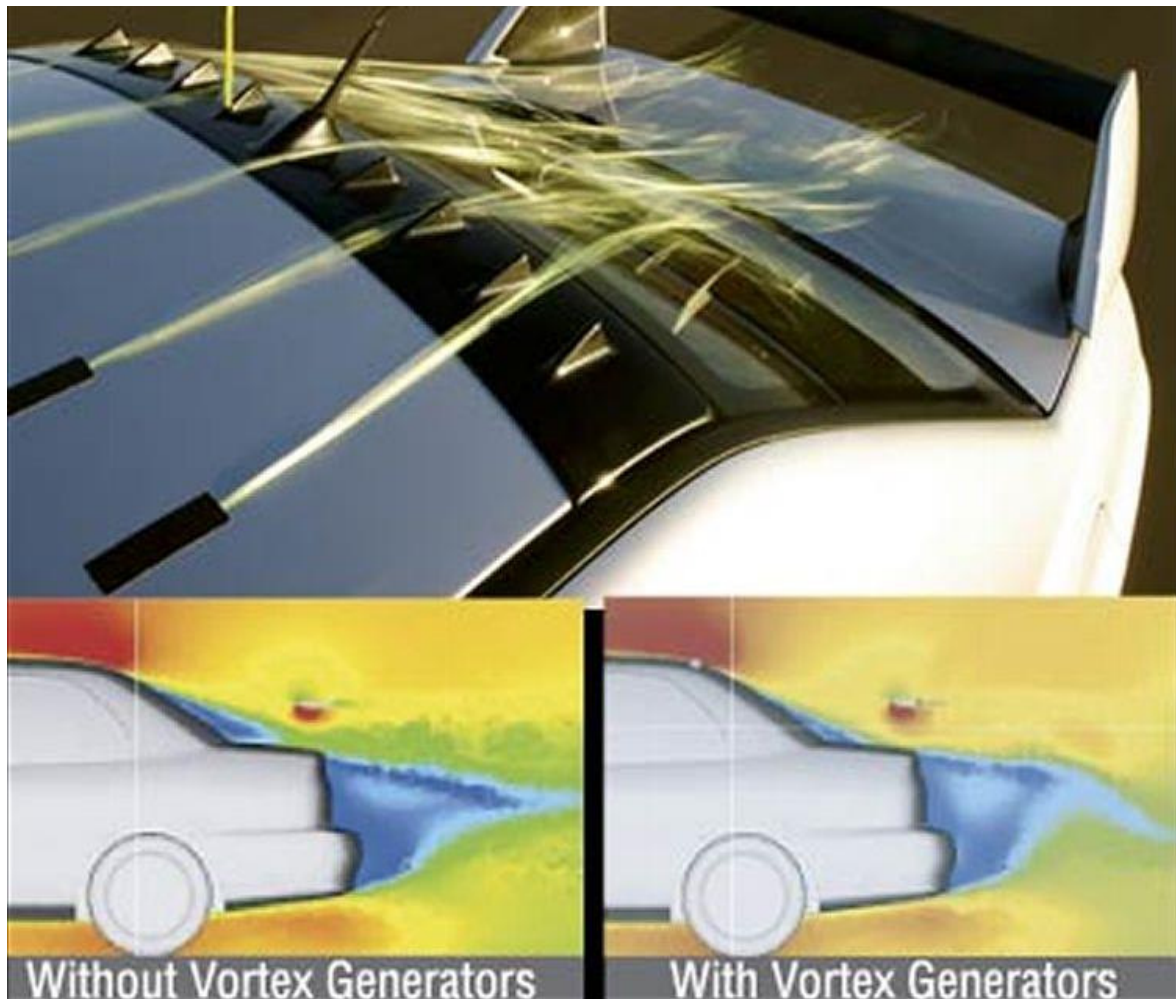
Aerodynamics has high influence in designing an open wheel race car. Road load has higher contribution in aerodynamic effect. By reducing the road load or improving the flow passed on vehicle body can give enormous advantages. In addition, drag force, lift force and down force are few road load factors that will affect the aerodynamic properties on open wheel race car. As a matter of fact, good aerodynamics properties can reduce the fuel consumption during driving, improve handling when taking high speed cornering and increase handling stability during high speed maneuver. However, early car model was designed without considering the aerodynamic factors. Early designs were based on horse carriage until such time as modern world being considered aerodynamic factor when designing a car. As an example, early model was designed to look like a carriage with bulk and square shape. For an example Henry Ford's car T-1 that has square shape. Retrieved from <http://classiccarpicturesalmanac.com/archives/cars/1914-ford-model-t-touring-wide-track.html>



**Figure 2.1:** T-1 Model on early Henry Ford's design

## **2.2 PREVIOUS STUDY**

Multiples studies Koike et al. (2004) have been conducted regarding open wheel race car aerodynamic. Installation of vortex generator on rear side of sedan car controls the separation of airflow and increases the aerodynamics performances. In their research, applying vortex generator on Mitsubishi Lancer Evolution car reduced the drag coefficient and lift coefficient by 0.006.



**Figure 2.2:** Velocity vectors around separation point

There are several factors that contribute to effect of vortex generator, stream wise vortices are formed whenever air going through the vortex generator. To add to it, lower layer of boundary layer formed and will cause change the flow separation point to be downstream. From this characteristic, we can safely assume pressure at entire rear surface will increase thus will reduce the drag force.

The studies identify how aerodynamic influence the performance of the open wheel race car. However, very few studies Edvaldo and Gabriel (2015) have been conducted on influence of elements inside the wheelhouse on the vehicle aerodynamic. On their research, to analyze the aerodynamics load on inside the wheelhouse can be possible by using a



mathematical model. On a contrary, flow behavior inside the wheelhouse can be too complex and have too much recirculation regions. In their research, they agree that analysis on box on wheels, wheel tire set are not suitable for aerodynamic performance research. However, Aerodynamic performance can be analyzed whenever the vehicle travel at low speed.

Krishna and Jayachandra (2012) in their research on conceptual design of wind friction reduction attachments to the rear portion of car for better fuel economy at high speeds, has suggested implementation of collapsible wind friction reduction attachment at the rear of the vehicle. By providing the wind friction reduction attachments to the rear portion of car bluff body, the wind friction drags coefficient can be reduced from around 0.4 to around 0.2

Drag force can also be significantly reduced by designing front wing for open wheel race car. It has been proved. (Price, 2011)