VIRTUAL TESTING WIND AND ANALYSIS PERFORMANCE
OF UMP LAB CIRCUIT

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for the award of the degree of
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I hereby declare that I have checked this project and in my opinion, this project is adequate in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering with Automotive Engineering.

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I hereby declare that the work in this project is my own except for quotations and summaries which have been duly acknowledged. The project has not been accepted for any degree and is not concurrently submitted for award of other degree.

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**Dedicated to my parents**

Mr. Baharom bin Mohamad

Mrs. Junailah binti Md. Ibrahim

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## ABSTRACT

The purpose of this project is to study about the virtual testing wind and analysis performance of the UMP lab circuit. But the main purpose is to analysis the performance of the circuit whether the circuit having a good condition or not based on the performance at cornering section. This target can be achieved by doing the simulation with current software. For this project, the software that being used is CarMaker software. The needed for this simulation are only the circuit and the model of the vehicle. For the circuit, the dimension and shape is taken by doing some estimation from the real circuit. The dimension can be changes since the circuit actually used for the go-cart race. But the important is the shape must follow with the actual one. For this project, the car model that being used is Perodua Kancil EX660. All the specifications and dimensions of the car can be added in the software to generate the new small car for the simulation. A modified technique of by the CarMaker software is proposed and critically analyzed. This analysis indicated that a methodical approach to vehicle set up and optimization combined with lap time simulation can give the best result to find the forces acting on the car and study about cornering. Not only for the car, had the project also studied about the performance of the circuit while the car is moving on it. To study about performance of the circuit, the preliminary result must be obtained in this project. By getting all the information, we can conclude that whether the circuit has a good performance or not especially on the cornering.

# ABSTRAK

Objektif daripada projek ini adalah untuk menganalisis dan mengkaji daya-daya tidakbalas angin dan menganalisis prestasi litar lumba UMP. Fokus lebih diberikan kepada analisis prestasi litar lumba sama ada litar tersebut dalam keadaan yang baik atau pun tidak terutamanya pada bahagian membelok. Keadaan ini boleh dicapai dengan melakukan simulasi mengunakan perisian yang telah ditetapkan. Keperluan untuk simulasi ini adalah litar dan juga model kereta. Litar yang digunakan adalah berdasarkan litar lumba UMP di hadapan bengkel makmal FKM. Ukuran litar hendaklah dilakukan dengan anggaran daripada litar sebenar kerana litar lumba tersebut adalah digunakan untuk litar lumba go-cart. Tetapi, bentuk litar hendaklah serupa dengan litar yang asal. Dalam projek ini, model kereta yang digunakan ialah daripada model Perodua Kancil EX660. Semua spesifikasi dan ukuran boleh dimuat turunkan ke dalam perisian CarMaker untuk menghasilkan kereta yang baru di dalam perisian tersebut. Untuk mengkaji daya-daya yang bertindak dan juga menganalisis prestasi litar, simulasi boleh dilakukan dengan melihat keadaan model kereta semasa proses simulasi dijalankan. Untuk mendapatkan hasil kajian yang lebih tepat, modifikasi boleh dilakukan dalam perisian tersebut. Ramalan awal boleh dibuat dan ianya hendaklah berdasarkan daripada simulasi yang telah dijalankan. Dengan memperolehi semua maklumat, kesimpulan boleh dibuat samada litar lumba tersebut dalam keadaan yang baik atau pun tidak terutama pada bahagian membelok.

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# LIST OF SYMBOLS

| | |
|---|---|
| $\boldsymbol{\delta}$ | Ackerman angle |
| $\boldsymbol{\rho}$ | Density of air |
| $\prod$ | Phi |
| $\boldsymbol{\lambda}$ | Slip angle |
| $\boldsymbol{\upsilon}$ | Sideslip velocity |

# LIST OF ABBREVIATIONS

| | |
|---|---|
| ABS | Anti-lock Braking System |
| CAD | Computer-Aided Design |
| CM | CarMaker |
| DOF | Degree-of-freedom |
| DTP | Discretized turning point |
| ECU | Electronic Control Unit |
| FKM | Fakulti Kejuruteraan Makanikal |
| FYP | Final Year Project |
| HIL | Hardware-in-the-Loop |
| LSA | Long Short Arm |
| SAE | Society of Automotive Engineers |
| UMP | Universiti Malaysia Pahang |
| VVE | Virtual Vehicle Environment |

# CHAPTER 1

# INTRODUCTION

## 1.1 INTRODUCTION OF THE PROJECT

In this project on virtual testing wind and analysis performance of UMP lab circuit, the thing that we want to discover is about the performance of the circuit and the force acting on the vehicle while moving on the circuit. Some force that acting are rolling resistance between the tire and the road, the aerodynamic force on the car, lift and drag force of the car, lateral force and many others. On every force, we make some prediction and try to make some improvement to both car and the road.

The cornering behavior of a motor vehicle is an important performance mode often equated with handling. “Handling” is a loosely used term meant to imply the responsiveness of a vehicle to driver input, or the ease of control. As such, handling is an overall measure of the vehicle-driver combination. The driver and vehicle is a “close-loop” system which means the driver observes the vehicle direction or position, and corrects his/her input to achieve the desired motion. For purpose of characterizing only the vehicle, “open-loop” behavior is used. Open loop refers to vehicle response to specific steering inputs, and is more precisely defined as ‘directional response” behavior.

The most commonly used measure of open-response is the understeer gradient. Understeer gradient is a measure of performance under steady-state conditions, although the measure can be used to infer performance properties under condition that are not quite steady-state. Open-loop cornering, or directional response behavior, will be examined in this project. The approach is to first analyze turning at low speed, and then consider the differences that arise under high-speed condition.

The main focus on this project is to study the performance of the circuit itself. It is important to know the basic information about cornering because many accident occurred because the lack information about the road and knowledge in taking a corner. In this project, new small car will be generated from the software that being used in this project which is the CarMaker (CM) software. The circuit also will be designed in this software according to the UMP lab circuit. After simulation have been done, some prediction can be made such as about the performance of the circuit and also about the vehicle itself whether having a sideslip or not during make a turn at each corner.

By knowing the problems occurred, some modification can be made in order to increase the performance of the circuit as well as improve the driving condition for the driver in a reality world. As the resulting on the CM software, we can see which corner of the track has a major problem to the car. Such a problem is the side slip of the car tire while cornering. By knowing this problem, we can make some correction on the road such as by increasing the angle on the cornering road. By increasing the road angle, the tire will not over slip or side slip will not happen. This is one of the important things that we must do to avoid the accident.

### 1.1.1 Road Design

In this project, the road design is important and a minor requirement of this simulation. For this road design, it is must follow all the basic condition of a good road. For some example, at the corner side, all the conditions and important thing must be follows so that the road has a good performance while a car moves on it. It also can decrease a percentage of accidents if the road has a good quality that is follow all the rules. For this project, the road design is consist of a corner, straight line and a corner again. All the parameters which is including the length, radius of a corner, degree of the corner and many more are estimated from the actual reading must be logical form the real one.

## 1.2 PROBLEM STATEMENT

Many incidents of accidents of vehicle occur because of the lack performance of the road and the vehicle itself. The driver must know the speed and the distance before taking a corner of the road because it's important to maintain the stability of the car so that the vehicles are not offset from the road. Other than that, the driver also must know the condition of the road such as at the cornering, uphill and downhill, at the straight line and many more. These are the common problems faced by the drivers. To prevent this road design musty be analyzed by any methods to reduce the accidents. Of the methods simulation will be more cost effective as not much expensive experiments need to be done.

## 1.3 OBJECTIVE

The objective of this project is

a) To study about the virtual testing wind and analysis performance of UMP lab circuit model.

b) Discover the force acting on the vehicle while moving on the lab circuit especially the forces that involve in cornering such as lateral force and many more.

c) We will study about the road itself. The things that we study about the road is to know what is the good road mean and what is the requirement to make the road safe and in good condition. The study will more concentrate on the road during straight and cornering.

## 1.4 SCOPE OF PROJECT

The scopes for this project are:

a) Learn the software that use for the simulation of this project which is the CarMaker (CM).

b) Modeling the UMP lab model circuit and also the vehicle which is PERODUA Kancil EX660 in the software.

c) Do the simulation of the car and the road in the CM.

d) During the simulation, we have to making an early prediction of the performance of the circuit whether the circuit is in good condition or not based on the driving condition on the simulation in the current software that being used.

## 1.5 FLOW CHART

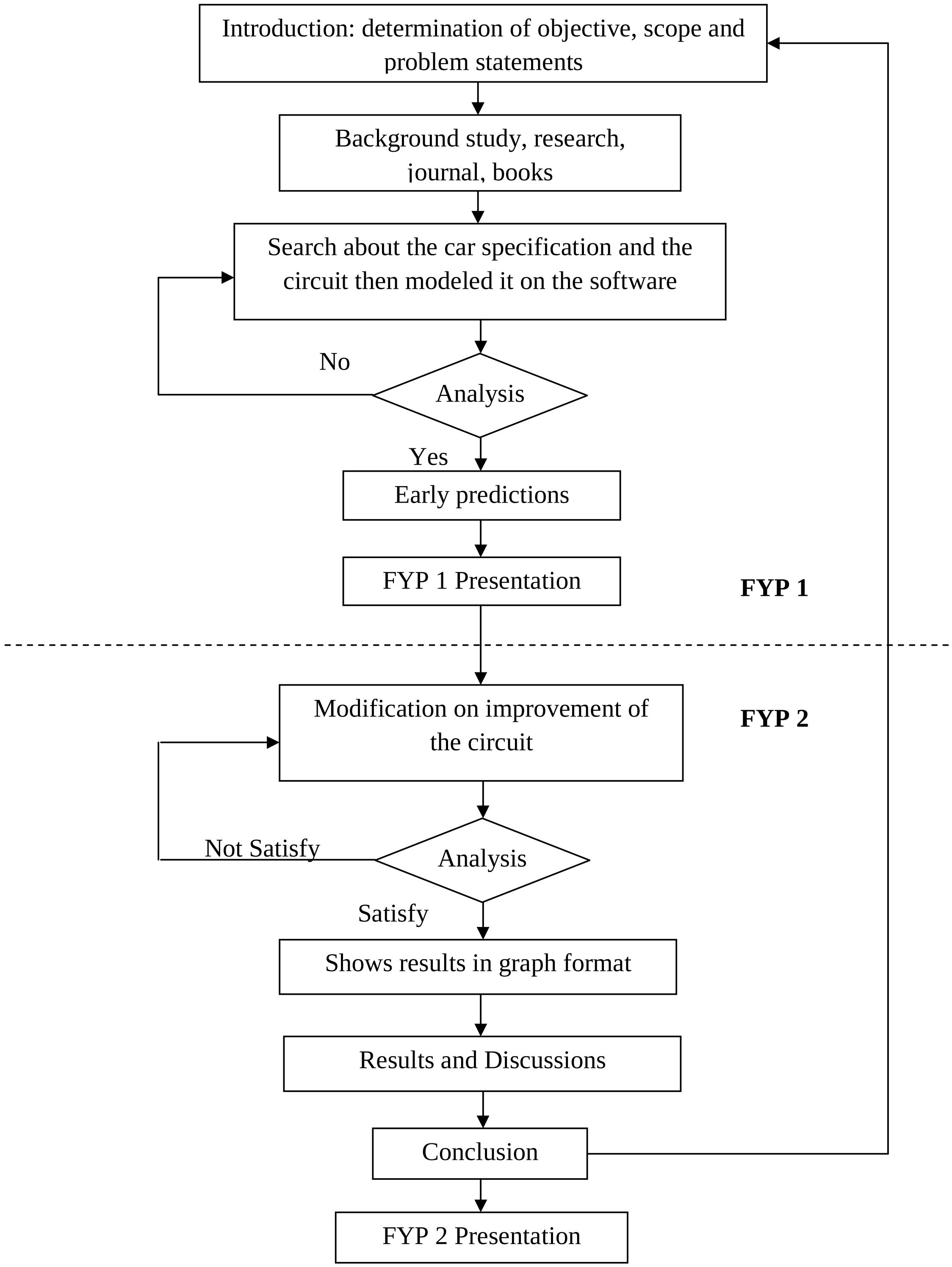


**Figure 1.1**: Flow chart of Final Year Project

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 VIRTUAL TEST DRIVING

Modern vehicles are becoming smarter each day. While talking cars with personality may still be in the realm of science fiction, many of today's vehicles are "smart" enough to sense their environments and make decisions that influence things, such as handling, stability, safety and comfort. For example, a vehicle equipped with an Anti-lock Braking System (ABS) can determine when the tires are locked and pulse the brake pressure so that stopping distance is minimized and driver control is maintained during safety critical situations. A more sophisticated system, Electronic Stability Control (ESP), extends this functionality so that controlled brake pressure is not only used to aid stopping, but also to maintain stability during cornering. Systems that make decisions to influence vehicle behavior are called active control systems. The decision making component of all active control systems, and therefore the intelligence in intelligent vehicles, is the Electronic Control Unit (ECU).

To develop and test active control systems and ECUs special testing methods are needed. This article outlines a few methods that have gained in popularity and acceptance, namely the virtual test driving, Hardware-In the- Loop (HIL) simulation, and automated testing. For this reason the article also demonstrates how projects based on the mentioned methods can be realized with Carmaker (Hodkin. D., and B.D.A. Phillips, 1963).

## 2.2 VIRTUAL TESTING DRIVING ON THE VIRTUAL PROVING GROUND

Simply connecting a voltage signal or waveform generator to the ECU input pins will not provide the information needed by the ECU to, for example, make a decision, supply a response, judge the effects, correct the response, and so on. To handle this, computer models are used to recreate or simulate the vehicle environment, and the ECU is then interfaced to the simulated environment. IPG calls this type of simulation environment Virtual Vehicle Environment (VVE), and testing with this method is called virtual test driving.

Due to the specific needs of active control systems, however, a certain type of virtual environment is necessary - one which, among other things, accurately reflects vehicle dynamics. The models must closely simulate the dynamics of the real world vehicle environment. An accurate representation of vehicle dynamics requires simulating the vehicle, driver, road, wind and almost everything else that influences the dynamic system. In addition, to allow scalability and customization, modularity should be enforced. IPG's Carmaker meets these special needs. The Virtual Vehicle Environment of Carmaker (**Figure 2.1**) consists of detailed and precise models that represent the steering, braking, chassis, power train and other vehicle subsystems. Its modularity allows the models to be replaced, exchanged, and modified (George A.R., 1981).

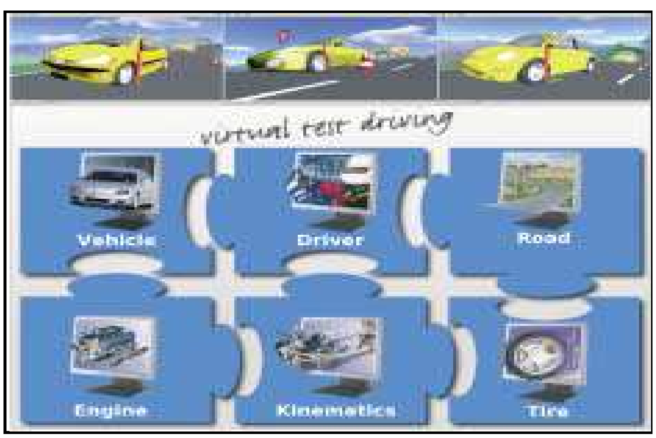


**Figure 2.1:** Carmaker's modular Virtual Vehicle Environment

## 2.3 DRAG COEFFICIENT

The drag coefficient ($C_d$, $C_x$ or $C_w$) is a dimensionless quantity which is used to quantify the drag or resistance of an object in a fluid environment such as air or water. It is used in the drag equation, where a lower drag coefficient indicates the object will have less aerodynamic or hydrodynamic drag. The drag coefficient is always associated with a particular surface area. The drag coefficient of any object comprises the effects of the two basic contributors to fluid dynamic drag: skin friction and form drag. The drag coefficient of a lifting airfoil or hydrofoil also includes the effects of induced drag. The drag coefficient of a complete structure such as an aircraft also includes the effects of interference drag.

Two objects having the same reference area moving at the same speed through a fluid will experience a drag force proportional to their respective drag coefficients. Coefficients for rough unstreamlined objects can be 1 or more, for streamlined objects much less.

$$F_d = \tfrac{1}{2}\rho v^2 C_d A \quad (2.1)$$

*A* is the reference area, usually projected frontal area. For example, for a sphere $A = \pi r^2$

The drag equation is essentially a statement that the drag force on any object is proportional to the density of the fluid, and proportional to the square of the relative velocity between the object and the fluid. The drag coefficient of an object varies depending on its orientation to the vector representing the relative velocity between the object and the fluid. For a streamlined body to achieve a low drag coefficient the boundary layer around the body must remain attached to the surface of the body for as long as possible, causing the wake to be narrow. A broad wake results in high *form drag*. The boundary layer will remain attached longer if it is turbulent than if it is laminar.

The boundary layer will transition from laminar to turbulent providing the Reynolds number of the flow around the body is high enough. Larger velocities, larger objects, and lower viscosities contribute to larger Reynolds numbers (McCormick and Barnes W., 1979).

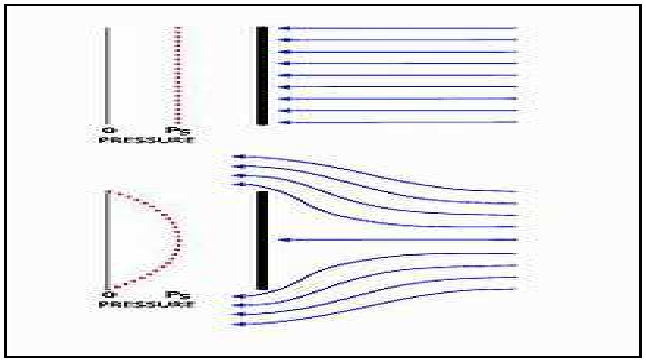


**Figure 2.2:** Flow around a plate, showing stagnation.

At a low Reynolds number, the boundary layer around the object does not transition to turbulent but remains laminar, even up to the point at which it separates from the surface of the object. $C_d$ is no longer constant but varies with velocity, and $F_d$ is proportional to $v$ instead of $v^2$. Reynolds number will be low for small objects, low velocities, and high viscosity fluids. A $C_d$ equal to 1 would be obtained in a case where all of the fluid approaching the object is brought to rest, building up stagnation pressure over the whole front surface. The top figure shows a flat plate with the fluid coming from the right and stopping at the plate. The graph to the left of it shows equal pressure across the surface. In a real flat plate the fluid must turn around the sides, and full stagnation pressure is found only at the center, dropping off toward the edges as in the lower figure and graph. The $C_d$ of a real flat plate would be less than 1, except that there will be a negative pressure (relative to ambient) on the back surface. The overall $C_d$ of a real square flat plate is often given as 1.17. Flow patterns and therefore $C_d$ for some shapes can change with the Reynolds number and the roughness of the surfaces (Hoerner, Dr.Ing. S.F., 1965).

For this project, its more to the force react at the vehicle and also the force act at the road. Drag force is one of the main forces that act on the body of the car during moving on the track. Drag force usually happen between the tire and the road. The