UNIVERSITI TEKNIKAL MALAYSIA MELAKA

PROJECT TITLE: OPTIMIZATON OF REAR SUSPENSION DYNAMIC PERFORMANCE BY USING VIRTUAL FORMULA

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Engineering Technology (FTKM)

By

STUDENT NAME: MUHAMMADAMIR FUAD BIN MUHALITH

MATRIX NUMBER: B071310173

IC NUMBER: 910215045349

FACULTY OF ENGINEERING TECHNOLOGY

2016

DECLARATION

I hereby, declared this report entitled "OPTIMIZATON OF REAR SUSPENSION DYNAMIC PERFORMANCE BY USING VIRTUAL FORMULA" is the results of my own research except as cited in references.

Signature	:	……
Author's Name	:	Muhammad Amir Fuad Bin Muhalith
Date	:	……

APPROVAL

This report is submitted to the Faculty of Engineering Technology of UTeM as a partial fulfillment of the requirement for the Degree of Engineering Technology (Automotive Technology) with Honors. The member of the supervisory is as follow:

……..

(Mr. Mohd Hafizi A Rahman)

ABSTRAK

Vi-Grade merupakan pengeluar utama didalam sektor automotif dalam menyediakan alat simulasi di untuk kereta lumba. Vi-Grade melancarkan pertandingan Formula Maya Vi-Grade untuk membolehkan pelajar meningkatkan pengetahuan mereka mengenai dinamik kenderaan, untuk membangunkan reka bentuk mereka dan membandingkan konsep dan menguji reka bentuk dan membangunkan idea. Tujuan projek ini adalah untuk belajar bagaimana untuk mengoptimumkan sistem penggantungan belakang perlumbaan formula maya, untuk mencapai kelajuan maksimum dan juga masa terpantas didalam acara pecutan. Untuk mengoptimumkan sistem belakang penggantungan, ia menggunakan perisian Vi-Grade. Pertandingan ini terbuka di seluruh dunia. Bagi mengoptimumkan sistem penggantungan itu ia mesti mengikut peraturan dan peraturan dalam Vi-Grade. Keputusan terbaik selepas di optimum akan dihantar ke Vi-Grade untuk mendapatkan keputusan akhir selepas bersaing dengan kereta dari negara lain di seluruh dunia. Di akhir projek ini, hasil optimum yang terbaik didalam suspensi belakang boleh digunakan untuk masa depan pembangunan system gantungan.

ABSTRACT

VI-GRADE is a global leader production automotive market and it's providing the simulation tool in racing car. Vi-Grade launched the Vi-Grade Virtual Formula competition to allow the student increase their knowledge of vehicle dynamics, to develop their design and compare the concept and test the design and develop the idea. The purpose of this project is to study and to optimizing the rear suspension of the virtual formula race car to achieve the maximum top speed and also the final time in the acceleration event. To optimize the rear suspension, it use the Vi-Grade software, this competition is open around the world. In order to optimize the suspension it must follow the rules and regulation in Vi-Grade. The best result after optimize must sent to VI-GRADE to get the final result after compete with other race car around the world. The end of this project, the best result of the optimizing of the rear suspension can be used for future a development.

DEDICATION

Dedicated to my father, Muhalith bin Sanip and my mother, Jamaliah bt Abdul Karim. To my supervisor Mr. Mohd Hafizi bin Abdul Rahman, lecturers and friends for all of their help and friendship.

ACKNOWLEDGEMENT

Firstly, I am grateful to the Allah S.W.T for the good health and well being that were necessary to complete this PSM project. I have completed this project even though there are many difficulties during the project occur.

I wish to express my sincere thanks to my supervisor Mr. Mohd Hafizi bin Abdul Rahman for sharing expertise and valuable guidance during the project. Thank you also for the consistence guidance and support during my project writing is invaluable to me and continuous direction and opinion regarding the flow of the project has invaluable contribution to achieve the objectives of this project.

I take this opportunity to express gratitude to all of the department faculty members for their help and support. I also thank my parents for the encouragement, support and attention. Their support is meant so much to me in finishing this report.

I also place on record, my sense of gratitude to one and all, who directly or indirectly involved in my PSM project.

TABLE OF CONTENT

CHAPTER 3: METHODOLOGY

CHAPTER 4: RESULT AND DISCUSSION

CHAPTER 5: CONCLUSION

LIST OF FIGURES

LIST OF TABLES

LIST OF SYMBOLS ANDABBREVIATIONS

LSD	Limited Slip Differential
DOE	Design of Experiment
FIT	Approximation
RSM	Response Surface Method
LSR	Least Squares Regression
MLSM	Moving Least Squares Method
HK	Hyper Kriging
RBF	Radial Basic Function
ARSM	Response Surface Method

CHAPTER 1
INTRODUCTION

1.0 Introduction

Vi-Grade Virtual Formula is competition to allow student develop their idea, compare the concept and develop design and increase the knowledge of vehicle dynamic. In this project, it focuses on how to optimizing the rear suspension characteristic in race car using the Virtual Formula software in order to achieve the requirement of handling, stability and the performance of the race car to get the best lap time in acceleration event. A several type of suspension available for the virtual race car such as lower upper control arm (LUCA), double wishbone pushrod, double wishbone pushrod with u-bar and each default setting will reflect to various characteristic in virtual race car. The suspension parameter such as k spring, damper (jounce and rebound), camber and torsion are interrelated to the handling and stability of the virtual race car. Every type of suspension has their own characteristic and the important roles to make the race car stay on the track without under steer or over steer. In Virtual Formula, the rules and regulation is given and the parameter can change based on the rules and regulation. The tuning of suspensions involves finding the right compromise. It is important for the suspension to keep the road wheel in contact with the road surface as much as possible.

1.1 Problem Statement

The suspension system that commonly used on the racing car are usually have a fixed parameter which is difficult to tune in order to achieve high performance and might be far away from its optimum setting. Therefore, to test the suspension on the real car would cost a lot of money and time. There is many software can be used such as ADAMS, Carsim and MatLab. Currently there is new Multi-Body Simulation (MBS) software named VI-Grade in the market which is more accurate, variety of setup and also due to its flexible parameters that can be change easily. VI-Grade offer more parameter that can be tested and the result is more precise and in-depth compare to the other software. VI-grade competition gives the default model and its must optimize the default model in order to get the better result from default model. To optimize the default model it must follow the rules and regulation in vi-grade virtual formula. It must refer the other journal to know the method need to use to get the best setup. In Vi-Grade virtual formula it's give the Vi-Grade software, the software can tune the parameter and test directly in virtual formula race track. The software can help to understand the problem and can give the correct value or setting to parameter.

1.2 Objective

The objective is:

1. To get the best lap time, maximum speed and low fuel consumption.
2. Performed DOE analysis on RR suspension to get the optimum value of max speed, lap time & fuel consumption.

1.3 Scope

The scope are:

1. Optimize the rear suspension characteristic to achieve the best lap time.
2. Only involve simulation using the software vi-grade.
3. Other specification is according to default.
4. The result for vi-grade not validated until real test.

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction of suspension

Suspension that include tires, tire air, springs, shock absorbers and linkages that connects a vehicle to its tires and allows comparative movement between the two. Suspension systems serve a dual purpose contributing to the vehicle's road holding/handling and avoiding completely efficient safety and driving pleasure, and keeping vehicle occupants comfortable and a quality of drive reasonably well separated from road disturbance, bumps, and vibrations. It is important for the suspension to keep the wheel get in contact with surface much as possible, because all the road or ground forces operating on the car do so through to get in contact with patches of the tires. The suspension also protects the vehicle itself and any shipping or luggage from damage, broken and wear. Suspension system is generally designed in relationship with the steering system. (Chinmaya Acharya, 2014)

In suspension system there are components that include spring and damper nonetheless to developed the driving comfort and also by improves the safety. To control the behaviour of the component, high knowledge about suspension system is required in order to adapt the parameter such as spring stiffness, damper, etc. This also requires the identification and detecting the fault involved. The suspension is design with the goal of keeping all four tires flat on the ground. Generally, suspension system is designed under an assumption that the frame is a rigid boy. Packaging of the suspension to the frame is

generally not an interference problem since most of the component to Stiff portion of the chassis to correctly distribute the load that will be passed through these components (Edmund et al. 1996).

- In vehicle suspension system it consists of wishbone, spring stiffness and the absorber that is used to absorb, transmit and filter all forces between the road and body. Spring stiffness responsible to carry the body mass separately the chassis from the road that lead to comfortable of driving. Similarity damper is used to achieve driving safety and driving comfort (Edmund et al, .1996).

2.1 Type of Suspension

Type of suspension used for this literature review is double wishbone and solid axle. Each type of suspension has their own function and will be discussed in details in this chapter.

2.1.1 Double Wishbone

Double wishbone suspension is designed using two A shaped of arm that are attached to the chassis with spring and absorber. Two mounting is set up to the structure of the car and another one was located to the wheel. This two road was mounted at two point is called double wishbone setup (Patil, 2013). The shock absorber and spring is mount at chassis. Usually they have unequal length of arm which is known as SLA (short–long arm). double wishbone suspension design to allow the engineer to control the parameter such as camber angle, toe angle, roll center height etc. to give good performance (Berkum, 2006).

The geometry of double wishbone suspension system design with spring and absorber to give an importance role to improve the stability of the vehicle. This suspension also gives more stability to the movement during the high speed, where the camber angle can be reducing as the wheel is moving in rough surface road (Patil, 2013). This adjustment for this type of suspension is easy, the parameter such as camber can be adjusting, it will give the camber angle to become more negative (Vivekananda et al., 2014).

The design of the coil spring will give advantage to the suspension system. There are two type of technique for coil spring is mounting. First, the spring located between frame and lower control arm as shown in figure 2.1. In this case, most of the load was carried by the lower arm. Second type of mounting where the spring is located between upper control arms. Second types of mounting where the spring is located between upper control arms and above of the frame as shown in figure 2.2. Upper arm and the spring mount to absorb almost the load. However, the second type is not popular since it is consuming a lot of space (Güler, 2006).

Figure 2.1: A First Type Coil is Mount (Güler, 2006).

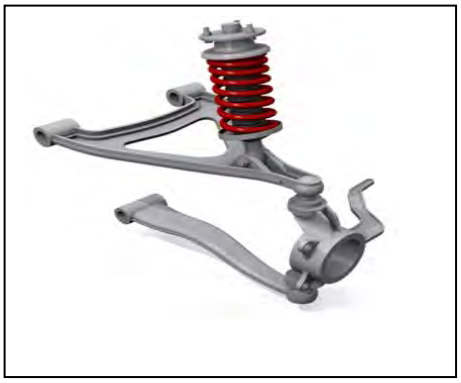

Figure 2.2: A Second Type Coil is Mount (Güler, 2006).

There are advantages when using the unequal length of double wishbone suspension system. Unequal length of double wishbone suspension is used to maintain stabilization and have suitable center (Shun-Kai et al. 2006).

Unequal length of double wishbone suspension also can maintain good traction between the roads and tire to reduce the interference between suspension and steer bar. With the proper structural parameter and arrangements, it affects the parameter of wheel spin and wheel location floating in permissible range. For formula SAE car, stabilization with high speed is more important than the ride the comfort (Liu et al., 2013).

To reach maximum grip when cornering, suspension plays important roles to keep the tires perpendicular to the ground under the entire condition road surface including bumps so the contact patch area between area between tire and ground is maintained at its maximum. Generally double wishbone suspension does the job well for keeping the tire perpendicular to the ground (Attia et al., 2001).

Double wishbone suspension has three type of arm. The first one is the wishbone are equal length and parallels shown in Figure 2.3. The second one is the wishbone with unequal length and parallel suspension system as shown in Figure 2.4. Lastly, unequal length and non-parallel wishbone suspension system as shown in Figure 2.5 (Unlusoy, 2000).

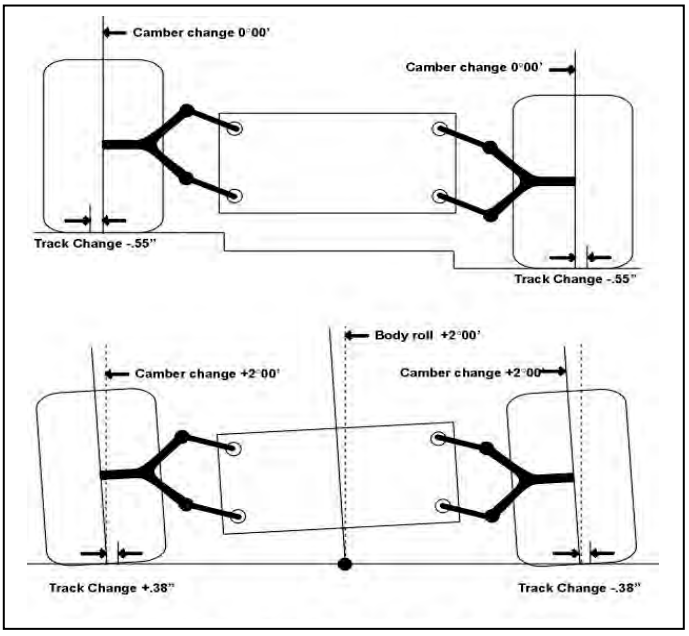

Figure 2.3: Equal length Double Wishbone and parallel (Unlusoy, 2000)

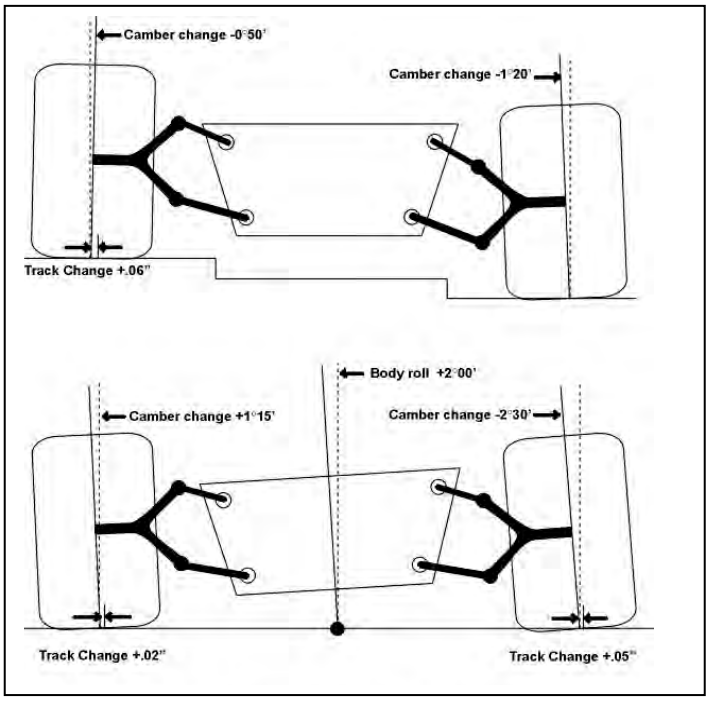

Figure 2.4: Unequal Double Wishbone and parallel (Unlusoy, 2000)

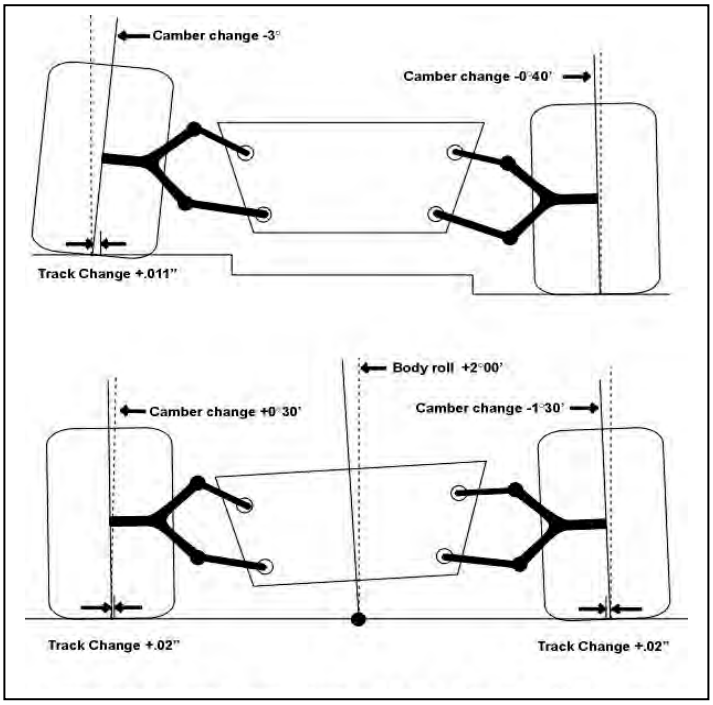

Figure 2.5: Unequal Double Wishbone and parallel (Unlusoy, 2000)

Refer to figure 2.3, the equal length of arm and parallel in double wishbone suspension, camber has no change under bump but when there is some change in boy roll, camber changes same degree as the body roll. If the body rolls change in 2 degrees, camber also follows the same degree change; the changing of camber will reduce the contact patch area between the tire and ground. The tires tend to be slip and the gripping will reduce. Then, unequal length double wishbone a parallel was invented by engineers, the changing of camber and track width give huge effect of reducing the body roll, but under bump there are some small trade –off in wheel control as shown in Figure 2.4. For unequal length a non-parallel double wishbone, camber angle during heavy loaded does not much effect the outsides wheel an also it is not too good under the bumpy surface as shown in Figure 2.5 (Unlusoy, 2000).

2.1.2 Pushrod Suspension

During a racing, pushrod style suspension is one of the best suspension that chosen due to its adjustability. It is also easy to modify the motion ratio /spring with the rocker, in case of pull rod activation the center of gravity can be lower. This type of suspension is used so that the spring and damper is mounted with the bell crank to give a better absorption of large wheel loads. By moving the spring into the frame it can reduce the car's drag and this design will improve the performance of race cars (Bayer, 2009).

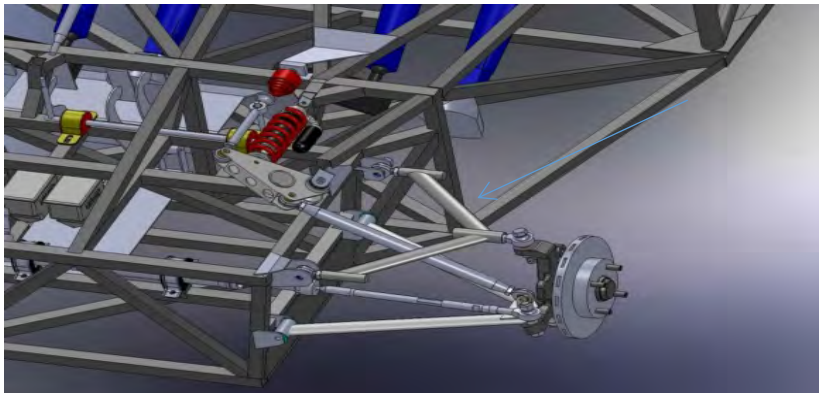

Figure 2.6: Position of Pushrod is Mount (www.locostusa.com)

There is other alternative for a race car suspension; one of them is a pushrod system. This system is widely used in many race car, it is because of the positioning and adjustment can be made easily. The pushrod was mounted below the lower A-arm position together with a bell crank near the top of the frame which can be seen on Figure 2.6. There are a few ways to mounted the damper, one of the way is by mounted in a vertically position. The pushrod is installed at the upper or lower A-arm. The rod is specially made by a carbon and coated with aluminum to hold the rod end. Furthermore, the strength and the stiffness of the rod can be achieved in a high level of compression and tension. However, it cannot stand from bending (Van Den Bos, 2001).

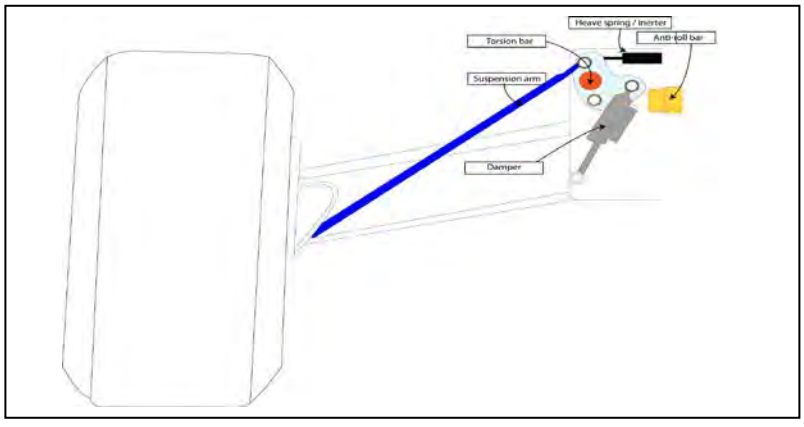

Figure 2.7: Pushrods Suspension System Configuration (www.f1fanatic.co.uk).