# STEERING SYSTEM DESIGN AND ANALYSIS OF FORMULA VARSITY RACE CAR

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# DECLARATION

"I admit this thesis is my original work except summary and passage which each of it I already telling its sources has not been previously submitted for assessment in any other course or institution, except where specifically stated"

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***With the name of Allah, The Most Gracious and Most Merciful***

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May Allah Bless Us

## ABSTRACT

The Formula Varsity racing car is a purposely built project for engineering students to apply their design and team working skills against each other in an engineering project. The design of a steering system for a Formula Varsity race car must contain all necessary components to ensure maximum handling performance for the car. It must also comply with the formula student rules. In order to design a competitive vehicle with optimum handling performance, many aspect need to be study and test includes the study of handling characteristic, cornering, braking, costing, and designing method which include concept design and design parameter. Once construction of the system was completed, analysis was conducted to investigate the suitable steering geometry that meets team desired. ADAMS software will be use to simulate and analyze the various condition of the system. During the development and construction of the formula varsity race car, some critical parts for improvement were recognized and future recommendations were suggested.

# ABSTRAK

Projek kereta lumba Formula Varsity adalah bertujuan untuk pelajar jurusan kejuruteraan bagi mempraktikkan kemahiran dalam menjalankan tugasan secara berkumpulan. Rekabentuk sistem stereng bagi kereta lumba Formula Varsity ini mestilah memenuhi segala kretiria yang diperlukan berpandukan undang-undang yang telah ditetapkan oleh FSAE bagi memastikan tahap prestasi pengendalian yang terbaik untuk kereta lumba tersebut. Dalam merekabentuk sebuah kereta lumba yang mempunyai tahap kawalan yang optima, banyak perkara yang perlu dikaji dan diuji termasuklah, ciri-ciri kawalan, membrek, lencongan dan juga cara merekabentuk sebuah kereta lumba termasuklah rekabentuk konsep serta parameter bagi rekabentuk tersebut. Setelah selesai membina sistem tersebut, analisa akan dilakukan ke atas sistem stereng tersebut untuk mengenalpasti geometri stereng yang bersesuaian dengan kehendak kumpulan. Perisian ADAMS View digunakan untuk mensimulasi dan menganalisis pelbagai keadaan sistem tersebut. Semasa membangunkan kereta lumba Formula Varsity ini, terdapat bahagian-bahagian yang kritikal yang perlu diperbaiki dari semasa ke semasa.

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# CHAPTER 1

# INTRODUCTION

## 1.1 Project Background and Problem Statement

UTeM Formula Varsity Racing Team is a group design project composed by UTeM's students, lecturers, and technician. All of the team members are from the Bachelor of Mechanical Engineering (Automotive) department and Bachelor of Mechanical Engineering (Design and Innovation) department. The intention is for a common core of group and unique contribution from each team member. The members will have to work as a team as the design of some parts will influence the one from others. So, each design modification that may affect the design of other part –it could be about steering parameter that would influence the handling characteristic. All of these should be discussed with the team-mates. This will be achieved by regular team meetings.

My part of the work deals with the analysis and design generally of the steering system. From my automotive background and my knowledge about formula one race car over the years, I set the analysis in order to design a steering system according to the Formula Student technical regulation (Appendix A).

Specific study of handling characteristics and steering geometry various angles such as camber, caster, kingpin inclination, and toe enables me to design a perfect steering system for the Formula Varsity race car.

Then, as the aim was to validate this design, it was decide to complete that step by analyze using ADAMS. A good analysis result will be possible to achieve according to the proper design we made for every single component in the system that meet our team desired.

## 1.2 Objective

My principal objectives that have been set as project goals in order to accomplice this thesis are to study the handling characteristic and steering geometry, to support on design a steering system for Formula SAE race car, and to analyze and simulate the steering geometry and handling characteristics.

## 1.3 Project Scope

1. Research and study on knowledge related to Formula Student race car generally further deeply learn about the steering system especially on steering geometry, and handling characteristics.

2. Exploring the Computer Aided Design (CAD) software such as Solid Work in order to get an ISO detail drawing and to obtain accurate measurement for each steering mechanisms.

3. Use Computer Aided Engineering (CAE) such as ADAMS to simulate and analyze the steering system in order to obtain behaviors, parameters, constraints and limitations of the steering system.

### 1.4 Gant Chart and Flow Chart

Below are the Gant chart and flow chart for the PSM 1 that shows overall work and task flow:

| TASK | WEEK | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| PSM TOPIC SELECTION | | | | | | | | | | | | | | | | |
| PSM TOPIC CONFIRMATION | | | | | | | | | | | | | | | | |
| LITERATURE REVIEW | | | | | | | | | | | | | | | | |
| PROBLEM STATEMENT AND DISCUSSION | | | | | | | | | | | | | | | | |
| CONCEPT DESIGN | | | | | | | | | | | | | | | | |
| STUDY ON ANALYSIS USING ADAMS | | | | | | | | | | | | | | | | |
| REPORT PREPARATION | | | | | | | | | | | | | | | | |
| PSM 1 REPORT DRAFT TO LECTURER | | | | | | | | | | | | | | | | |
| REPORT CORRECTION | | | | | | | | | | | | | | | | |
| SUBMIT PSM 1 REPORT | | | | | | | | | | | | | | | | |
| SEMINAR PREPARATION | | | | | | | | | | | | | | | | |
| PSM 1 SEMINAR AND PRESENTATION | | | | | | | | | | | | | | | | |

**Table 1.1: PSM 1 Gant chart**

| TASK | WEEK | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| DRAWING DIMENSION MEASUREMENT | | | | | | | | | | | | | | | |
| DESIGN A SCEMATIC DIAGRAM | | | | | | | | | | | | | | | |
| BUILT ADAMS CODING IN (.ADM) FILE | | | | | | | | | | | | | | | |
| RUN ADAM SIMULATION | | | | | | | | | | | | | | | |
| PLOT GRAPH REQUIRED | | | | | | | | | | | | | | | |
| DISCUSS THE RESULT | | | | | | | | | | | | | | | |
| MAKE CALCULATION REQUIRED | | | | | | | | | | | | | | | |
| CONCLUDE THE RESULT | | | | | | | | | | | | | | | |
| SUBMIT DRAFT & MAKE CORRECTION | | | | | | | | | | | | | | | |
| SUBMIT PSM REPORT | | | | | | | | | | | | | | | |
| SEMINAR PREPARATION | | | | | | | | | | | | | | | |
| PSM SEMINAR AND PRESENTATION | | | | | | | | | | | | | | | |

**Table 1.2: PSM 2 Gant chart**

# CHAPTER 2

# LITERATURE REVIEW

This Literature review is based on the readings and observation made during the thesis and previous experience. In this way, some pieces of information are difficult to attribute or reference.

## 2.1 Formula Student Racing Car

Formula Student is the biggest and best of its class over the world. This competition promotes careers and excellence in engineering, by challenging university students to design, build, develop market and competes as a team with a small single seated racing car. It provides the students with a real-life exercise in design and manufacture and the business elements of automotive engineering. It teaches students all about teamwork, under pressure and to tight timescales. It demands total commitment, lots of late nights, and many frustrations and challenges along the way, but the net result is the development of highly talented young engineers.

Formula Student attracts entries from universities all over the world, from the UK, mainland Europe and from the Americas, Asia and Australasia. For the universities, Formula Student represents a valuable project that blends academic work and learning

with the development of practical engineering skills. They are increasingly using it to attract school leavers to their degree programs, and to forge closer links with local industry.

Formula Student in Malaysia is still new and there is no single formula student car being developed in this country. Although there is some institute declares that they have developed a formula student car. Their claim is just supported base on the shape of the racing car which is similar to the formula student car but the design is not base on Formula Student Technical and Regulation. For the purpose to develop the first formula student car in Malaysia Universiti Teknikal Malaysia Melaka has granted RM 20 000 research money to develop the formula student car.

## 2.2 Formula Student History

Formula Student is a UK based racing car competition run by the Institute of Mechanical Engineers (IMechE) in partnership with the Institution of Engineering & Technology (IET), RS Components, Shell and SolidWorks,for Universities and Colleges from all over the world and is based on the successful Formula SAE event which takes place in the USA. In the United States, SAE Inc started running their Formula SAE programme in 1981. In 1998 two US cars and two UK cars competed in a demonstration UK Event that was held at the MIRA Proving Ground. The initiative was considered to be very worthwhile in providing students with excellent learning opportunities and practical skills. The IMechE accepted the management of the European venture in a partnership with SAE. Formula Student is different from Formula SAE in that it is designed to be a progressive learning exercise throughout a three or four year academic course. However, the same rules are used for both Formula Student and Formula SAE (with some minor changes) and this means student teams can enter their cars in the Formula SAE in the US, Formula Student and Formula SAE in Australia. (Source: Electronic Reference, http://www.sae-a.com)

**Figure 2.1: Jim Hall with the University of Texas at Austin entry**

(Source: Electronic Reference, http://www.sae-a.com)

## 2.3 Steering

Steering is the term applied to the collection of components, linkages, and so on which allow for a vessel (ship, boat) or vehicle (car) to follow the desired course. The steering system allow the driver to guide the vehicle to move along the road either straight line or turning right or left as desired. The steering system must perform several important functions, which are as follows:

1. Provide precise control of front-wheel direction.
2. Maintain the correct amount of effort needed to turn the front wheels.
3.Transmit road feel (slight steering wheel pull caused by road surface) to the operator's hands
4. Absorb most of the shock going to the steering wheel, as the tires hit bumps and holes in the road.
5. Allow for free suspension action.

The most conventional steering arrangement is to turn the front wheels using a hand operated steering wheel which is positioned in front of the driver, via the steering column, which may contain universal joints to allow it to deviate somewhat from a straight line. Other arrangements are sometimes found on different types of vehicles, for example, a tiller or rear wheel steering. Tracked vehicles such as tanks usually employ differential steering that is, the tracks are made to move at different speeds or even in opposite directions to bring about a change of course. (Source: Abdullah M. A, 2004)

## 2.4 Steering Linkage

Steering linkage is a combination of arms, rods, and ball sockets that connect the steering mechanism to the steering knuckles. The steering linkage mechanisms typically include a pitman arm, center link, idler arm, and two tie-rod assemblies. This configuration of linkage is known as parallelogram steering linkage (Figure 2.2) and it used on many passenger vehicles. Below are the steering linkage mechanisms:

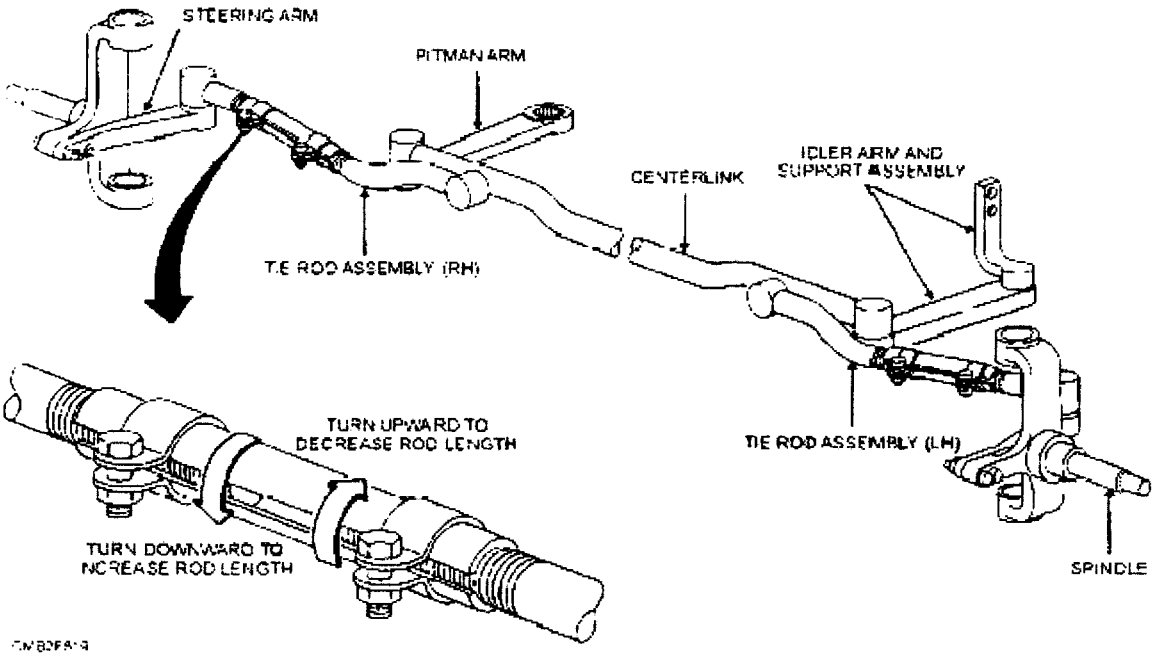


**Figure 2.2: Parallelogram steering linkage**

(Source: Electronic Reference, http://www.tpub.com)

### 2.4.1 Pitman arm

The pitman arm transfers steering mechanism motion to the steering linkage (Figure 2.2). The pitman arm is splinted to the steering mechanisms output shaft (pitman arm shaft). A large nut and lock washer secure the pitman arm to the output shaft. The outer end of the pitman arm normally uses a ball-and-socket joint to connect to the center link.

### 2.4.2 Centre link

The parallelogram steering linkage (Figure 2.2) uses a center link, it also known as an intermediate rod, track rod, or relay rod, which is simply a steel bar that connects the steering arms (pitman arm, tie-rod ends, and idler arm) together. The turning action of the steering mechanism is transmitted to the center link through the pitman arm.

### 2.4.3. Idler arm

The center link is hinged on the opposite end of the pitman arm by means of an idler arm (Figure 2.2). The idler arm supports the free end of the center link and allows it to move left and right with ease. The idler arm bolts to the frame or subframe.

### 2.4.4 Ball sockets

Ball sockets are like small ball joints; they provide for motion in all directions between two connected components. Ball sockets are needed to ensure the steering linkage is not damaged or bent when the wheels turn or move up and down over rough roads surface. Ball sockets are filled with grease to reduce friction and wear. Some of the ball sockets have a grease fitting that allows chassis grease to be inserted with a grease gun. Others are sealed by the manufacturer and cannot be serviced. (Source: Electronic Reference, http://www.tpub.com)