DESIGN AND DEVELOPMENT OF A BELL CRANK FOR MONOSHOCK FRONT SUSPENSION FOR FORMULA VARSITY RACE CAR

MUHAMMAD SAHAIL BIN ZAINOL ABIDIN

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

"I hereby declare that I have read this thesis 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 : …….
Supervisor Name : …….
Date : …….

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MUHAMMAD SAHAIL B. ZAINOL ABIDIN

This report was submitted in accordance with the partial requirements for the Honor of Bachelor of Mechanical Engineering (Automotive)

Faculty of Mechanical Engineering

Universiti Teknikal Malaysia Melaka

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DECLARATION

"I hereby declare that the work in this report is my own except for summaries and quotations which have been duty acknowledged"

Signature : …….
Author Name : Muhammad Sahail bin Zainol Abidin
Date : …….

For my beloved mother, Aziziyah binti Ahmad

and

my respected father, Zainol Abidin bin Salleh

To Mr. Muhd Ridzuan bin Mansor
(Final Year Project supervisor)

All UTeM technicians that involved in this project

and

All my friends that giving helps, ideas and opinion to fulfill this project

Thank You…

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ABSTRACT

This Final Year Project (FYP) presents the design and development of a bell crank for monoshock front suspension for Formula Varsity 2010 race car. The development process involved conceptual design, design selection, material selection, load and analysis, and product fabrication. In the first stage, a 3D model of a bell crank was developed using CATIA V5R16 computer aided design software. Further analysis has brought the selection of aluminum alloys, Al6061-T6 as the bell crank material. Suspension load analysis was also performed to determine the maximum load for the component during cornering condition. The result later been used to determine the factor of safety of the bell crank and maximum translational displacement. The factor of safety of the bell crank is 5.51 and the maximum translational displacement is 0.0904mm. This result showed that the product was able to withstand the load as required. The development process was later been carried out by fabricating the bell crank using 5-axis Computer Numerical Control (CNC) machine and manual hand milling technique. The fabricated part then be evaluated and weighted. The bell crank final weight after fabrication was 0.405 kg.

ABSTRAK

Projek Sarjana muda (PSM) ini adalah mengenai mereka bentuk dan pembangunan bel engkol untuk suspensi hadapan kereta lumba Formula Varsity. Proces yang terlibat dalam pembangunan ini adalah reka bentuk konsep, pemilihan reka bentuk, analisis beban dan fabrikasi produk. Yang pertama, proses mereka bentuk rekaan bel engkol di dalam bentuk tiga dimensi mengunakan perisian reka bentuk berbantu komputer, CATIA V5R16. Aluminium aloi, Al6061-T6 telah dipilih sebagai bahan bagi bel engkol setelah dibuat analisis lanjutan terhadap bahan. Analisis beban untuk suspensi telah dibuat bagi menentukan beban maksimum semasa keadaan mengambil pusingan. Melalui analisis ini faktor selamat bel engkol dan perubahan jarak maksimum bagi bel engkol dapat ditentukan. Faktor selamat bel engkol ialah 5.51 dan perubahan jarak maksimum adalah 0.0904mm. Kedua-dua nilai ini menunjukan bahawa bel engkol ini berupaya menahan beban yang dikenakan keatasnya. Bel engkol ini melalui proses fabrikasi dengan menggunakan mesin kawalan pengdigitan berbantu komputer 5 paksi dan teknik miling manual. Bel engkol yang telah siap difabrikasi kemudiannya diperiksa kualitinya dan ditimbang. Berat bel engkol selepas selesai proses fabrikasi adalah 0.405 kg.

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F_{LA}	=	Load from lower arm
$F_{Lateral}$	=	Lateral force acting on the tire
F_{PR}	=	Load from pushrod
F_{UA}	=	Load from upper arm
LA	=	Lower arm
m	=	Mass of tire
PR	=	Push rod
r	=	Radius of cornering
S_Y	=	Yield strength
UA	=	Upper arm
v	=	Velocity due cornering
β	=	Angle between PR and LA
σ_{max}	=	Maximum stress

CHAPTER I

INTRODUCTION

1.1 Background

Formula Varsity is a student competition race car that organized by Universiti Teknikal Malaysia Melaka (UTeM). In this competition, the students compete in each other in a challenge to design, manufacture, and race their single seater open wheel race car in real trek condition. The Formula Varsity is a competition that mimic or similar to the others students competition race car held in others countries such as Formula SAE in United State and Formula Student in United Kingdom. Until year 2010, UTeM had successfully organized three times Formula Varsity.

Results from this competition have brought many efforts later for racing team members to improve the design and build a better efficient race car for future event. Acknowledge that suspension system in a race car is important in producing a competitive race car, a study was conducted to come with a different approached of suspension system that focuses on developing a bell crank for front monoshock suspension. Below is an example of a monoshock suspension system that has been built by Dartmouth College in Formula SAE race car.

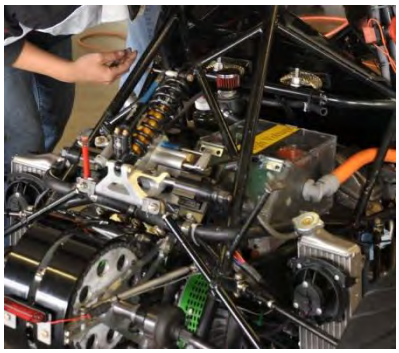

Figure 1.1: Rear monoshock suspension system FSAE, Dartmouth College (http://www.dartmouth.edu/~dfr/)

1.1 Objective

The objective of the project is to design the bell crank, to analyze the bell crank with structural analysis and Finite Element Method (FEM) by using CATIA V5R16, and to fabricate the bell crank by manual and CNC machine.

1.2 Problem Statement

In Formula Varsity race car design, suspension system is one of the most important things that should be in consideration. The current Formula Varsity front suspension is using a monoshock actuated by the rocker arm. This rocker arm is designed to transfer front load to the monoshock absorber. The current design for front suspension Formula Varsity 2010 need to be simplified the design and actuator component movement toward the damper to gain a better tire load transfer to the front suspension while on ride. Besides that, the current front suspension did not have a component that allowed little roll movement or anti-roll mechanism at front of the vehicle. To overcome this problem, new design of bell crank for front suspension is needed.

1.3 Scope

Scopes for this project are:

i) Identify the data, information and gathering literature review for bell crank and suspension system

ii) Design several concept designs and making a design selection

iii) Find a suitable and good material that suit the bellcrank

iv) Analyze the effectiveness of the bell crank functioning for front suspension

v) Fabricate the bell crank by using 5-axis CNC machine

CHAPTER II

LITERATURE REVIEW

2.1 Introduction to Suspension System

Auto racing began shortly after the invention of the automobile. Since then, motorsports has grown into an extremely popular activity all over the world. Technological advances have propelled the sport to speeds that have not been seen before. Races can be won by thousandths of a second forcing engineers and race teams to spend large amounts of resources on finding the last little bits of speed within their vehicles (Borg, 2009).

The Formula SAE, Formula Student, and Formula Varsity fall into the category of formula car racing. A formula car is an open wheeled vehicle with only one seat, typically in the middle of the vehicle. Formula cars are purpose built for racing with very few compromises.

A part of improving lap times of any racing vehicle is to optimize the suspension. The suspension controls the attitude of the tire to the road surface through the design of the linkage kinematics. The suspension also reacts to the loads created by the tire. The load swill forces the suspension to elastically deform. This compliance will change the orientation of the tire to the road. To control and predict this compliance, race engineers will thoroughly analyze the suspension members.

The term of suspension give a meaning as „supporting from above" or „suspender" since earliest form used on the roads did literally suspended the body of horse-drawn carriage. Modern car suspension have two role which is „suspends" the body and maintaining the contact patches of all four tires with road surface (Campbell, 1981).

The suspension system enables the wheel to maintain contact with the road, assuring stability and control of the vehicle. By definition, a suspension system is used to support a load from above (Staniforth, 2006).

Good suspension must have:

i. Optimal damping and spring rates to keep the tire to the ground at all times
ii. Strong component that not deflect under the loads induces upon them
iii. Incorporate a kinematics design to keep the tire as perpendicular to the ground as possible (Jawad and Baumann, 2002).

The three crucial elements of a suspension system are follows:

i. Flexibility, provided by a spring that distorts and recovers (typically compresses and expands) as the wheel transverses disturbance in the road surface
ii. Damping; which is essential to restrain the body and wheel from resonant bouncing motions
iii. Location of the wheel axle

2.2 Suspension System in Common Use

There are two main categories of suspension system which is non-independent and independent type of suspension. An independent type suspension has each wheel moving up and down without affecting the wheel on the opposite side of vehicle.

On the others hand, the non-independent systems movement of wheel will affect the wheel on the opposite side of the vehicle (Newbold and Bonnick, 2000).

2.3 Springing Medium

2.3.1 Leaf Spring

Leaf springs are usually used on the rear axles of a large car, pickup truck and heavy truck. The advantages of the leaf spring are it is cheap, it is locates the axle, robust and simply connected. But the leaf springs disadvantages are it give a harsh ride, require more space not flexible as coil spring type, amount of deflection is limited and has a high unsprung weight.

Figure 2.1: Front leaf spring loaded on vintage hotrod vehicle

(http://www.hotrodders.com)

2.3.2 Torsion Bar

Torsion bar is a straight bar which can either be round or square section and fixed at one end to the chassis. Its function is equivalent a coil spring before it had been coiled. Each of the bar section is increased and serrated or splined to connect with the lever or chassis.