DESIGN AND DEVELOPMENT OF CARBON FIBER SUSPENSION PUSH ROD FOR UTeM FORMULA STYLE RACE CAR

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This technical report is submitted in accordance with the requirements of the Bachelor of Mechanical Engineering (Automotive)

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DECLARATION

"I hereby, declare this thesis entitled Design and Development of Carbon Fiber Suspension Push Rod for UTeM Formula Style Race Car is the result of my own research except as cited in the reference"

Signature : …………………………………………………

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Date : 24 May 2010

DEDICATION

To my beloved family especially my father,
Abdul Ghaffar B. Daud
And also to my beloved mother,
Jawahair Binti Ahmad
Who keep me continuously motivated with their great support and encouragement throughout my Bachelor Degree program

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During this work I have collaborated with many colleagues for whom I have great regard and I wish to extend my warmest thanks to all those who have helped me with my work. All support I have received is most valuable thing is my life.

ABSTRACT

The Formula Society of Automotive Engineer (SAE) is a student project that involves a complete design and fabrication of carbon fiber suspension push rod for UTeM open wheel formula-style racecar. This thesis will cover the components of the suspension which is push rod. This thesis will include the calculation of load acting on the push rod, the composite laminate analysis and also the new design of the push rod. It also fabricated by using carbon fiber and polyester resin as the composite material. As the carbon fiber is choose as material, the push rod suspension properties such as strength will be increase and reduce the total weight. The tests such as compression test were conducted to determine the strength of push rod suspension when the maximum load is applied. Based on the result, carbon fiber suspension push rod is able to replace and function according to the required specification from the Formula SAE.

ABSTRAK

Formula SAE *(Persatuan Jurutera Automotif)* adalah satu projek pelajar yang melibatkan rekabentuk dan menyiapkan sistem suspensi batang penolak karbon serat bagi kereta lumba pelajar. Tesis ini akan menghuraikan tentang komponen suspensi seperti batang penolak. Tesis juga akan menghuraikan pengiraan berkaitan dengan daya yang bertindak ke atas batang penolak, analisis komposit laminat dan rekabentuk yang baru untuk dibuat. Ia telah direkabentuk dengan menggunakan bahan karbon serat dan poliester sebagai bahan komposit. Dengan menggunakan bahan tersebut, ia akan meningkatkan keupayaan dari segi kekuatan dan ia mengurangkan berat keseluruhan. Dua ujian seperti pemampatan (compression) telah dijalankan untuk mengetahui kekuatan pada batang penolak apabila daya maksima dikenakan. Berdasarkan daripada hasil pengiraan, batang penolak karbon serat mampu menggantikan dan juga berfungsi dengan baik berdasarkan speficikasi yang dikeluarkan oleh Persatuan Jurutera Automotif (SAE).

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NOMENCLATURE

SAE	=	Society of Automotive Engineers
UTeM	=	Universiti Teknikal Malaysia Melaka
GPa	=	Giga Pascal
kPa	=	Kilo Pascal
CATIA	=	Computer Aided Tridimensional Interactive Application
CAD	=	Computer-aided Design
σ_y	=	Stress, MPa
ASTM	=	American Society for Testing and Materials
M	=	Mass, kg
L	=	Length, m
c	=	Centre to rear axle, m
b	=	Centre to front axle, m
W	=	Weight, N
F_f	=	Force at the front, N
h	=	Centre of the gravity
a	=	Acceleration, ms^{-2}
F_{tire}	=	Force at the tire, N
Lateral force	=	Force, N
K_{Tf}	=	Front roll stiffness, Nm^2/deg
K_{Tr}	=	Rear roll stiffness, Nm^2/deg
a_y	=	Acceleration in lateral, ms^{-2}
ΔF_{FZM}	=	Weight transfer due to the roll, N
ΔF_{FZL}	=	Weight transfer due to the lateral force, N
F_{FOZ}	=	Normal force on the tire, N

CHAPTER I

INTRODUCTION

1.1 Introduction of Formula Race Car

The Formula SAE competition is designed to give engineering students the opportunity to design, fabricate, test and race formula style racing cars. At the FSAE competition, each car is judged against the competitors to decide which team's car best achieves the goals. The cars are judged in static design, dynamic abilities and track performance. The static events include categories such as production cost analysis, design, and a marketing presentation. The dynamic events include skid-pad and acceleration performance tests. After finish builds a car, it will test the car at the track to see the limit abilities of the car.

Nowadays, the formula student race car has makes a lot of improvement especially in term of weight from the heavyweight body chassis, suspension and others components. This is because the optimum powers to weight ratio could increase the performance especially in ride and handling performances. Before this, the components such as suspension system use steel and metal. Currently, many race car components use composite material such as carbon fiber and fiber glass to reduce the weight of vehicle.

The suspension system material also has made some improvement from using material like steel to composite material such as fiber glass. Many of team in formula one such as Ferrari team using composite as a material at suspension system. The most important reason using composite material at the suspension system is the handling performances. Reducing the weight of the components can give a higher performance to car (Savage, 2008).

Figure 1.0: Student Formula Race Car

(Source: http://www.3trpd.co.uk/images/casestudies/race-car-big3.jpg)

1.2 Problem Statement

In order to makes some improvement in performances of the car especially in term of reducing weight, composite material is selected for the construction of the push rod suspension component. Therefore, sufficient understanding about the composites material especially in carbon fiber composite and also understanding about the function of push rod suspension system is a subject matter to complete this thesis.

1.3 Objectives

The objective of this project is to design and develop carbon fiber-polyester composite suspension push rod for UTeM Formula Style race car.

1.4 Scope of Project

The scopes of the projects are:

1. To calculate the load acting on the component during operation
2. To perform composite laminate analysis
3. To produce detail design of the component using 3D CAD software
4. To fabricate the component using carbon fiber and polyester matrix
5. To perform compression test to evaluate the component performance

1.5 Expected Result

The material that be using is carbon fiber and expected result should be the push rod suspension is more light than the current steel push rod suspension and also can hold the force that act on the push rod suspension. This expectation should be achieved in order to product lightweight push rod suspension for UTeM's Formula Student race car.

CHAPTER II

LITERATURE REVIEW

2.1 Formula History

The first SAE Mini-Indy was held at the University of Houston in year 1979. The competition was inspired by a how to article that appeared in Popular Mechanics magazine. The competition used Mini Baja as a guide and it has to design and build small, "Indy-style" vehicles using the same stock engine. For the first time the competition is held, thirteen schools had entered and eleven compete.

Three students from University of Texas at Austin saw the potential and proposed a new mini-Indy with new rules. The new rules kept restriction to a minimum, any four –stroke engine with a 25.4 mm intake restriction. The University of Texas at Austin hosted the competition through 1984. In 1985, the competition was hosted by The University of Texas at Arlington. There, Dr. Robert Woods, with guidance from the SAE student activities committee, changed the concept of the competition from one where students built a pure racing car, to one that mirrored the SAE Mini-Baja competitions, where they were to design and build a vehicle for limited series production.

General Motors hosted the competition in 1991, Ford Motor Co. in 1992, and Chrysler Corp. in 1993. After the 1992 competition, the three formed a consortium to run Formula SAE. At the end of the 2008 competition, the consortium, based on economic pressure, ceased to exist. The event is now funded by SAE through company sponsorships and donations along with the team's enrollment fees. (http://en.wikipedia.org/wiki/Formula_SAE)

2.2 Formula Student Car Specification

The Formula SAE is one of the events for student to develop their potential to build a formula car. Hence, Society of Automotive Engineers (SAE) has stated the rules and regulation for Formula SAE, all the race car must fulfill the specification to make the team qualify on enter this Formula SAE. According to the article 6.1 in rules and regulation for Formula SAE about the requirement of suspension system is the car must be equipped with a fully operational suspension system with shock absorbers, front and rear, with usable wheel travel of at least 50.8 mm (2 inches), 25.4 mm (1 inch) jounce and 25.4 mm (1 inch) rebound, with driver seated. The judges reserve the right to disqualify cars which do not represent a serious attempt at an operational suspension system or which demonstrate handling inappropriate for an autocross circuit (http://student.sae.org/, 2008). These are example race car specification that required by Formula SAE:

Table 2.1: Car Specification (Source: http://student.sae.org/, 2008)

Dimensions	Front	Rear
Overall length, Width, Height	92 inches long, 60 inches wide, 52 inches high	
Wheelbase	66 inches	
Track	52 inches	60 inches
Weight with 150lb driver	175 lbs	245 lbs

Suspension Parameters	Front	Rear
Suspension Type	Double unequal length A-Arm. Pushrod actuated horizontally oriented spring and damper	Double unequal length A-Arm. Direct acting spring and damper
Tire Size and Compound Type	20x7.5-13 R25A Hoosier	20x9-13 R25A Hoosier
Wheels	8 inch wide, 3 pc Al Rim, 2 inch neg. offset	9 inch wide, 3 pc Al Rim, 3 inch neg. offset
Design ride height (chassis to ground)	1.0 inches	1.3 inches
Center of Gravity Design Height	9.0 inches above ground (confirmed with testing)	
Suspension design travel	1.2 inches jounce / 1.2 inch rebound	1.4 inches jounce / 1.2 inch rebound
Wheel rate (chassis to wheel center)	146 lb/in	170 lb/in
Roll rate (chassis to wheel center)	3.14 degrees per g	
Sprung mass natural frequency	4.46 Hz	5.32 Hz
Jounce Damping	90% of critical damping at X in/sec	58 % of critical damping at X in/sec
Rebound Damping	62% of critical damping at X in/sec	50 % of critical damping at X in/sec
Motion ratio / type	0.31 / linear	0.54 / progressive rate
Camber coefficient in bump (deg / in)	1.31 deg / in	1.01 deg / in
Camber coefficient in roll (deg / deg)	2.32 deg / deg	2.62 deg / deg
Static Toe and adjustment method	0.125 inch toe out via adj steering links	0 to 0.25 inch toe in via adj toe links
Static camber and adjustment method	-1.5 deg via shim plates on A-arm	-0.5 deg via shim plates on upright
Front Caster and adjustment method	13 degrees non-adjustable	
Front Kingpin Axis	2 degrees non-adjustable	
Kingpin offset and trail	.8 inches offset, 0 inches trail	
Static Akermann and adjustment method	110% non-adjustable	
Anti dive / Anti Squat	0	-30%
Roll center position static	2.2 inches above ground	1.2 inches above ground

2.3 Suspension

Generally, suspension is the critical sub-system of the vehicle that makes the vehicle more comfort and smooth during cornering and braking as well as lane keeping. The suspension system development year after year has a lot of improvements. The suspension has a lot of type and it depends on the vehicle and also their use.

2.3.1 History of Suspension

In 16th century, a few researchers tried to solve a problem of feeling every bump in the road. For example is wagon, by slinging the carriage body from leather straps attached at four post of chassis that looked like unturned table. The term carriage body suspended from chassis is called suspension. Gottlieb Daimler in Germany and some European car makers had tried to apply coil springs. However, most manufacturers stood fast with leaf springs which less cost, easy to produce and also easy to assemble to the car. After that, in 1804, Obadiah Elliot from London was invented the venerable leaf spring, which today some manufactures still use in rear suspensions. In 1934, General Motors had introduced a coil spring suspension with each tire sprung independently (Zakaria, 2006).

2.3.2 Function of Suspension System

The suspension system works comprise of unsprung mass which is tyre mass, wishbone, spring, damper, wheel knuckle (king pin) and tie-rod for front suspension. Frame or unitized body, wheels, wheel bearings, brake system and steering system. All the components in these system are working together in order to provide a safe and comfortable mean of transportation. The suspension system functions are as follows:

i. Support the weight of the frame, body, engine, transmission, drive train, passengers and cargo.
ii. Provide a smooth, comfortable ride by allowing the wheels and tires absorb vibration due to uneven road surface while maintain the body.
iii. Work with the steering system to help keep the wheels in correct alignment.
iv. Keep the tires in contact path with the road, even after striking bumps or holes in the road.

v. Allow rapid cornering without extreme body rolls (vehicle leans to one side).

vi. Allow the front wheels to turn from side to side for steering.

The suspension system must consider the dynamics of moving vehicle from two perspectives:

i. Ride – ability of vehicle to smooth out bumpy road

ii. Handling – ability of vehicle to perform safely during acceleration, braking and also cornering.

2.3.3 Type of Suspension System

Figure 2.1: Type of Suspension System

(Source: http://www.autospeednet.com/sites, 2008)

The suspension used in vehicle can be divides in to major type which is independent suspension and non-independent suspension. Independent suspension can be defines as each wheel on the same axle can move vertically independently of its own. As the result, independent suspension movement can be isolated from affecting the other and it will give better ride quality and handling characteristics. The simplest example of independent suspension is MacPherson strut, double wishbone suspension system and many more. In the other hand, non-independent suspension can be defines which on the same axle, the left and right wheels are interlinked. So, whenever it goes over bumps with one wheel can affect the wheel on the opposite side. Also in addition, if one wheel gets stuck, a lot of traction will lose because the opposite wheel does not adjust to the terrain and sit flat on the surface. The example for non-independent is De Dion tube.

2.3.3.1 MacPherson Strut System

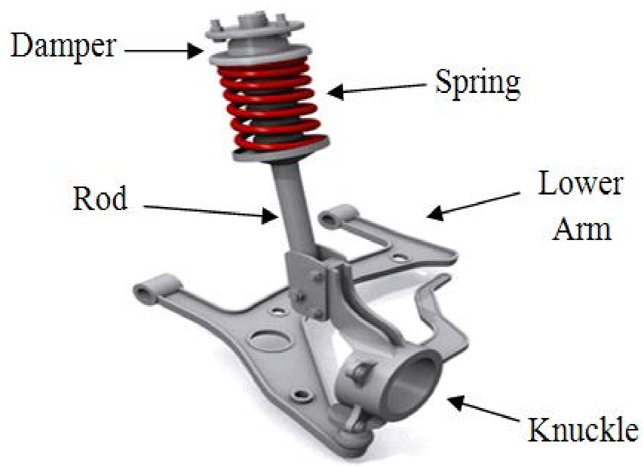

Figure 2.2: MacPherson Strut Suspension
(Source: http://www.carbibles.com/suspension_bible.html)

MacPherson is one of the famous suspension systems used in the vehicle. This type of suspension consists of a spring and shock absorber unit called a strut. The lower end of the strut is located by a ball joint, fitted to the end of the suspension control arm. Its upper end is located in a molded rubber mounting. If the unit is on the front, the upper mounting includes a bearing to allow the complete strut to rotate with the steering. A tension rod, or stay bar, extends from the body sub-frame, to the outer end of the control arm. This maintains the location of the control arm during braking, and accelerating (www.carbibles.com, 2008).

2.3.3.2 Double Wishbone System

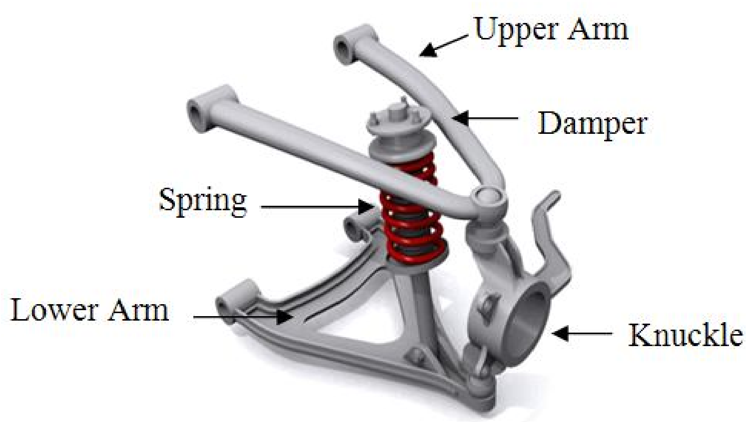

Figure 2.3: Double Wishbone Suspension System
(Source: http://www.carbibles.com/suspension_bible.html)

In double wishbone suspension, it is using two parallel wishbone-shaped arms to locate the wheel. Each wishbone (or arm) has two mounting positions to the chassis and one joint at the knuckle. The shock absorber and coil spring mount to the wishbones to control vertical movement. Double-wishbone designs allow the engineer to carefully control the motion of the wheel throughout suspension travel, controlling such parameters as camber angle, caster angle, toe pattern, roll center height, scrub radius, scuff and many more (Wikipedia, 2006).

Camber angle is the angle made by the wheel of an automobile between the vertical axis of the wheel and the vertical axis of the vehicle as it viewed from the front or rear. This is for designing the steering and suspension system. If the top of the wheel is further out than the bottom, it is called positive camber and if the bottom of the wheel is further out than the top, it is called negative camber (www.madabout-kitcars.com, 2008).