DESIGN AND ANALYSIS OF THE SUSPENSION SYSTEM FOR SINGLE SEATED EDUCATIONAL RACING VEHICLE

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This report is submitted in fulfillment of the requirement for the Bachelor of Mechanical Engineering (Automotive)

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DECLARATION

I declare that this project report entitled “Design and Analysis of The Suspension System For Single Seated Educational Racing Vehicle” is the result of my own work except as cited in the references.

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Date : _____

SUPERVISOR'S DECLARATION

I hereby declare that I have read this project report 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 : _____

Name of Supervisor: DR. FUDHAIL BIN ABDUL MUNIR

Date : _____

DEDICATION

I am hereby is dedicated this report to my beloved parents, Zaharuddin Bin Zakaria and Zaiton Binti Hamid who always keep support and encourage me when I needed them the most. Not to forget to my siblings, my friends and to my supervisor, Dr. Fudhail Bin Abdul Munir for supporting me throughout this project and their understanding in the way I am.

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First of all, in this great opportunity, I would like to thank to Allah for providing me a great health and strength throughout this final year project. My warm thanks to whom had helped and guide me during my study period in Universiti Teknikal Malaysia Melaka (UTeM) and also whom had given me an advice and encourage me throughout my studies in UTeM.

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And I also would like to express millions of thanks to my parents, relatives, my friends and those who are involved in this project either directly or indirectly for helping me in completing this project.

Once again, a big gratitude to my supervisor for giving me the heads up on how to properly do the project and giving me step-by-step on how to even run the project. All those criticism and views from my presentations were hopefully used to improve myselves throughout the entire project and I hope to fulfil the specification and needs of this subject as I instructed to do so.

ABSTRACT

The suspension system is one of the most important and basic systems in a vehicle. The purpose of the vehicle suspension system is to maximize the friction between the road surface and the tires to provide the stability of the steering and also a good handling of the vehicle. In this project, the suspension was designed by using a CATIA V5 software for the single seated racing vehicle. In case of the racing vehicle, the most suitable suspension system is a push rod suspension system because of the characteristic of the system is convenient with the racing vehicle. Furthermore, the designed suspension will be analyses with a Von Misses analysis and Translational Displacement analysis in a CATIA software. The parameters of the suspension are also considered in this project while running an analysis of the suspension by using MATLAB Simulink software to find a pitch body and roll dynamic of the vehicle. The objective of this projects is to design a low-cost suspension system and perform a stress analysis on the designed suspension system. Then, to analyses the behavior of the suspension in the pitch and roll dynamic of the vehicle.

ABSTRAK

Sistem suspensi adalah salah satu sistem yang paling penting dan asas sistem di dalam kenderaan. Tujuan sistem suspensi kenderaan ini adalah untuk memaksimumkan geseran antara permukaan jalan dan tayar untuk kestabilan stereng dan juga pengendalian kenderaan yang baik. Dalam projek ini, sistem suspensi telah direka dengan menggunakan perisian CATIA V5 untuk kegunaan kereta lumba. Untuk kereta lumba, sistem suspensi yang paling sesuai adalah sistem "pushrod" kerana ciri-ciri sistem ini sesuai dengan kenderaan yang laju. Tambahan pula, suspensi yang direka akan dianalisis dengan "Von Misses" analisis dan "Translational Displacement" analisis dalam perisian CATIA. Parameter suspensi juga diambil kira ketika menjalankan analisis suspensi dengan menggunakan perisian MATLAB Simulink untuk mencari "pitch body" dan "roll dynamic" kenderaan. Objektif projek ini adalah untuk mereka-bentuk sistem suspensi kos rendah dan membuat analisis tekanan pada sistem suspensi yang direka. Dan seterusnya, untuk menganalisis kelakuan suspensi itu dalam kondisi "pitch body dan "roll dynamic" kenderaan.

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CATIA	Computer Aided Three-dimensional Interactive Application
MATLAB	Matrix Laboratory
CAD	Computer Aided Design
CAM	Computer Aided Manufacturing
CAE	Computer Aided Engineering
COG	Center Of Gravity

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Suspension system is among the most important and basic systems in a vehicle. The purpose of vehicle suspension system is to augment the friction between the surface of road and the tires to provide the stability steering and good handling of the vehicle [1]. The suspension also helps to support the vehicle weight, keeping the vehicle tires in contact with the road and maintaining the correct vehicle ride height [2]. In order to achieve the stability and vehicle ride comfort, there were three principles must be resolved which is road isolation, road handling and cornering. Numerous studies have been conducted to achieve the stability and ride comfort in the vehicle.

In addition, there are three elements that consist in a vehicle suspension system, which are wishbone, spring and shock absorber. The spring is like an elastic object that used to save a mechanical energy. They can twist, pulled or stretched by some of the force and then can return back to their original form when the force is released. A coil spring is made from a special wire of a single length, which is heated and wound on a former, to produce the required shape. The load carrying ability of the spring relies on upon the width of the wire, the general width of the spring, its shape, and also the range of the coils [3]. Shock absorbers are generally in charge of the undesirable structure-borne noise in cars. The part of the shock absorbers is to give a superior handling, comfort and the wellbeing of the car during travel by means of damping the relative movement between wheel and body of the car. [4]

The purposes of these elements are to filter and transmit the force exerted by the vehicle body to the road. The spring element is important as it carries the body mass and isolates the vehicle from uneven road surfaces that subsequently contributes to the drive comfort [5]. In addition, the damper system in the vehicle also contributes to safety as it absorbs the damping of the body wheel oscillations.

Generally, the suspension systems are categorized into two groups, dependent and independent system. A suspension connected to a rigid axle between the left and the right of the wheels is called a dependent suspension since the vertical movement of one wheel is delivered to the opposite wheel in these cases. The major disadvantage of this rigid steer able axle is their susceptibility to tramp-shimmy steering vibrations [6]. The independent suspension system allows the left and right wheel to move without affecting the other's motion. Nearly all the passenger cars and light trucks use an independent front suspension because of the advantages in providing room for the engine and also for the better resistance to steering induced vibrations. There are many forms and designs of independent suspensions. However, double wishbone and MacPherson strut suspensions are perhaps the simplest and most commonly used designs.

The double wishbone suspension as shown in Fig.1.1 is also known as the short long arm or double A-arm suspension. Each wishbone or arm has two mounting points that attached to the chassis and is connected to the knuckle by spherical joint. The damper and coil spring system is put between the chassis and both of the control arms to smoothen the vertical development. For this situation, the guiding connection is appended to the tie-rod by utilizing a spherical joint and the tie-rod is associated with the steering rack by a universal joint. The double wishbone is utilized as a part of an elite of the cars and SUVs because of its better kinematic reaction over different suspensions [7].

Various methods for the designing and modelling of the double wishbone suspensions are exist in the literature. The author has made use of the displacement matrices and the loop-closure constraints to synthesise and analyse these mechanisms by modelling the double wishbone suspension as a spatial RSSR-SS linkage [8]. Other reported methodologies, focused on the designing of the suspension system by

optimising some particular suspensions performance indices, such as camber, caster, toe, and king-pin inclination [9-11]. However, in these works, the kinematic constraint equations are used solely in the formulating constrained optimisation problems. According to Wang et al. [12], the design of experiments module in the software Adams\View can be utilized to obtain the optimal values for the key design parameters of the suspension system by setting up the desired ranges for those design parameters.

Arikere et al. [11] are reported that the loop-closure equations for the double wishbone are derived by using lower A-arm angle as a surrogate input, while holding the steering input at a constant value. The kinematic analysis of the double wishbone is performed by using Euler angles that associated with the spherical joint that join the lower A-arm to the knuckle, as the surrogate input [13-14].

An American automotive engineer, Earle S. MacPherson has developed the MacPherson Strut suspension by using a strut configuration system [15]. Solid model of the suspension system is shown in Fig.1.2**.** One end of the strut is attached to the knuckle via the prismatic joint and the other end is connected to the chassis by revolute joint while the other end is connected to the chassis by spherical joint. The strut is also carries the spring and the damping elements. The steering link is attached to the tie-rod using the spherical joints, meanwhile the tie-rod is connected to the rack by universal joint. In spite of the fact that the MacPherson strut suspension system has less great kinematic characteristic contrasted with the double wishbone suspension [7]. It is sufficiently minimal to be good with the transversely mounted engines and is accordingly utilized broadly in front wheel drive cars.

A numerous technique for the kinematic analysis of MacPherson strut suspension system exist in the literature, a prominent one being [15]. Modelling the MacPherson strut suspension as a spatial mechanism, linearized approximate and non-linear position analysis is reported, based on the vector algebra. Later, a formulation in terms of the Cartesian coordinates of some defined a point in the links and also at the kinematic joints [16], whereas the constraint of the equations using Euler parameters is formed [17].

However, the focus of this project is on the double wishbone suspension design; it's a simple and widely used independent suspension system. This suspension assembly improves the drive comfort by making more stable ride while minimizes unnecessary vehicle movement during driving [18]. There two systems that usually used in the racing car such as Formula 1, Formula SAE, Formula Varsity, etc. The two systems are push rod and pull rod suspension system. Although, the system is quite the same but there is pro and cons for both systems.

Generally, racing cars tends to utilize push rod suspension system at the front of the car while pull rod system at the rear of the car [19]. However, a push rod suspension system will be design for both front and rear of the car. This is because a push rod system is more aerodynamically than the pull rod system and push rod system help the car maintains at the same level while pull rod system give a higher load on upper arm of suspension.

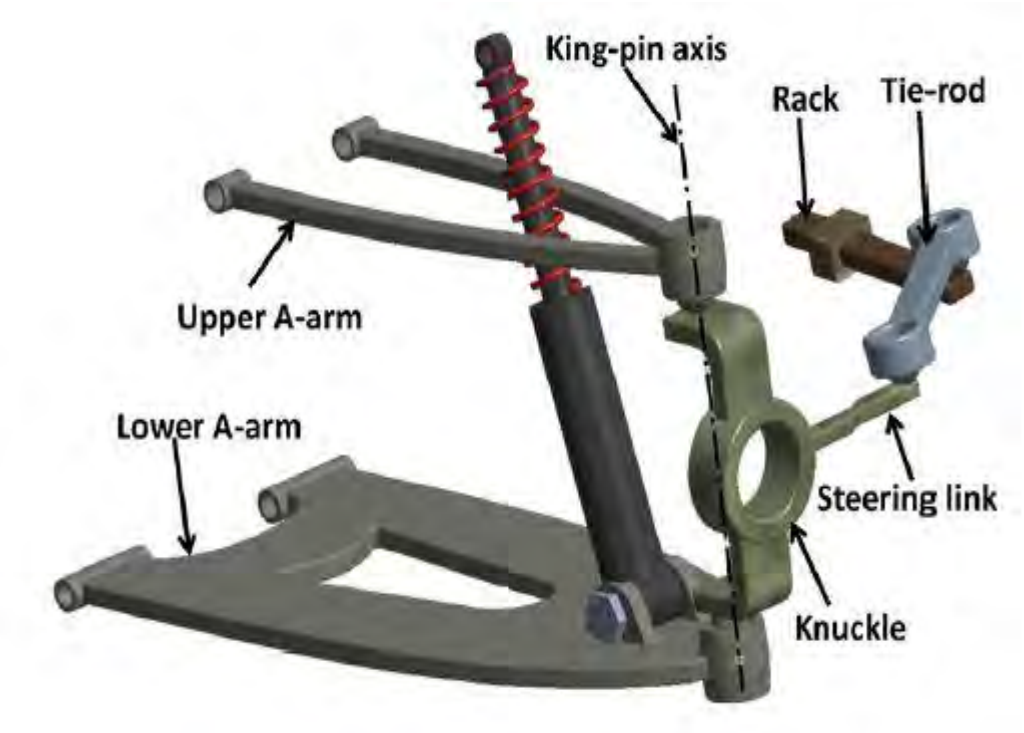

Figure 1.1: Double wishbone suspension [14]

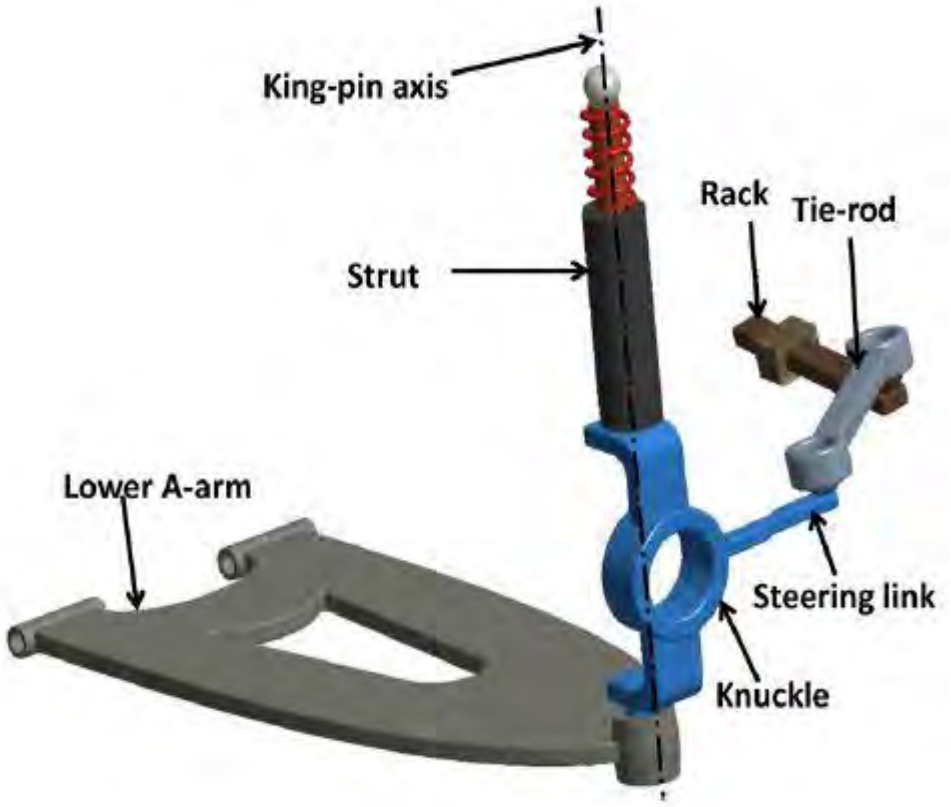

Figure 1.2: MacPherson strut suspension [14]

1.2 PROBLEM STATEMENT

The aim of this project is to design and analysis the suspension system for single seated racing car. This project focused on designing a double wishbone suspension system by using CATIA software for the single seated racing vehicle. The designing of the push rod suspension system will give the advantage for a racing car such as formula varsity or formula SAE. Hard cornering, braking or other road disturbance in the racing will affect the vehicle handling and stability. It is observed that by using this suspension system, the pitch and roll for the car is needed to be considered. So, to overcome this problem, the research had been made to design and analysis a low-cost push rod suspension system for a single seated racing vehicle.

1.3 OBJECTIVES

The objectives of this project are as follows:

1. To design a low-cost suspension system by using CATIA software for a single seated educational racing vehicle.
2. To perform a stress analysis on the designed suspension system.
3. To analyse the behaviour of the suspension in roll and pitch by using MATLAB Simulink software.

1.4 SCOPES OF PROJECT

The scopes of this project are as follows:

1. Focus on the design of the suspension system.
2. Stress analysis will be performed to determine the feasibility of the suspension system.
3. Analysis of the designed suspension in roll and pitch will be conducted in the second semester.

CHAPTER 2

LITERATURE RIVIEW

2.1 History Suspension System

The main suspension system has been intended for the light chariot of Ramses II around the year of 1296 B.C. Tragically, this suspension system was awful because of its shaky condition. Although, the Greeks have found numerous new standards with a specific end goal to take care of this issue, they were unable to find the best answer for good suspension system. Around then, one suspension system has been found that was truly agreeable for driving power and suspension. Nonetheless, there were issues for that design in which it decreases the paces and the rapid wear of the component and should be changed frequently. By that time, history saw a rapid evolution of suspension system design with a few issues have been found and distinguished. Regardless of the positive improvement of suspension system design, there still issues relating to the system, for example, mechanical noise coming from an iron chain suspension and also a portion of the passenger must be safe from the sea sickness.

A modern automobile suspension system has been introduced by a young man by the name of William Brush in 1906 [20]. This is because of the pile up at unpaved street with the speed of 30 mph which is included his sibling. The impression is that the car's right wheel began shimmy savagely and the whole car

vibrated furiously. Brush has outlined a suspension system for the Brush Two-Seat Runabout car model. It highlighted a revolutionary suspension system that consolidated two developments that never assembled together. Front coil springs and devices to every wheel that damped spring bounced (shock absorbers) mounted on a flexible hickory axle.

Some European car producers had tried coil springs, with Gottlieb Daimler in Germany being the main type. In any case, most manufacturers stood quick with leaf springs. They were less expensive and by basically including leaves or changing the shape from full elliptic to the three quarter or half elliptic, the spring could be made to support varying weights.

Following a couple of years, General Motors, Chrysler, Hudson and others reintroduced coil spring front suspension. This time with every wheel sprung independently. In that year, most car began utilizing hydraulic shock absorbers and balloon (low pressure) tires. Coupling solid front axle with shock absorber and these tires truly exasperated front-end shimmy. Suspending every wheel separately diminished the impact of spring bounce [21].

Air suspension, which Lincoln ballyhooed for some model in 1984 was presented in 1990 by the Cowey Motor Works of Great Britain. It didn't function admirably on the grounds that it leaked. The primary practical air suspension was produced by Firestone in 1933 for a test car called the Stout-Scarab [22]. This was a rear engine vehicle that utilized four rubber treated roars as a part of place of conventional springs. Air was provided by small compressor connected to each bellow.

Figure 2.1: Stout-Scarab

2.2 Classification of the suspension system

The suspension system is always derived by some mechanical way. Generally speaking, the design of the suspension systems is classification in two groups [23-24]:

i. Dependent suspension system.
ii. Independent suspension system.

Each group can be functionally quite different and they are studied and discussed accordingly [25-26]. Recently, both suspension systems can be found on ordinary vehicles and commercial vehicles.

2.2.1 The dependent suspension system

The dependent suspension system is otherwise called a solid axle suspension, when both wheel, left and right are mounted to the same solid axle as in Figure 2.2. For this situation, any development of any wheel will be transmitted to the opposite wheel making them to camber together. Solid drive axles are typically utilized on the rear axle of numerous passenger car, trucks and on the front axle in numerous four-wheel drive vehicles.

The benefit of the solid axles is viewed as the camber angle which is not influenced by rolling of the vehicle body. In this manner, produce a little camber in cornering with the exception of that which arises from slightly more compression of the tires on the outside of the turn. Besides, wheel alignment is readily kept up, which contribute to minimize the tire wear. While for the disadvantage of the solid steerable axles is their susceptibility in shimmy steering vibration, overwhelming mass, and etc. The most sorts of solid axles are Hotchkiss, Four link and De Dion.

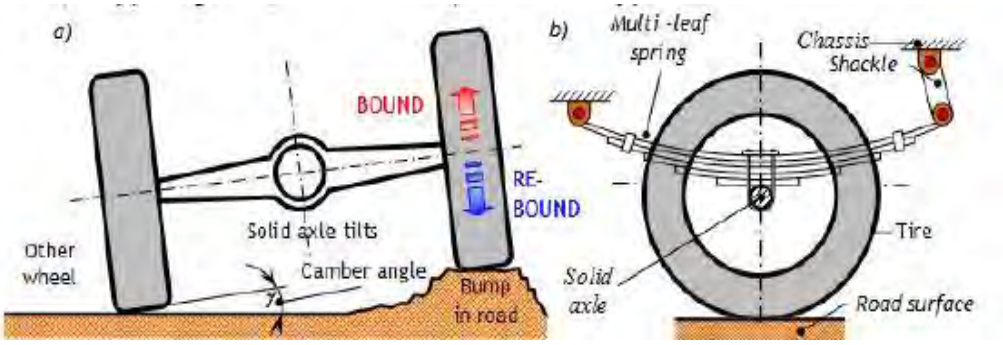

Figure 2.2: The dependent suspension system; **a)** front view **b)** side view [30]

2.2.2 The independent suspension system

The independent suspension system allows one wheel to move upward and downward with a minimum effect on the other wheel as in Figure 2.3. Mostly, the passenger cars and light truck use independent front suspension system because it provides much more space for installing vehicle engine than a dependent suspension system. Apart from that, independent suspension system likewise permits a great deal more displacement of wheel, better resistance in steering vibration like wobble and shimmy as well as offer a higher performance in passenger comfort. As the disadvantage of the independent suspension system, it can be viewed as the complexity of the design and manufacturing cost because of expanding of the quantity of parts.

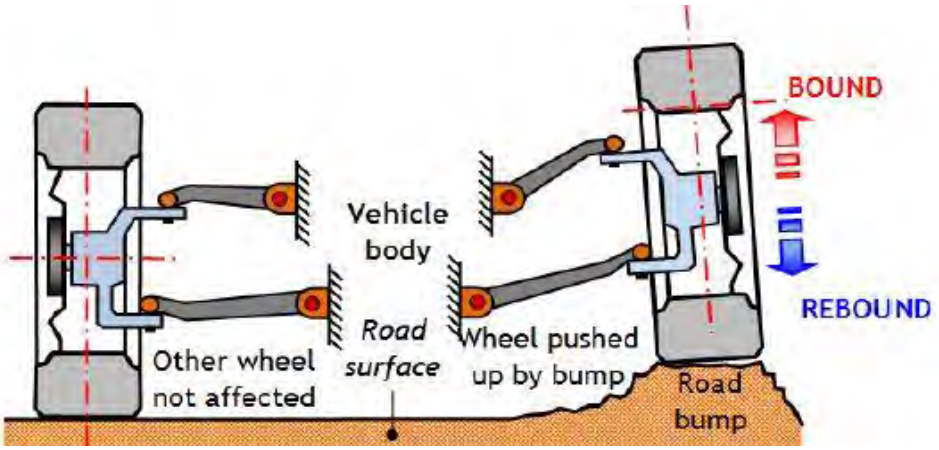

Figure 2.3: The independent suspension system [30]