"I hereby declare that I have read through this report entitle "*Analysis on Passive Vehicle Suspension System*" and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (Control, Instrumentation and Automation)"

Signature	:	…………………………………….
Supervisor name	:	Dr. Aliza Bte Che Amran …………………………………….
Date	:	18/6/2014 …………………………………….

ANALYSIS ON PASSIVE VEHICLE SUSPENSION SYSTEM

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A report submitted in partial fulfillment of the requirements for the degree of Bachelor in Electrical Engineering (Control, Instrumentations and Instrumentations)

Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2014

I declare that this report entitle "*Analysis on Passive Vehicle Suspension System*" is the result of my own research except as cited in references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ……………………………………

Name : Chin Fen Ying ……………………………………

Date : 17/6/2014 ……………………………………

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ABSTRACT

Vehicle suspension system plays an important role in automobile industry in order to guarantee good ride quality of vehicle. Basically, traditional suspension system which is passive suspension system consists of springs, shock absorbers and linkages that connect a vehicle body to its wheels. However, passive suspension system is an open loop system which does not contain any controllers to control the performance of the vehicle suspension system when passing through bumpy on the road. In this report, construction of an experiment setup to represent passive vehicle suspension system for quarter car model is considered. Experimental setup for passive suspension system is important because proper modeling of vehicle suspension system could lead to good controller design and hence improve the performance of the vehicle suspension system. This report primarily focuses on the two-degree-of freedom quarter-car model to represent passive suspension system. Semi-active and active suspension system will not be covered in this project A number of experiments have been carried out using the experiment setup in order to identify the characteristic of this experimental setup. Experiments with different vehicle body mass, different period for one pulse and different pulse width of input pressure of the road excitation have been conducted. The experiments results are evaluated based on the vehicle body displacement and tire displacement of the experimental setup. However, experiments give different results when three parameters are varied. Experiment results show that the pulse width of the input pressure is directly affected the characteristic of this passive suspension system experimental setup. Lastly, simple simulation has been done in order to compare the simulation and experiments results. The amplitude and shape of the simulation and experimental results are evaluated in this report.

ABSTRAK

Sistem kenderaan memainkan peranan penting bagi menjamin kualiti perjalanan kenderaan yang baik. Pada asasnya, sistem suspensi tradisional yang merupakan sistem suspensi pasif terdiri daripada spring, penyerap henjutan yang menghubungkan kenderaan dan roda . Walau bagaimanapun, sistem suspensi pasif ialah sistem gelung terbuka yang tidak mengandungi apa-apa pengawal untuk mengawal prestasi sistem kenderaan apabila melalui permukaan jalan raya yang beralun. Oleh itu, pembinaan sebuah setup eksperimen untuk mewakili sistem kenderaan pasif untuk suku model kereta telah dipertimbangkan. Penyediaan eksperimen sistem pasif adalah penting kerana pemodelan baik sistem suspensi kenderaan boleh membawa kepada reka bentuk pengawal yang baik dan dengan itu meningkatkan prestasi sistem penggantungan kenderaan. Laporan ini memberi tumpuan terutama kepada dua darjah kebebasan model suku – kereta untuk mewakili sistem suspensi pasif. Sistem suspensi separuh–aktif dan aktif tidak akan termasuk dalam projek ini Beberapa eksperimen telah dijalankan dengan menggunakan setup eksperimen untuk mengenal pasti ciri setup eksperimen ini. Eksperimen dengan jisim kereta yang berbeza dan tekanan input berbeza lebar denyut telah dijalankan. Keputusan eksperimen dinilai berdasarkan anjakan badan kenderaan dan anjakan tayar. Tetapi, keputusan eksperimen akan berubah apabila tiga parameter berdasarkan eksperimen set dimanipulasi. Saiz input tekanan secara langsung memberi kesan kepada ciri bagi sistem suspensi pasif persediaan eksperimen ini.. Akhir sekali, simulasi telah dilakukan untuk membandingkan keputusan simulasi dan eksperimen. Amplitud dan bentuk keputusan simulasi dan eksperimen telah dinilai dalam laporan ini

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LIST OF ABBREVIATIONS

M_s	-	Mass of vehicle body (sprung mass)
M_{us}	-	Mass of the wheel and tire (unsprung mass)
k_s	-	Spring constant of the suspension system
k_t	-	Spring constant of the tire
b_s	-	Dashpot constant (shock absorber)
r	-	Vertical displacement of road input
X_s	-	Vertical displacement of sprung mass
X_{us}	-	Vertical displacement of unsprung mass

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CHAPTER 1

INTRODUCTION

The purpose of this chapter is to provide an introduction about the project carried out in this course. First of all, an overview of vehicle suspension system is being introduced. Then, problem statement of this project is explained. Next, project objectives and scopes are discussed at the end of this chapter.

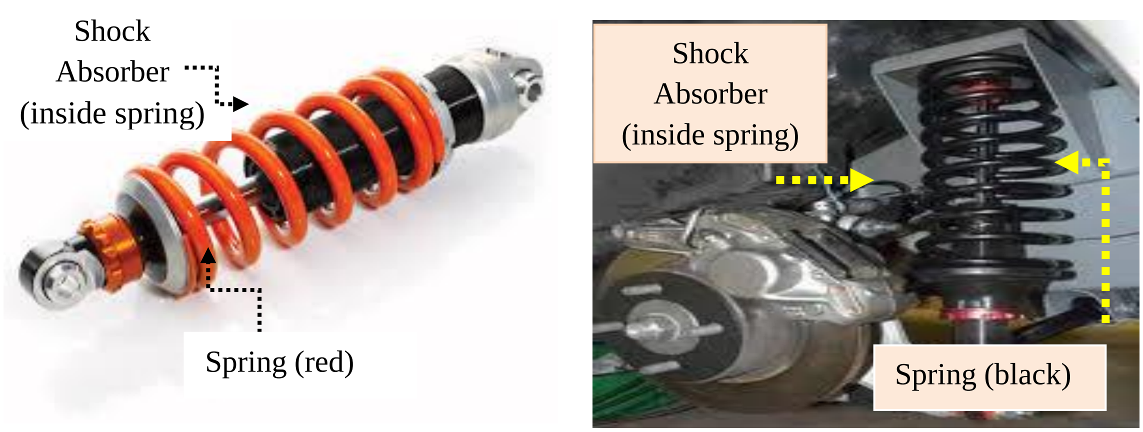
1.1 Research Background

Nowadays, condition of local roads in Malaysia is getting worst. Roads are full of potholes, improper road shoulders and bumps. This condition causes a lot of problems especially damage to vehicles' parts and system where the potential damage includes tire puncture, premature wear on shocks and struts, wheel rim damage, suspension damage, steering system misalignment and engine damage. Moreover, those dreadful road conditions will affect drive stability, steering and braking which will lead to road accident. For example, a broken shock or strut which caused by severe hitting of a deep pothole could alter the steering and handling of the vehicle and create dangerous driving. This situation highlights that quality of road surface is very important in ensuring safe driving on the road. Besides that, good suspension system will increase the protection of vehicles from bad road conditions and hence decreases the rate of accidents in our country. In the above mentioned case, good suspension system will helps the vehicle to "absorb" the impact of the pothole thus the driving quality is not interrupted by bad road surfaces. Figure 1.1shows the road conditions in Malaysia.

(a) (b)

Figure 1.1: (a) Bad road quality in Malaysia [19] and (b) Pothole on the road surface in Malaysia [18]

Vehicle suspension system plays an important role in automobile industry in order to guarantee good quality of car. A good vehicle suspension system provides high vehicle handling, good drive stability, ensures the comfort of passengers, and good isolation from road noise, road shocks and vibration. Suspension system consists of springs, shock absorbers and linkages that connects a vehicle to its wheels and allows relative motion between the two [16]. In other words, the suspension system separates the car body and the car wheel. The shock absorber dissipates shock energy received from road bump without causing undue oscillation in the vehicle. However, the spring absorbs the shock energy received from road bump and converts it into potential energy of spring. Figure 1.2 shows an example of a spring and shock absorber.



(a) (b)

Figure 1.2: (a) Diagram of spring and shock absorber [20], and (b) How absorber and spring are attached to a vehicle [21]

The suspension systems can be divided into three types which are passive, semi-active, and active suspension system. The passive suspension system is an open-loop control system that does not contain any external energy sources and only consists of passive elements which are spring and shock absorber. Due to open-loop control system characteristic, the performance of the passive suspension system cannot be adjusted to achieve the desired performance. Passive suspension system has the ability to store energy via a spring and dissipate it via a shock absorber. However, passive suspension system does not have the function of supplying energy to the system. The performance of the passive suspension system can be improved by adding active components to the system.

Semi-active suspension system is modified from passive suspension system by changing the shock absorber to a variable shock absorber [4]. The damping coefficient of the shock absorber can be adjusted in order to follow the road conditions. Active suspension system is a closed-loop control system that consists of external energy source. It is modified by adding force actuator to the system. The performance of the active suspension system can be adjusted due to its closed-loop control system characteristic. Besides that, it has the ability to store, dissipate and to introduce energy to the system. At the moment the sensor of the system detects the changes of the road surface, the data of the road surface will be sent to the controller. Then the controller will calculate amount of energy need to be added or dissipated from the system in order to keep the tire in touch with the road and thus improve the handling quality and ride comfort [2]. Figure 1.3 shows the schematic of passive, semi-active and active suspension system. Schematic of Figure 1.3 is suggested by D.S.Joo et al. [8].

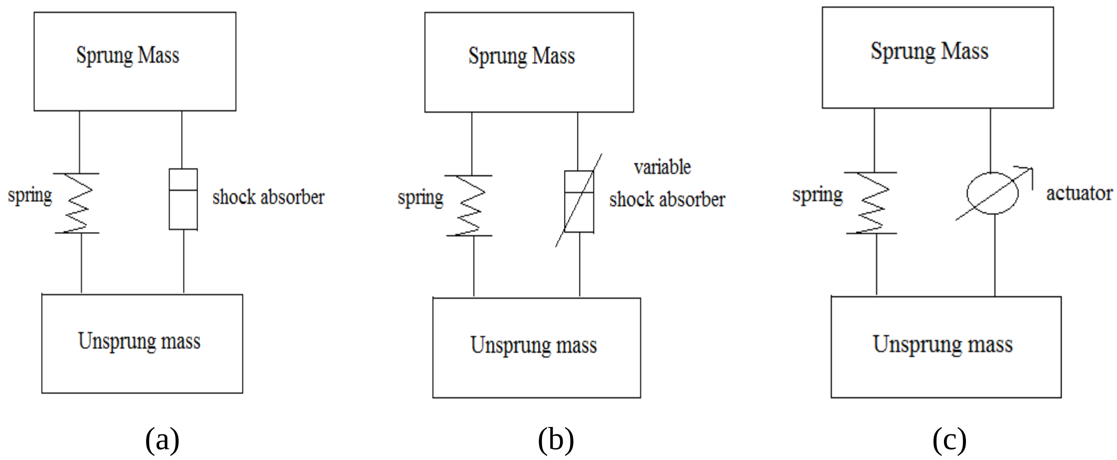


Figure 1.3: (a) Passive suspension system [8], (b) Semi-active suspension system [8], and (c) Active suspension system [8]

1.2 Research Motivation

At present, vehicle suspension system plays an important role in order to guarantee good performance of car. Vehicle suspension system aims to provide passenger with ride comfort while maintaining the safety and stability of the vehicle [3]. However, most of the vehicles are using traditional passive suspension system which has very limited performances and not able to provide good performance of vehicle. When a wheel passes through a bump, there is a vertical force and energy is transferred to the spring which makes it to oscillate vertically. Oscillation of the wheel causes the wheel and the car's frame to move upwards and thus the wheel loses contact with the road surface. Then, the wheel will move downwards back to the ground due to the gravity. When the oscillation of the wheel is large, the suspension travel and the wheel deflection of car are large. Suspension travel is the measured distance between the sprung mass with the unsprung mass. Wheel deflection is the measured distance between unsprung mass with the road profile. Sprung mass are parts of the vehicle supported on the spring such as car body, the frame, the engine, and associated parts. Unsprung mass are parts of vehicle that are not supported by spring, the wheels, tires, and brake assemblies. Figure 1.4 shows the explanation of suspension travel and wheel deflection in picture.

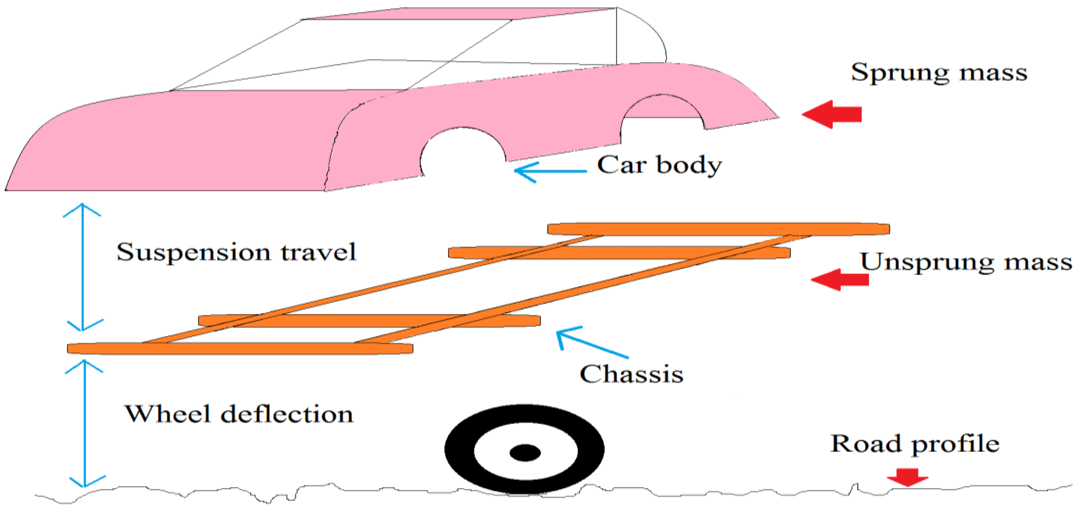


Figure 1.4: Suspension travel and wheel deflection

Therefore, large oscillation between sprung mass and unsprung mass (suspension travel) cause passengers to feel bumpy on the road and bad drive stability. Besides that, passengers will feel the same condition if large oscillation occurs between unsprung mass with road profile (wheel deflection). Passengers feel insecure and not comfortable when sitting inside the car. In long run, bad suspension system could affect the backbone of the passengers and may cause serious injuries.

Thus, analysis on passive suspension system is conducted in order to determine the characteristic of the vehicle suspension system. Proper modeling of vehicle suspension system could lead to good controller design and hence improve the performance of the vehicle suspension system. Vehicle suspension system with controller or active suspension system will be conducted by future final year student. This research will carry out study and analysis on passive suspension system only which represents the open loop system of active suspension system.

1.3 Objectives

- To construct a prototype to represent passive suspension system based on modeling of quarter-car suspension system
- To run open-loop experiments and identify the characteristics of the prototype in terms of the vehicle body and tire positions
- To observe the difference between passive suspension system simulations and experiments in terms of the vehicle body and tire positions

1.4 Scope of Research

This report will primarily focus on the two-degree-of freedom quarter-car model to represent passive suspension system. Semi-active and active suspension system will not be covered in this project. In this report, the simulation and the experiment setup will carry out at the same time. The modeling of the system is simulated by using MATLAB. The performances covered in this project are the vehicle body displacement and tire deflection of vehicle. If the model represents the system well, then the research could be continued on designing a controller. Therefore, vehicle suspension system with controller or active suspension system will be conducted by future final year student.

CHAPTER 2

LITERATURE REVIEW

In previous chapter, a brief introduction about this project has been provided. Now, this chapter will explain more about the vehicle suspension system. Besides that, techniques used to improve vehicle suspension system which have been proposed by other researches will be presented in this chapter.

2.1 Basic Principles

As mentioned in Chapter 1, vehicle suspension system plays an important role in automobile industry in order to guarantee good quality of vehicle. Good suspension system ensures safe ride of passengers and good handling performance by making sure the wheels of vehicle follow the road condition. In addition, suspension system isolates the vehicle body from road shocks and vibration generated by the road surface for comfortable ride [4]. Basically, vehicle suspension system consists of spring, shock absorber and linkages that connect a vehicle to its wheel [16]. There are three types of vehicle suspension system commonly used in the markets which are passive, semi-active, and active suspension system.