SUPERVISOR'S ENDORSEMENT

" I hereby declare that I have read through this report entitle "*Modeling and Design of an Active Car Suspension System Using Half Car Model*" and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (Industrial Power)"

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Date : 8th June 2012

MODELING AND DESIGN OF AN ACTIVE CAR SUSPENSION SYSTEM USING HALF CAR MODEL

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A report submitted in partial fulfillment of the requirements for the degree of the Bachelor of Electrical Engineering (Industrial Power)

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STUDENT DECLARATION

I declare that this report entitle "*Modeling and Design of an Active Car Suspension System Using Half Car Model*" is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : .....

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Date : 8th June 2012

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ABSTRACT

The purpose of this project was focused on comparison between the active suspension responses with the passive suspension response using half car model (two of four wheels). A good car suspension system could provide significant improvements in ride comfort and road handling when riding over road bumps. The road disturbances in this project will be simulated by an impulse input. As a fulfilment of this project, a controlling method needs to be selected. The controller is designing in order to improve the output responses of the system. The controller needs to be design carefully to achieve better simulation since each controller has their own method. For LQR, the value of Q and R need to be tune carefully to ensure the best performance is achieved. MATLAB software will be used in order to simulate the response of the system and SIMULINK in MATLAB is used to write the coding for the designed controller. The car suspension system is simulated by using MATLAB to obtain the ride performance under various road conditions. Simulation results will indicate the feasibility of the designed controller. The results is analyzed and discussed in order to compare the differences between active suspension and passive suspension systems. The result for this project shows that the output response for active suspension system is better than passive suspension system in term of increasing the ride comfort and improving the car handling performance where the output response has less overshoot and a settling time shorter; so that the problem occurs for passive suspension system where its vibration amplitude high and the time required to terminate the vibration is quite longer can be overcome by active car suspension system.

ABSTRAK

Tujuan projek ini adalah memfokuskan pada perbezaan di antara sambutan sistem aktif dan juga sambutan sistem pasif dengan menggunakan model satu per dua kereta (dua dari empat tayar). Sistem suspensi kereta yang baik dapat memberikan peningkatan yang ketara dalam keselesaan pemanduan dan pengandalian jalan apabila melalui bonggol di jalanraya. Gangguan jalan yang digunakan dalam projek ini adalah input denyut. Sebagai memenuhi projek ini, satu kaedah pengawalan perlu dipilih. Pengawal adalah untuk merancang bagi meningkatkan sambutan keluaran sistem. Pengawal tersebut perlu direkabentuk dengan teliti untuk mencapai simulasi yang lebih baik kerana setiap pengawal mempunyai kaedah tersendiri untuk direka. Untuk LQR, nilai Q dan R perlu di di tala dengan betul untuk memastikan prestasi yang terbaik dapat dicapai. Perisian simulasi MATLAB digunakan untuk mendapatkan sambutan sistem tersebut dan aplikasi SIMULINK di dalam MATLAB digunakan bagi menulis aturcara bagi tujuan rekabentuk pengawal. Keputusan simulasi akan menunjukkan kemungkinan pengawal itu dibentuk. Seterusnya, keputusan akan dianalisis dan dibincangkan untuk membandingkan perbezaan di antara sistem suspensi aktif dan juga sistem suspensi pasif. Keputusan yang diperolehi dalam projek ini ialah reaksi keluaran sistem bagi sistem suspensi aktif adalah lebih baik berbanding sistem suspensi pasif yang mana reaksi keluaran sistem dapat mengurangkan had maksima hentakan dan masa pengenapan yang lebih pendek dari segi meningkatkan keselesaan pemanduan dan meningkatkan prestasi pengendalian kereta. Oleh itu, masalah yang berlaku untuk sistem suspensi pasif yang mana amplitud getarannya yang tinggi dan masa yang diperlukan untuk menamatkan getaran yang panjang boleh diatasi dengan sistem suspensi aktif.

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LQR	–	Linear Quadratic Regulator
FLC	–	Fuzzy Logic Controller
PISMS	–	Proportional Integral Sliding Mode Controller
K	–	Optimal Feedback Gain
Q	–	State Weighting Matrix
R	–	Control Cost Matrix

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CHAPTER 1

INTRODUCTION

1.1 Introduction

A car suspension system is a system that connects the wheels of the automobile to the body, in such a way that the body is cushioned from jolts resulting from driving on uneven road surfaces. The performance of the suspension system has been greatly increased due to increasing vehicle capabilities. Several performance characteristics have to be considered to achieve a good suspension system. These characteristics deal with the regulation of body movement, the regulation of suspension movement and the force distribution. Ideally the suspension should isolate the body from road disturbances and inertial disturbances associated with cornering and braking or acceleration. The suspension must also be able to minimize the vertical force transmitted to the passengers for their comfort.

The suspension affects an automobile's comfort, performance, and safety. It is for the sake of passenger comfort and controls the vehicle body attitude and maintains a firm contact between the road and the tires to provide guidance along the track. The automotive suspension system is designed to compromise between the comforts as the road handling can be improved by using the electronically controlled suspension system. Hence, the suspension system may be categorized as passive, semi-active or active suspension systems.

1.2 Problem Statement

The suspension system that commonly applied on the vehicle is a passive suspension system in which its spring stiffness and damping value is constant. In the passive suspension system, it damping system has not yet gives a high performance where its vibration amplitude still high and the time required terminating the vibration is quite longer. To overcome this condition, it is then introduced a semi-active and active suspension system. Active suspension system is introduced to improve the riding comfort but the controller need to be design carefully in order to get a good performance due to complexity of the model.

1.3 Objectives

The objectives of this project are:

i. To study and analyze the concept of passive and active car suspension systems using half car model.
ii. To develop controller for active car suspension system for half car model by using MATLAB Simulink.
iii. To analyze the suspension response for active and passive car suspension systems.
iv. To justify the best value of Q and R for the LQR controller.

1.4 Scope Project

This project focuses on the design of active car suspension system by using half car model. The controller will be designed by using LQR controller method which is the tuning will be done by trial and error method. To simulate the response of the systems, the MATLAB software will be used. The result will be compared after the results obtained from both of the method were in order to compare which systems perform well.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Suspension system is a nonlinear and unstable system, thus providing a challenge to the control engineers or researchers. It has become a benchmark to improve ride comfort and road handling. There are many efforts that have been done to develop the controller for this system. Early works and researches on advanced suspension have been carried out by many researchers in the past few decades in order to improve the stability and ride handling performance of the vehicle.

2.2 Theory

Generally, there are two categories of vehicle's suspension i.e. conventional suspension and advanced suspension systems. Conventional suspension system refers to the passive suspension system whereas advanced suspension system indicates semi-active suspension or active suspension system [1].

2.2.1 Passive Suspension System

Conventional suspension system is also known as a passive suspension system consisting of spring and damper mounted at each wheels of the vehicle in parallel and generally control the motion of the sprung mass (mass of the vehicle body) and also wheel by controlling the relative velocity. Passive suspension systems have a fixed damping characteristic determined by their design, which means the systems do not offer variable damping force and hence better ride comfort and road handling may not be achieved during different maneuvers [1]. Figure 2.1 shows the schematic diagram of the passive suspension system in a quarter car model.

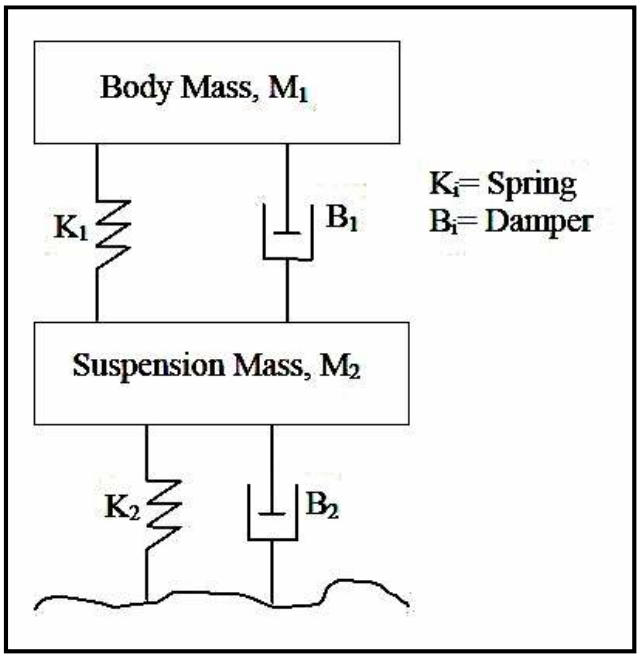

Figure 2.1: Passive Suspension System

The function of spring in vehicle suspension is to support the vehicle body and at the same time it is used to absorb and store the energy. The damper or shock absorber is a component of the vehicle suspension used to dissipate the vibration energy stored in the spring and control the input from the road that is transmitted to the vehicle. Other purposes of suspension system are to isolate sprung mass from the unsprung mass (mass of the

wheel) vibration, to provide directional stability during cornering and to maneuver and provide damping for the high frequency vibration induced fire excitations [5].

2.2.2 Semi-active Suspension System

Semi-active suspensions on the other hand are less complex, more reliable and commercially available. Semi-active suspension system is quite similar with the conventional suspension system. This kind of suspension has a spring and controllable damper in which the spring element is used to store the energy meanwhile the controllable damper is used to dissipate the energy. Some of the semi-active suspension systems use the passive damper and the controllable spring. The controllable damper usually acts with limited capability to produce a controlled force when dissipating energy [1]. Figure 2.2 shows the schematic diagram of semi-active system with passive spring and controllable damper as a component of suspension.

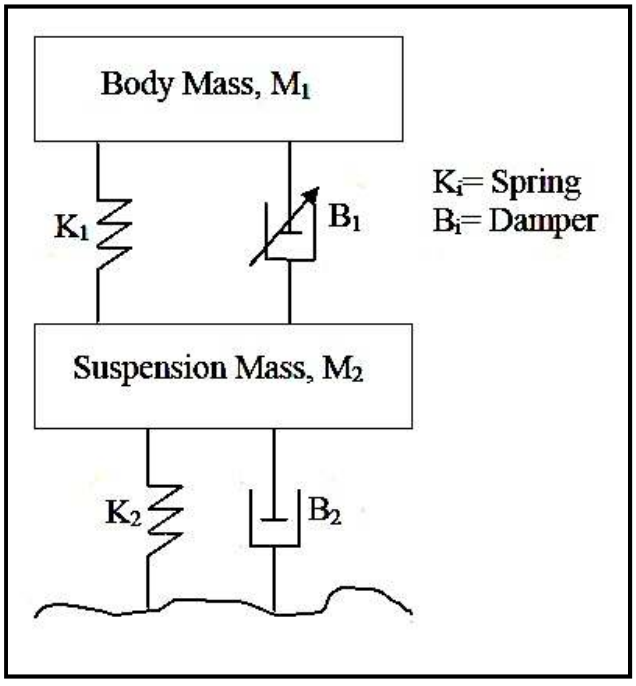

Figure 2.2: Semi-active Suspension System

2.2.3 Active Suspension System

Active suspension system has an ability to store, dissipate and to introduce energy to the system. The hydraulic actuator is connected in parallel with a spring and absorber, while the sensors of the body are located at different points of the vehicle to measure the motions of the body [2]. It may vary its parameters depending upon operating conditions. Figure 2.3 shows the active car suspension system.

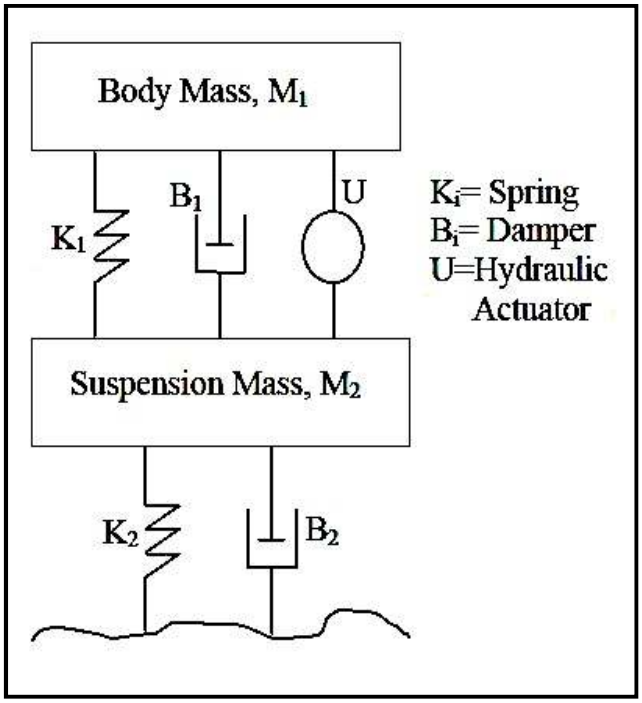

Figure 2.3: Active suspension system

An active shock absorber is an extra force provided by an external power system is applied between the wheels and the body of the car. It has the additional advantages that negative damping can be provided and that a larger range of forces can be generated at low velocities, thereby potentially allowing an increase in system performance [5].

2.2.4 Active Suspension System Overview

Generally, an active suspension has an actuator connected between the sprung and unsprung masses of the vehicle. The actuator mounted between car body and car wheel. Illustration of the active suspension system is shown in Figure 2.4 below. The system consists of hydraulic actuator mounted between car body and car wheel. The actuator can generate control forces which are calculated by a computer to suppress the system responds to the changes of the road condition, thus holding the vehicle in a constant state of equilibrium [5].

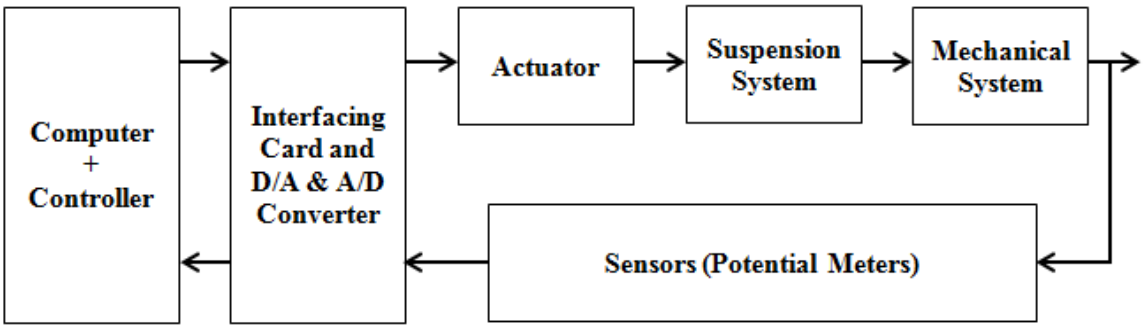

Figure 2.4: Block diagram of control for active suspension [5]

The active suspensions are equipped with sensors, which are linked to a powerful computer system, which has information about the vehicle and its response to different road conditions. The different actuator located at each wheel. The system process information obtained from the sensors and then sends a signal to provide and appropriate response in the actuator. The computer system and actuator will keep the car level on a smooth surface. However if the vehicle were to encounter an irregularity in the road surface or a bend, then the signals from the sensors will enable the computer system to calculate the change in load in that particular actuator and cause response to compensate for the change in load [16].

The time for the sensors to detect the change and the actuator to respond is a matter of milliseconds is the main reason of many people are not aware of any change in road conditions. The active suspension system must support the car, provide directional control during car handling and provide effective isolation of passengers or payload from road disturbances. There are four important parameters which should be carefully considered in designing a vehicle suspension system which are [1]:

i. Ride comfort whereby directly related to the acceleration sensed by passengers when travelling on a rough road.
ii. Body motion which are known as bounce, pitch and roll of the sprung mass are created primarily by cornering and braking maneuvers. Body motions may be present even on perfectly smooth roads.
iii. Road handling is associated with the contact forces of the tires and the road surface. These contact forces create the necessary friction which prevents the tires from sliding on the road surface. The contact forces are assumed to depend linearly on the tire deflection.
iv. Suspension travel refers to the relative displacement between the sprung and the unsprung masses. All suspension system trade-off the suspension travel for an improved ride comfort.

No suspension system could minimize all four of the above mentioned parameters simultaneously. The advantage of controlled suspension is that a better set of design trade-offs are possible compared with passive systems[1].

2.3 Previous Study

2.3.1 Linear Quadratic Regulator Controller

The study shows that an active suspension gives a better performance in terms of comfort ride compared to the passive suspension. An active suspension also increases a tire to road contact in order to make the vehicle more stable. This concludes that LQR controller can be considered one of the solutions for excellent comfort ride and good handling of cars into the new millennium [1].

According to F. Hasbullah and W. F. Faris[2], the LQR controller gives a better performance in terms small percentage overshoot and faster settling time. The study focused on comparison of performance between LQR, fuzzy logic and passive system. The application of the Linear Quadratic Regulator and Fuzzy Logic Controller in the field of active vibration isolation for a vehicle suspension system is presented and the performances of the two active controllers are compared with the passive system. The simulation shown that the fuzzy logic controller needs less force to control the actuator, while the passive system has the smallest percentage overshoot but has the worst settling time [2].

2.3.2 Fuzzy Logic Controller

In 1999, T. Yoshimura [3] presented an active suspension system for passenger cars using linear and fuzzy logic controls method. It was implemented in passenger cars using the vertical acceleration of the vehicle body as the principal source of control and FLC (fuzzy logic control) as the complementary control. By minimizing the mean squares of the