AN OBSERVER DESIGN FOR ACTIVE SUSPENSION SYSTEM

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DEDICATION

This thesis is dedicated to my beloved parent, Ahmad Bin Razak and Halimah Binti Haji Dris, my sisters, Noormadiad and Zuhana,to my brother Azman and not forgotten to all my friend, thank you for the sacrifice and support.

May Allah bless all of you. Amin!

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In the name of ALLAH SWT, the most Gracious, who has given me the strength and ability to complete this study. All perfect praises belong to ALLAH SWT, lord of the universe. May His blessing upon the prophet Muhammad SAW and member of his family and companions.

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PUBLICATION

The following paper, based on the work described in this thesis, has been submitted for publishing:

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ABSTRACT

The purpose of this project is to construct an active suspension control for a quarter car model subject to excitation from a road profile using an improved sliding mode control with an observer design. The proportional-integral sliding mode was chosen as a control strategy, and the road profile is estimated by using an observer design. The performance of controller will be compared with the LQR controller. There are three parameters to be observed in this study namely, wheel deflection, the body acceleration and the suspension travel. The performance of this controller will be determined by performing computer simulations using the MATLAB and SIMULINK toolbox.

ABSTRAK

Cadangan untuk projek ini adalah untuk membina model sistem gantungan aktif yang subjek keatas permukaan jalan dengan menggunakan kawalan ragam gelincir yang di pertingkatkan keupayaan dengan penggunaan pemerhati. Kawalan ragam gelincir berkadaran-kamiran di pilih sebangai pengawal dan permukaan jalan di perhati dengan menggunakan pemerhati. Prestasi pengawal yang di perkenalkan di analisis prestasi dengan pegawal jenis LQR. Tiga parameter output diperhatikan yang di namai, pantulan tayar, halaju badan dan pergerakan gantungan. Prestasi pengawal akan di analisis dengan menggunakan penyelakuan komputer aturcara MATLAB dengan SIMULINK yang mudah di guna pakai.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

1.1 Suspension System

Comfort and road-handling performance are the characteristics that have to be considered in order to achieve a good suspension system. Ideally, the suspension should isolate the body from road disturbance 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. This objective can be achieved by minimizing the vertical car body acceleration [1].

Generally, a suspension system for a car is categorized as passive, semi-active and active suspension system. A passive system is a conventional suspension that consists of the conventional spring and shock absorber as shown in figure 1.1. The springs are assumed to have almost linear characteristics; while, most of the shock absorbers exhibit nonlinear relationship between force and velocity. In passive system, these elements have fixed characteristics. When the suspension system must operate over a wide range of conditions, there should be a compromise in choosing the spring stiffness and damping parameters. In other words, it is desirable that the above parameters could be adjustable to improve the performance of the system.

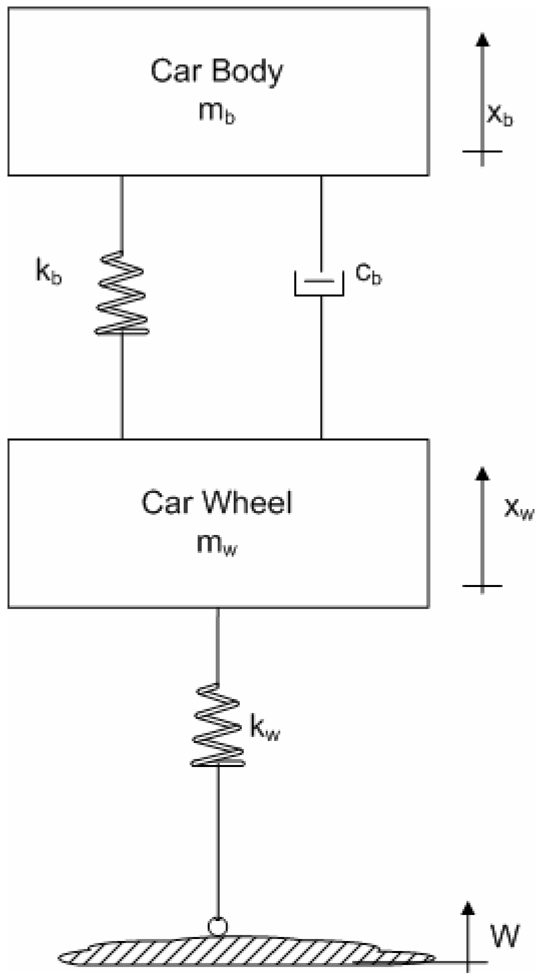

Figure 1.1: The passive suspension system.

The performance of passive suspension system can be improved by using the semi-active suspension system as shown in figure 1.2. Semi-active suspensions provide real-time dissipation of energy, which is achieved through a mechanical device called an active damper. The active damper is installed in parallel with a conventional spring. The main feature of this system is the ability to adjust the damping of the suspension system, without any use of actuator. This type of system requires some form of measurement with a controller board in order to properly tune the damping force.

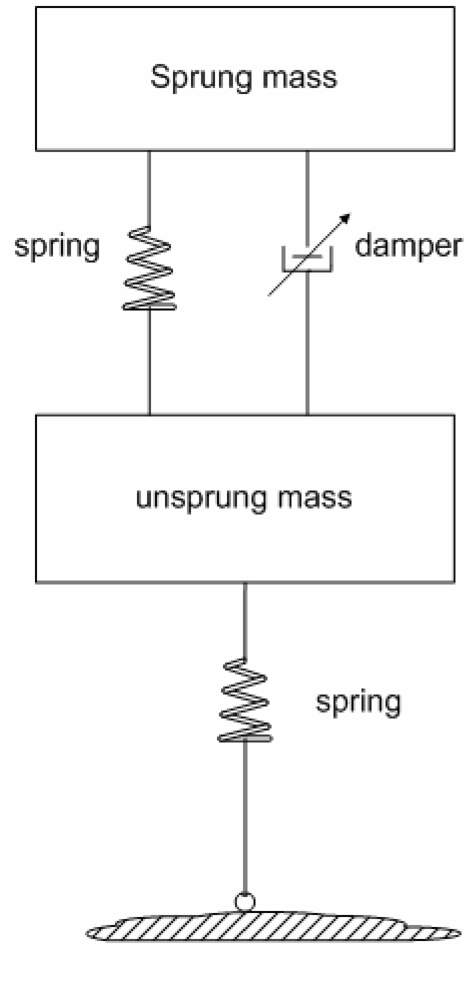

Figure 1.2: The semi-active suspension system

The demand of better ride comfort and controllability of road vehicles has motivated many automotive industries to consider the use of active suspension. Active suspension employs pneumatic or hydraulic actuators which in turn creates the desired force in suspension system as shown in figure 1.3. The actuator is secured in parallel with spring and shock absorber. Active suspension requires 2 accelerometers that mounted at sprung and unsprung mass, and a unit of displacement transducer to measure the motions of the body, suspension system and the unsprung mass. This information is used by the online controller to command the actuator in order to provide the optimum target force. Active suspension may consume large amounts of energy in providing the control force. Therefore, in the of active suspension system the power consumptions of actuator should also be considered as an important factor. In analysis of suspension system, there are varieties of performance criteria which need to be optimized. There are three performances criteria which should be considered carefully in designing a suspension system; namely, body acceleration, suspension travel and wheel deflection. The performance of the system can be further improved by introducing the suitable controller into the active suspension system.

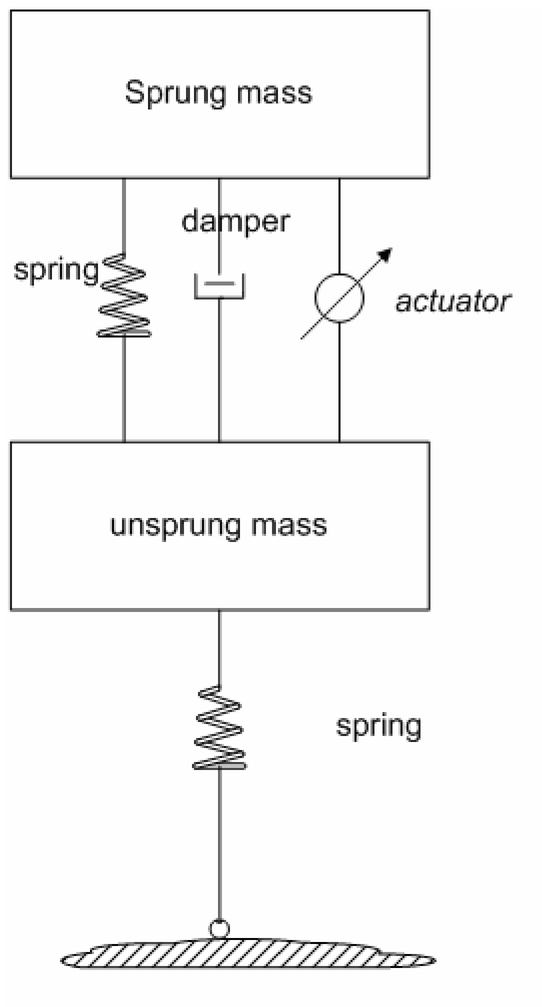

Figure 1.3: The active suspension system

1.2 Active Suspension System Control Strategies

The objective of the active suspension system is to improve the suspension system performance by directly controlled the suspension forces to suit with the performance characteristics. There are various linear control strategies have been established by previous researchers in the design of the active suspension system. Amongst them are a fuzzy reasoning [4], robust linear control [7], H_∞ [8], and adaptive observer [9]. The results of the study have demonstrated that active suspension system is more effective in the vibration isolation of the car body is compared with passive system.

The purpose of this study is to utilize the concept of proportional integral sliding mode control in active suspension system [1, 2, 5, 6,] with observer design for road estimator. Therefore, the estimated road disturbance will be another state for the system.

1.3 Objective of study

The objectives of this research are as follows:

I. To develop the mathematical model of quarter car active suspension system with an observer.

II. To design an observer that act as a road profile estimator for the active suspension system.

III. To design a Proportional Integral Sliding Mode Control (PISMC) for the quarter car active suspension system.

IV. To study the performance of the PISMC with a disturbance observer.

Theoretical verification of the proposed controller and observer on its stability and reachability will be accomplished by using a Lyapunov's second method. The performance of the active suspension system will be observed by using extensive computer simulation that will be performed using MATLAB software and SIMULINK Toolbox subjected to various types of road profiles and parameter value.

1.4 Scope of work

The scopes of work for this study are as follows:

I. Familiarization of a quarter car active suspension system with Proportional-Integral Sliding Mode Controller

II. Mathematical derivation of an observer for a quarter car active suspension system.

III. Design an Observer for a quarter car active suspension system using Sliding Mode Control technique.

IV. Perform a simulation works by using a MATLAB/Simulink to observe effectiveness of the observer.

V. Compare the performance of the proposed PISMC with Observer design with Validate with a Linear Quadratic Regulator (LQR) technique.

1.5 Structure and Layout of Thesis

The necessary components for achieving objective of the study are given in the succeeding chapters. The mathematical modeling of a quarter car is derived in chapter 2. The state space representation of the dynamic model of the passive, semi active and active suspension system are outlined. Finally, various road profiles that represent the uncertainty in the suspension systems will be represented.

In chapter 3, the proposed controller, proportional integral sliding mode control with disturbance observer is presented. By using a Lyapunov's stability theory, it will be shown that for the system with mismatched uncertain, the system is bounded stable. In chapter 4 discussion on an observer design is performed. The literature review and mathematical model will discuss in this chapter.

Chapter 5 represents the computer simulation for the proposed observer and controller. In this chapter, the performance of road handling and ride comfort will be compared with the LQR controller. To assure the robustness of the proposed observer, various road profiles will be applied in the system. The chattering and boundary layer effect of the controller will be presented by varying the parameter in the continuous switching gain.

The summary of the result and future research based on this study will be presented in chapter 6.

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