FUZZY CONTROL ON VEHICLE ACTIVE SUSPENSION SYSTEM

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SUPERVISOR'S DECLARATION

I hereby declare that I have checked this project and in my opinion, this project is adequate in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering

Signature
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Position: Lecturer
Date: 6 December 2010

STUDENT'S DECLARATION

I hereby declare that the work in this project is my own except for quotations and summaries which have been duly acknowledged. The project has not been accepted for any degree and is not concurrently submitted for award of other degree.

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ABSTRACT

The active suspension system is a possible way to improve suspension performance although the passive system can effectively handle some control of suspension system. The main propose of this project is to assess performance of active suspension system in comparison and passive suspension system by implementing Fuzzy and Proportional-Integral-Derivative. The quarter car system is designed and constructed based on the four wheel independent suspension. Mathematic model that used in simulation is based on the dynamic diagram of quarter car system. Passive suspension is a system that not equipped with any controller but there are two controllers that used in active suspension system. The two controllers that applied to simulate the action of active system are Fuzzy Logic controller and Proportional-Integral-Derivative controller. First controller that used in active system is PID controller. This controller design deals with the selection of proportional gain, derivative gain and integral gain parameters (K_p, K_d and K_i). The parameter of this control is adjusted by tuning the PID controller using the heuristic method. Fuzzy Logic controller is applied to the block diagram that controlled by PID controller to improve the active suspension system. From the result of simulations, the Fuzzy-PID scheme can reduce vibration than PID scheme. In conclusion, the active suspension with PID controller combined with FLC is more effective and stable rather than passive suspension system.

ABSTRAK

Sistem gantungan aktif adalah sebuah cara yang mungkin untuk meningkatkan prestasi gantungan walaupun sistem pasif secara efektif dapat menangani beberapa kawalan dari sistem gantungan. Tujuan utama dari projek ini adalah untuk menilai prestasi sistem gantungan aktif dalam perbandingan dan sistem suspensi pasif dengan melaksanakan Fuzzy dan Proporsional-Integral-Derivatif. Sistem kereta suku direka dan dibina berdasarkan sistem gantungan empat roda. Model matematik yang digunakan dalam simulasi berdasarkan pada rajah dinamik sistem kereta suku. Gantungan pasif adalah sistem yang tidak dilengkapi dengan kawaln apapun tetapi ada dua pengawal yang digunakan dalam sistem gantungan aktif. Kedua-dua kawalan yang digunakan untuk mensimulasikan tindakan sistem aktif adalah Fuzzy Logic dan pengawal proporsional-Integral-Derivatif. Pengawal pertama yang digunakan dalam sistem aktif ialah pengawal PID. Pengwal ini dipengaruhi oleh pemilihan proporsional, derivatif dan integral (K_p, K_d and K_i). Parameter pengawal ini disesuaikan dengan menggunakan kaedah cuba jaya. Pengawal Fuzzy Logic diterapkan pada diagram blok yang dikendalikan oleh pengawal PID untuk memperbaiki sistem gantungan aktif. Daripada keputusan simulasi, Fuzzy-PID dapat mengurangkan getaran dari PID. kesimpulan, sistem gantungan aktif dengan pengawal PID dan pengawal FL lebih berkesan dan stable daripada sistem gantungan pasif.

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LIST OF SYMBOLS

ω	Circular Natural Frequency
m_1	Sprung Mass
m_2	Unsprung Mass
c_1	Sprung Mass Damping Coefficient
k_1	Suspension Spring Constant
k_2	Tire Spring Rate
Δ	Determinant
$\ddot{x}$	Acceleration
$\dot{x}$	Velocity
x	Displacement
f_n	Natural Frequency
t	Time
F	Force
w	Road Profile
K_p	Proportional Gain
K_i	Derivative Gain
K_d	Integral Gain
g	Acceleration Due To Gravity
l	Distances Of The Suspension Locations
θ	Rotary Angle Of The Vehicle Body At The Centre Of Gravity.

LIST OF ABBREVIATIONS

PID	Proportional-Integral-Derivative
FLC	Fuzzy Logic Control
DOF	Degree Of Freedom
PI	Proportional- Integral
P	Proportional
C-o-A	Center-Of-Area
C-o-M	Center-Of-Maximum
M-o-M	Mean-Of-Maximum
trimf	Triangular Membership Function
trapmf	Trapezoidal Membership Function
gaussmf	Gaussian Membership Function
gbellmf	Generalized Bell Membership Function
EOM	Equations Of Motion
CST	Control System Toolbox
VS	Very Small
S	Small
M	Medium
L	Large
VL	Very Large

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

An automobile or car are used for transporting passenger which also carries its own engine and are designed to run primarily on the road. Today, many automotive companies produce highly developed model. They develop a good performance model with new design and technology. One of the performance requirements is advanced suspension systems which prevent the road disturbances to affect the passenger comfort while increasing riding capabilities and performing a smooth drive. There are two main functions for car suspension system. The first function is to isolate the car body from shock and vibration caused by irregular road surface. The second function is to maintain constant contact between road surface and the tires.

In the last few decades, many researchers have been carried out to improve vehicle suspensions. Among the proposed solutions, active suspension is a possible way to improve suspension performance although the passive system can effectively handle some control of suspension system. Passive suspension systems have been design to achieve performance of vehicle but intrinsic limitations prevent them from obtaining the best performances for both objectives. Replacement of the passive suspensions of car by active systems has the potential of improving safety and comfort under nominal conditions because active system offer more design flexibility. Many methods are applying to improve the suspension problem especially the performance of active suspension designs, such as linear optimal control, fuzzy logic and neural network control, adaptive control, H1 control and nonlinear control. Fuzzy logic is an intelligent control method that currently uses to investigate this suspension system problem. (Shao-jun et al, 2004)

For this project MATLAB SIMULINK will be used to design an active suspension for a quarter car model. The block diagrams are drawn in SIMULINK based on the quarter car model according to the given parameters.

1.2 PROBLEM STATEMENT

Passive control method has a disadvantage of disturbance rejecting when used to control suspension system**.** Active control is believed can give a better control for active suspension system in term of maintaining a smooth drives for the drivers. The pneumatic tyre is the first line of defences and is the most important of all the suspension mediums. To the extent that, while uncomfortable, it would be quite feasible to drive a car around the roads, at reasonable speeds with no other form of bump absorption. The loads fed into the wheels without such tyres would be enormous and continual wheel failure would be the norm.

The Road disturbances can lead to a number of undesirable circumstances. It can be a reason to driver discomfort and decrease ride quality. The basic problem in suspension system of car is the ability of the car to move on its suspension to response the road shock. Another problem is weight transfer during braking and acceleration causes pitching movement depending on their direction. These pitching motions lead to steering geometry variations as well as rider discomfort. Next problem is the suspension compression at each end during the action of cornering forces.

1.3 OBJECTIVES

The main objectives in this project is to assess performance of active suspension system in comparison and passive suspension system using quarter car model by implementing Fuzzy and Proportional-Integral-Derivative.

1.4 SCOPES

The scopes of the research are:

(i) Experimental data/result from previous study will be taken as references.
(ii) Find dynamic model of suspension system.
(iii) Find mathematical modelling based on dynamic model.
(iv) Simulation study on dynamic model with various active controls
(v) Applied fuzzy control on the system.
(vi) Comparative study PID and Fuzzy-PID

1.5 ORGANIZATION OF THE PROJECT

This project work towards developing active suspension and passive suspension for quarter car, using MATLAB SIMULINK is presented in five chapters. As the development progress can be divided in to 5 main categories.

The first chapter introduces the suspension system and details the problem statement, objective and scope of this project.

The second chapter reports on the review of literature on passive and active suspension system that inspires the scope of the present report. This chapter also review the controller that will used for simulation such as PID and Fuzzy Logic Controller.

Chapter three proposes a novel method of design of the system in software by using Simulik software. In this chapter the dynamic model of passive suspension will be develop and the mathematical modeling will occurred based on the dynamic model. This mathematical modeling will be used to run the simulation after block diagram for dynamic model is developed.

Chapter four, deals with result and discussion of active suspension system's operation and design. Besides that, performance of each control scheme and comparative study between various control schemes will be discussed.

A compressive summary of the project efforts and the conclusions derived from this project work is presented in chapter five. Constraints and future research potential of the passive and active suspension system are also presented.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter is based on the car suspension, vibration control, Fuzzy Logic control, Proportional-Integral-Derivative controller and familiar control technique. Basics understanding in this chapter must be recognizable before proceed to next chapter.

The review for this chapter is based on active suspension and passive suspension system. The performance of active and passive suspension system will be compare. Quarter car model for active suspension system will be the dynamic model for this project. The mathematic modelling can be performed after finding the dynamic model and the parameter for this model. The control method that use in this project is FLC and PID will be analyzed.

2.2 CAR SUSPENSION

Suspension is the term given to the system of springs, shock absorbers or damper and linkages that connects a vehicle to its wheels. Figure 2.1 shows car suspension systems. The purpose of the suspension system is to provide a smooth ride in the car and to help maintain control of the vehicle over rough terrain or in case of sudden stops, increasing ride comfort results in larger suspension stroke and smaller damping in the wheel-hop mode (Salem et al, 2009). These goals are generally at odds, so the tuning of suspensions involves finding the right compromise. It is important for the suspension to keep the road wheel in contact with the road surface as much as possible, because all the forces acting on the vehicle do so through the contact patches of the tires. The suspension also protects the vehicle itself and any cargo or luggage from damage and wear. The design of front and rear suspension of a car may be different. In general, based on the damper used vehicle suspension systems can be classified into three types. There are passive, semi active and active suspension systems. This project only considers the passive and active suspension system. Each type has its own advantages and disadvantages. However semi active and active models are the one most commonly used in practical applications. The details of the three types are given in the following sections.

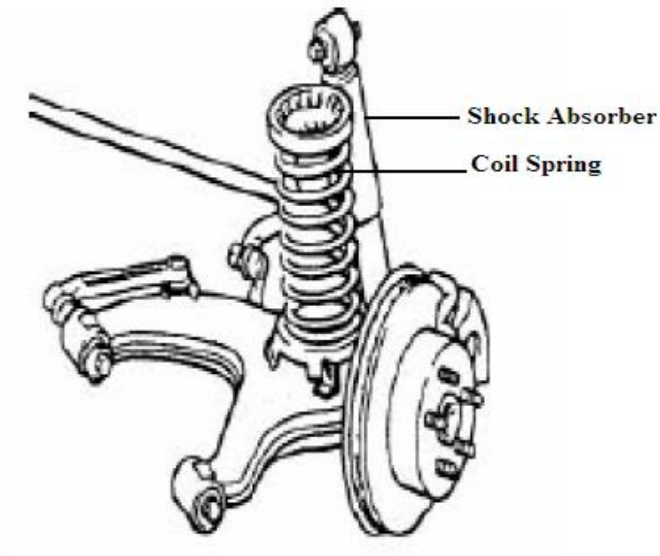

Figure 2.1: Car suspension systems.

Source: Salem et al (2009)

2.2.1 Passive Suspension System

Passive suspension systems are designed as a compromise between ride and handling performance. Ride is primarily associated with the ability of a suspension system to accommodate vertical inputs. Handling and attitude control relate more to horizontal forces acting through the center of gravity and ground-level moments acting through the wheels. A low bounce frequency for maximum ride comfort normally leads to a low pitch frequency.

Passive suspension system consists of an energy dissipating element, which is the damper, and an energy-storing element, which is the spring. Since these two elements cannot add energy to the system this kind of suspension systems are called passive (N. Khajavi et al, 2007). Figure 2.2 shows passive suspension systems.

Where: w: Displacement of road

m_1: Sprung Mass

m_2: Unsprung Mass

c_1: Sprung Mass Damping Coefficient

k_1: Suspension Spring Constant

k_2: Tire Spring Rate

x_1: Displacement of the car body

x_2: Displacement of wheel (unsprung)

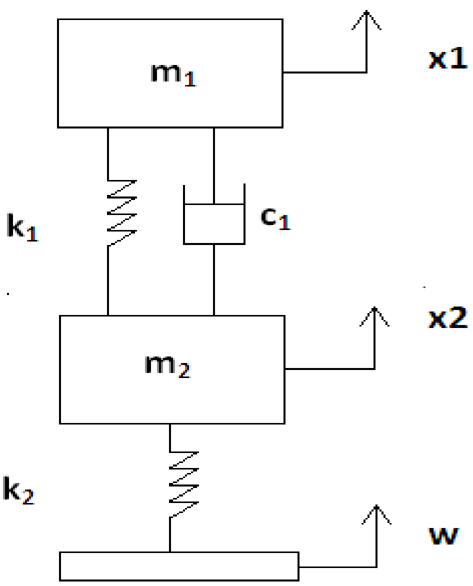

Figure 2.2: Passive suspension systems.

Source: Senthil Kumar (2008)

2.2.2 Semi Active Suspension System

To replace complexity and cost while improving ride and handling the concept of semi active suspension has emerged. In this kind of suspension system, the passive suspension spring is retained, while the damping force in the damper can be modulated (adjusted) in accordance with operating conditions (Chander). Figure 2.3 shows the schematic view of a semi active suspension system. The regulating of the damping force can be achieved by adjusting the orifice area in the damper, thus changing the resistance of fluid flow. Most recently the possible application of electro-rheological and magneto-rheological fluids to the development of controllable dampers has also attracted considerable interest.

Where: m_1: Sprung Mass

m_2: Unsprung Mass

c_1: Sprung Mass Damping Coefficient

w: Displacement of road

k_1: Suspension Spring Constant

k_2: Tire Spring Rate

x_1: Displacement of the car bod

x_2: Displacement of wheel (unsprung)

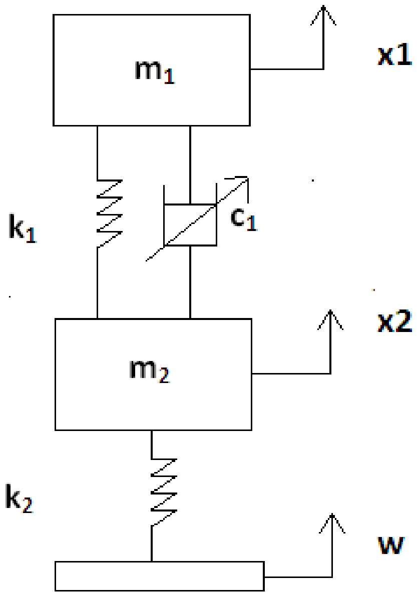

Figure 2.3: Semi active suspension system

Source: Chander

2.2.3 Active Suspension System

Active systems provide independent treatment of road-induced forces from body-inertia forces through active control of some of the suspension system functions. Theoretically this means that the compromise in conventional suspension systems can be eliminated. Active suspension systems, however, usually involve a continuous power requirement, fast-acting devices, complex control algorithms, and closed-loop control systems. The cost of these systems has limited their application on mass-produced vehicles. (Sofian et al, 2009)

The basic idea in active control of suspensions is to use an active element (the actuator, e.g., a hydraulic cylinder) to apply a desired force between the car body and the wheel axle (J. D'Amato et al, 1999). The actuator is usually hydraulically controlled and applies between body and wheel a force that represents the control action generally determined with an optimization procedure (Yahaya et al, 2002). Figure 2.4 shows active suspension system considered in this study. This desired force is computed by the car's control unit to achieve certain performance objectives under external disturbances for example passenger comfort under road imperfections. Active suspension systems include sensors to measure suspension variables such as body velocity, suspension displacement, and wheel velocity and wheel or body acceleration (Yahaya et al, 2002). Sensors are used to measure the accelerations of sprung mass and unsprung mass and the analog signals from the sensors are sent to a controller (Chander). The controller is designed to take necessary actions to improve the performance abilities already set.

Where: m_1: Sprung Mass

m_2: Unsprung Mass

c_1: Sprung Mass Damping Coefficient

k_1: Suspension Spring Constant

k_2: Tire Spring Rate

x_1: Displacement of the car bod

x_2: Displacement of wheel (unsprung)

w: Displacement of road

F: Force

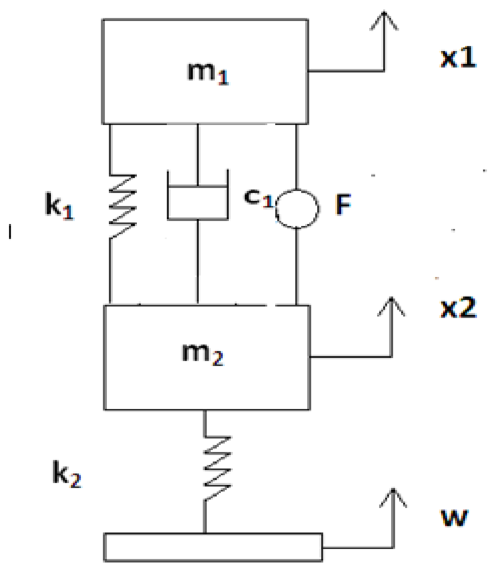

Figure 2.4: Active suspension system

Source: Chander