I declare that this report entitle " Fuzzy Logic Controller For Vehicle-Active Suspension System " 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 : ....

Name : NUR SYAWANA BTE MURAD

Date : 2 JULY 2012

“ I hereby declare that I have read through this report entitle “ Fuzzy Logic Controller for Active Vehicle Suspension System” and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (Control, Instrument and Automation)”

Signature : ....

Supervisor’s Name : ..Datuk Prof. Dr. Mohd Ruddin b. Ab.Ghani..

Date : .02 July 2012..

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ABSTRACT

This project is about implement controller for vehicle suspension system. Vehicle suspension system consists of wishbones, the spring, damper, and shock absorber which are interact between body and road surface. The main function of suspension system is to stabilize handling stability and ride comfort. Thus, it is need more consideration for suspension design that will compromised between stabilize handling stability and ride comfort since they are normally in conflict. In order to overcome the problem, a comparison between conventional controller and advanced technology control had been done. Then, electronic control of Fuzzy Logic was suggested will be design and applied to the system of vehicle suspension system. It is because it is advanced control technology can withstand the conflict in riding over road surface. It was completed using MATLAB and SIMULINK.

ABSTRAK

Projek ini adalah tentang mengaplikasikan kawalan untuk gantungan system bagi kenderaan. Gantungan system bagi kenderaan terdiri daripada tulang garpu, spring, peredam, dan penyerap kejutan di mana ia berkaitan antara badan kenderaan dan permukaan jalan. Fungsi utama sistem gantungan ini adalah untuk memberi kestabilan pada pengawalan tangan serta keselesaan memandu. Oleh itu, ia memerlukan lebih perhatian untuk rekaan sistem gantungan yang akan menyeimbangkan diantara kesimbangan memandu dan perjalanan yang sentiasa bermasalah. Untuk mengatasi masalah ini, perbandingan antara pengawal konvensional dan pengawal termaju telah dilakukan. Kemudian, kawalan elektronik iaitu Logik Kabur telah disarankan dan direka untuk diaplikasikan dalam system gantungan kenderaan. Ini kerana teknologi kawalan termaju boleh bertahan dengan konflik pemanduan di atas permukaan jalan. Ia telah dilengkapkan dengan menggunkan perisian MATLAB dan SIMULIK.

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LIST OF SYMBOLS

A	-	System Matrix
B	-	Input Matrix
C	-	Output Matrix
D	-	Feedforward Matrix
D_1	-	Damping Constant of Suspension System
D_2	-	Damping Constant of Wheel and Tire
e	-	Close Loop Eigenvalue
F	-	Force
K	-	LQ Optimal Gain
k_1	-	Spring constant of suspension system
k_2	-	Spring constant of wheel and tire
m_1	-	Body mass
m_2	-	Suspension mass
Q	-	Real symmetric matrix
R	-	Real symmetric matrix
S	-	Solution matrix for Riccati Equation
u	-	Control Force
v	-	Velocity
x	-	Displacement
x_1	-	Tire Deflection
x_2	-	Suspension Velocity
x_3	-	Suspension Deflection
x_4	-	Body Velocity
Z_1	-	Height of body system
Z_2	-	Height of suspension system
Z_r	-	Road input profile

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CHAPTER 1

INTRODUCTION

1.1 Introduction Statement

The main function of suspension system in an automobile is to improve the ride comfort and stability so that it can provide better handling characteristics for any road conditions. Thus in this research will design, simulate and implement application of fuzzy logic controller in active vehicle suspension system. This study will focus on active suspension system for quarter car model and fuzzy logic controller is designed in order to overcome any road disturbances such as potholes, cracks, and uneven road. In order to get a good suspension system must include some characteristics which are wheel effects, damper reflection, suspension displacement and the body acceleration. Therefore, fuzzy logic controller was applied as main alternative to solve this problem. Fuzzy logic seems the most suitable as it have many rules and flexible with automatic condition. More over, active suspension system is usually complex and with high responsibility. Active suspension is differs from passive and semi-active suspension system since it has a hydraulic or pneumatic actuator which is installed in parallel with the spring and damper [1]. Thus, this study hopes the implementation will improve technology of vehicle suspension engineering and control system to a better quality.

1.2 Problem Statement

The suspension system is the automotive system that connects the wheels of the automobile to the body, in such that the body is cushioned from jolts resulting from driving on uneven pavement or rough road surfaces [1]. The best suspension system should reduce the effect of road disturbances. When the body has large oscillation because of road disturbances, the controller applied should dissipate it quickly. Nowadays, most of the car was applied with conventional controller for the suspension system, but cannot give best impact for road comfort and handling stability. There are always been conflict between them.

There have been many years where the study of active vehicle suspension system has been done by the researchers. Many control method has been proposed in order to overcome these suspension problem such as Linear Quadratic Gaussian (LQG) control, adaptive control, non-linear control are developed and proposed so as to manage the occurring problems [2].

In order to design the controller of active vehicle suspension system, there are some important things need to be considered. It must be consider the interaction between vehicle ride comforts and optimum handling stability when involve in any possibility of road disturbances, speed and vehicle load. Thus, to overcome the problem, advanced control electronic which is Fuzzy Logic Controller will be designed to improve the suspension system. However, there are lots of road disturbances and only some conditions will be countered.

Fuzzy logic controller has been applied in many applications, such as cruise control, automatic transmission, cold-rolling mills, self parking model car, image stabilizer for video camera and a fully automated washing machine. With the proven diversity of fuzzy logic controller, the technique was selected in the research.

1.3 Project Objectives

There are two objectives of this project need to be achieved:

1. To make a comparison about the suspension stability between passive suspension and active suspension.
2. To make a comparison between LQR Controller and Fuzzy Logic Controller for Active Suspension System.

1.4 Project Scope

This study will not done for full-vehicle suspension model which is 7 DOF as this study limit for basic suspension model, quarter-car model which is 2 DOF. Hence, in this project will be focus on quarter vehicle model so that can simplify the control scheme. For this research will be limit to the vertical response which is including the response apart of the bounce control.

CHAPTER 2

LITERATURE REVIEW

2.1 Chapter Overview

Through this chapter, will be state and analyze all the related research by researcher that have related with this study. This chapter includes all the important studies which have been done before. In this part, will be embedded research from others about same subject of suspension system but using different controller as the solver. The sources that attach in this chapter include journal paper, reference book, thesis and internet sources.

2.2 Concept of Suspension System

Suspension system is function in vehicle to improve the ride comfort and stability. The purpose of a suspension system is to support the vehicle body and increase ride comfort. The ride comfort is improved by means of the reduction of the body acceleration caused by the car body when road disturbances from smooth road and real road roughness [3]. Figure 2.1 and Figure 2.2.Nemat Changizi, August 2010 explain model of car used is quarter car model with two degrees of freedom. It is because this model uses a unit to create the control force between body mass and wheel mass [4].

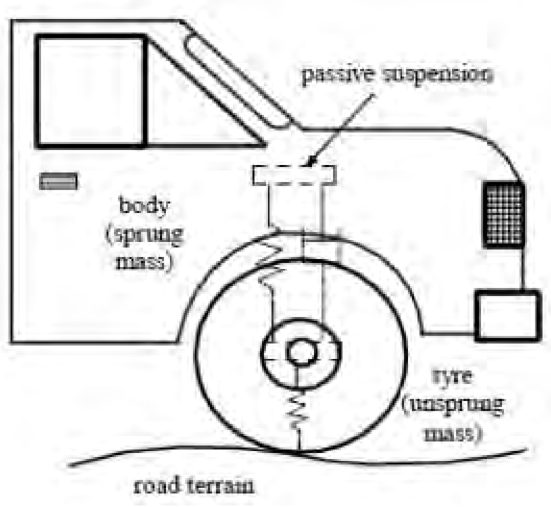

Figure 2.1 : A quarter car representation of passive B [4]

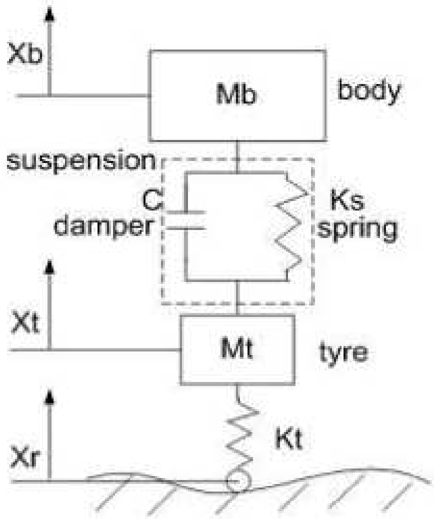

Figure 2.2.1: Quarter-car model [4]

For quarter car model above represent for passive suspension system. There are several types of suspension system, which are passive, adaptive, semi-active suspension system and active suspension system. There are many types of suspension design that used by different manufacturers.

Mohd Asqalani Bin Naharudin, 2008 [6] explain about semi-active suspension system. A semi-active suspension system utilizes a variable damper or other variable dissipation component in the automotive suspension. An example of a variable dissipater is a twin tube viscous damper in which the damping coefficient can be varied by changing the diameter of the orifice in a piston.

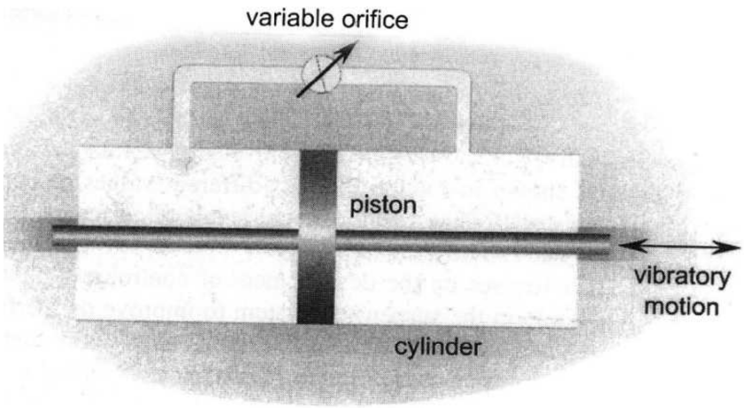

Figure 2.2.2 : Schematic of a variable damper [6]

Comparison between semi-active and active suspension system shows semi-active use less power than fully active suspension system. The power consumption in a semi-active system is only for purpose of changing the real time dissipative force characteristics of the semi-active device. Semi-active systems cannot cause the suspension system to become unstable unlike active systems [6]. However, in this study suspension system used is active vehicle suspension system as the real car move on the road is type of active suspension system.

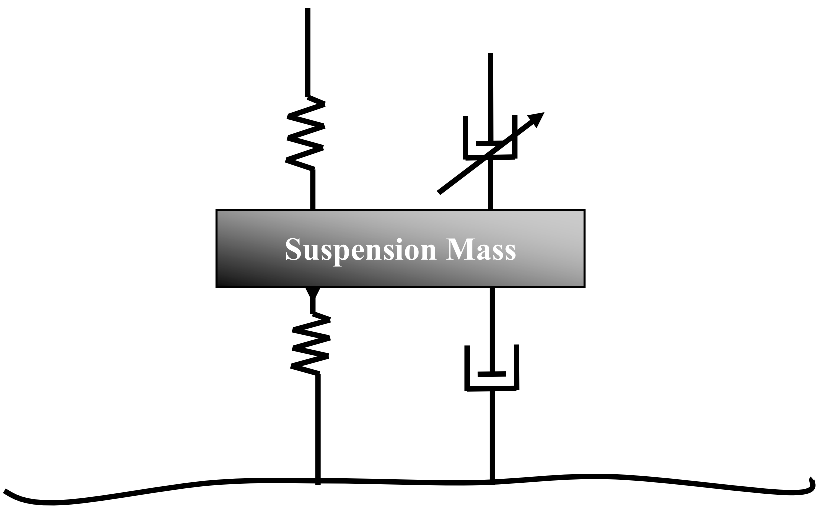

Figure 2.2.3 : The semi-active Suspension System [1]

Meanwhile in active system, the component of spring or damper is replaced with an actuator. An actuator is controlled by using the feedback from the vehicle body. Technically, active suspension system is used to control the movement of a vehicle using onboard controller by controlling the tire movement during cornering, braking and accelerating. The method of the controller for active suspension can be divided into four types based upon the control techniques namely Solenoid Actuated, Hydraulic Actuated, Electromagnetic Recuperative and Magneto-rheological Damper.

Saban Cetin, and Ozgur Demir, 2008 [5] state that the model of active suspension system consists of a body and a wheel which are connected with a suspension system. The suspension system is consisted of spring, damper, nonlinear elements. An actuator is also connected between the car body and the wheel while the wheel spring is in contact with the road profile. If road that widely used is flat and do not have any disturbance, then suspension would not be necessary.

A car suspension is comprises with several of components and provides all the solution for car stabilization. Tan Wei Teck, 2001 [1] explain in his thesis about spring element in car suspension. The springs play an important part in handling of the suspension system. Springing action should be as soft as possible for the best ride comfort. Road shocks should be swallowed and not transmitted to the vehicle. Springing action should also be progressive, taking a bump in the roadway softly at first and gradually hardening towards the end of the deflection. Springing action should assure evenness of ride regardless of vehicle load.

$$F = k x \tag{2.1}$$

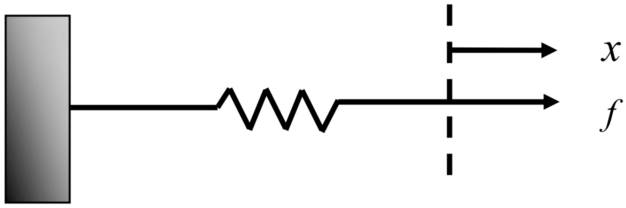

Figure 2.2.4 : Spring system [1]

Second thing play an important part in the suspension system is damper. Function of damper or shock absorbers are required to help the metallic spring to control the spring action. Tan Wei Teck, 2002 [1] state generally, the spring is the element that cushions the shock and therefore needed a shock absorber as a brake on the spring to keep it from continuing its spring action. In a typical damper, the comparison resistance is considerably lower than the rebound resistance.

The shock absorber is to control movement of vehicle against initial forces. The force F is required to expand the damper with velocity V:

$$F = Dv \qquad (2.2)$$

$$F = D\frac{dx}{dt} \qquad (2.3)$$

Where D is constant known as the damping coefficient and unit SI is Newton Second/Meter (Ns/m^{-1})

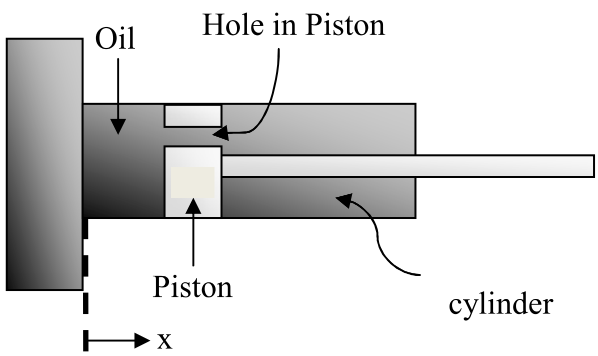

Figure 2.2.5 : The simple damper construction [1]

2.3 Quarter Car Model

Car model for this study used is Quarter Car model. A two-degree-of-freedom (DOF) Quarter Car Model automotive suspension system is shown in Figure 2.7. Mohd Asqalani Bin Naharudin, 2008 [6] explain the Quarter Car Model represents the automotive system at each wheel i.e. the motion of the axle and of the vehicle body at any one of the four wheels of the vehicle. The suspension itself is shown to consist of a spring ks, a damper bs and a variable damper bsemi. The variable damper bsemi can be set to zero in a passive suspension. The sprung mass ms represent the quarter-car equivalent of the vehicle body mass. The unsprung mass mu represents the equivalent mass due to the axle and tire. The vertical stiffness of the tire is represented by the spring kt. the variables Zs, Zu and Zr represent the vertical displacements from static equilibrium of the sprung mass, unsprung mass and the road respectively.

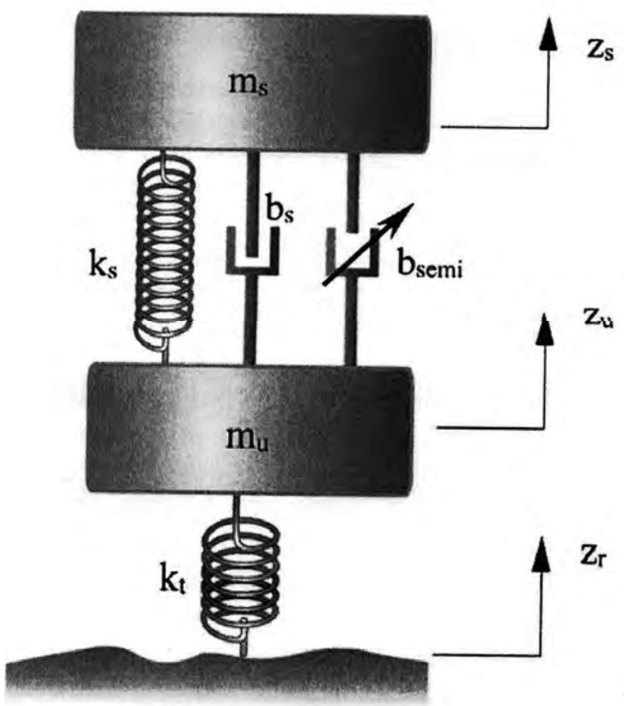

Figure 2.3 : Quarter Car Active-Suspension [6]

2.4 Controller used for Active-Suspension System

2.4.1 Fuzzy PID Controller

Saban Cetin, and Ozgur Demir, 2008 [5] has been done research for nonlinear Quarter Car Model. In the control literature, there are several types of control systems which use Fuzzy Logic as an essential system component. In this study direct action type fuzzy logic controller applied to the 2-DOF nonlinear car model. The direct action fuzzy PID controller is placed within the feedback control loop and manages the PID options through fuzzy algorithm.

Conventional PID controller is the most widely used in industrial because of its simple structure. However, main problem of PID is for the fix gains do not produce reasonable performance over a wide range of operating conditions and systems (time-delayed systems, nonlinear systems, etc). Fuzzy PID controller used in this paper is based on two input FLC structure with couple rules.

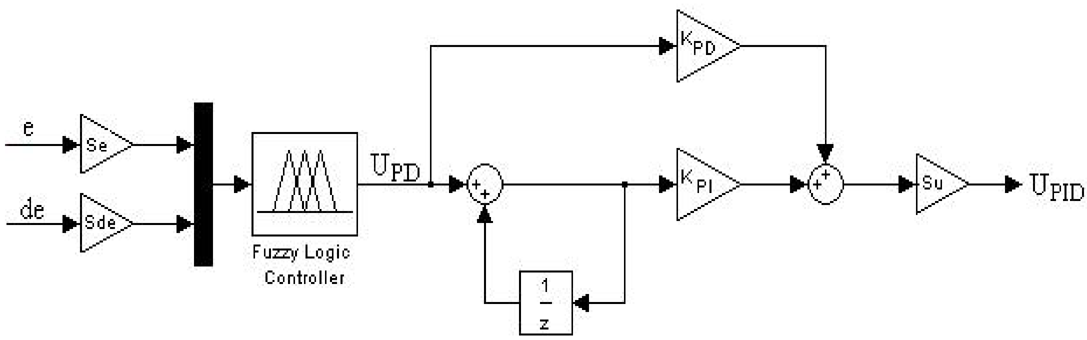

Figure 2.4.1 : Block diagram of the two input Fuzzy PID Controller [5]

The linguistic labels used to describe the Fuzzy sets were 'Negative Big' (NB), 'Negative Medium' (NM), 'Negative Small' (NS), 'Zero' (ZE), 'Positive Small' (PS), 'Positive Medium' (PM) and 'Positive Big' (PB). Therefore a total of 49 rules were developed [7].

2.4.2 Indirect adaptive interval type-2 Fuzzy Neural Network (FNN) controller

Tsung Chih Lin, Mehdi Roopaei and Ming-Che Chen, 2010 [8] state FNN controller is defined as an FNN logic system equipped with an adaptation algorithm. Moreover, FNN is constructed from a collect of fuzzy IF-THEN rules using fuzzy logic principles and the adaptation algorithm adjusts the free parameters of the FNN based on the numerical experiment data. Like the conventional adaptive control, the adaptive FNN control has direct and indirect FNN adaptive control categories.

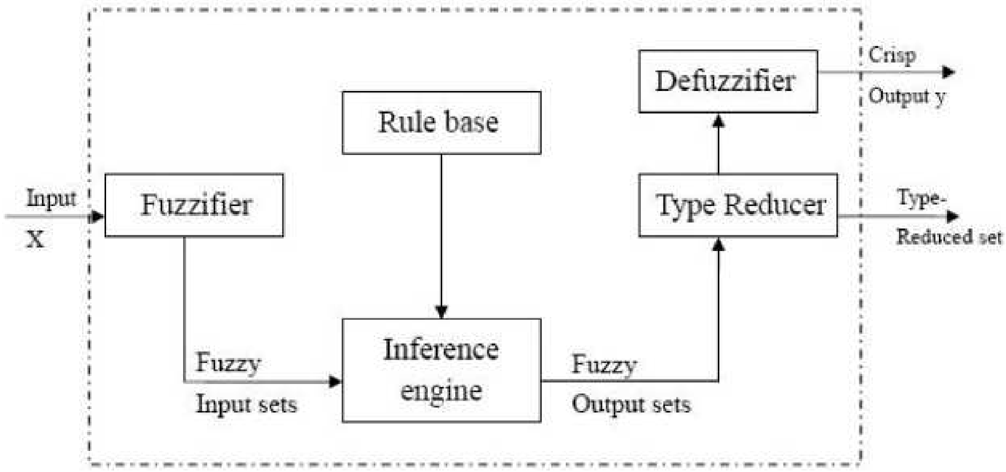

Figure 2.4.2 : The structure of type-2 Fuzzy Logic System [8]

There are five main parts in a type-2 FLS: fuzzifier, rule base, inference engine, type-reducer and defuzzifier. After defuzzification, fuzzy inference, type-reduction and defuzzification, a crisp output can be obtained. By using FNN also one of method for controller buat need to involve in lots of math equation.