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SIMULATION AND EXPERIMENTAL INVESTIGATION ON SEMI ACTIVE SUSPENSION SYSTEM WITH SKYHOOK, GROUNDHOOK, AND HYBRID CONTROLLERS

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This report was submitted in accordance with the partial requirements for the honor of Bachelor of Mechanical Engineering (Automotive)

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I verify that this report is my own word except summary and extract that every one of it I have clarify the resource”

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For loving father and mother and also other family members.

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ABSTRACT

Semi active suspension change their damping force in real time by simply changing the damping coefficient according to a control policy. In this study, a number of semi-active control algorithms namely skyhook, groundhook and hybrid skyhook-groundhook controllers will be investigate through simulation and experimental method with Magneto Rheological (MR) damper. The effectiveness of these control algorithms in disturbance rejection are investigated along with their ability to consistently provide the target force in the same direction with the damper velocity to overcome the damper constraint. A full scale quarter-car test rig which consists of two units accelerometers, two units displacement transducers, one unit force sensor, semi-active suspension system which using MR damper, and 3-phase AC motor is used to simulate the sinusoidal road profile by using slider crank mechanism for road profile simulator. An (Integrated Measurement and Control) IMC device is used for controlling the MR damper and also for acquiring the experimental data. From the simulation and experimental results, hybrid skyhook-groundhook controller shows significant improvement in four performance criteria namely body acceleration, body displacement, suspension deflection, and wheel acceleration without allowing excessive wheel acceleration magnitude. The hybrid skyhook-groundhook controller is also superior to the counterparts in overcoming the damper constraint by producing the target forces consistently in the same sign with the damper velocity.

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LIST OF NOMENCLATURES

m_1	=	Sprung Mass
m_2	=	Unsprung Mass
x_1	=	Sprung Mass Displacement
x_2	=	Unsprung Mass Displacement
k_s	=	Suspension Stiffness
k_t	=	Tire Stiffness
x_{in}	=	Input Displacement
ζ_1	=	Sprung Mass Damping Ratio
ζ_2	=	Unsprung Mass Damping Ratio
ω	=	Natural Frequency
ω_{n1}	=	Sprung Mass Natural Frequency
ω_{n2}	=	Unsprung Mass Natural Frequency
c	=	Damping Coefficient
k_1	=	Stiffness
c_{sky}	=	Skyhook Damping Coefficient
v_1	=	Sprung Mass Velocity
v_2	=	Unsprung Mass Velocity
c_{ground}	=	Groundhook Damping Coefficient
F_{sa}	=	Semi-Active Damping Force

F_{sky}	=	Skyhook Damping Force
v_{12}	=	Relative Velocity
c_{sa}	=	Semi-Active Damping Coefficient
σ_{sky}	=	Skyhook Component of Damping Force for Hybrid Control
σ_{ground}	=	Groundhook Component of Damping Force for Hybrid Control
α	=	Relative Ratio between Skyhook and Groundhook for Hybrid Control
G	=	Controller Gain
x_{12}	=	Relative Velocity
i	=	Electric Current

CHAPTER I

1 INTRODUCTION

1.1 BACKGROUND

The purpose of this project is to investigate the performance criterion of semi active suspension system with using skyhook, groundhook, and hybrid controller. A few years ago, automotive suspension designs have been a compromise between the two conflicting criteria of road holding and passenger comfort. The suspension system must support the weight of the vehicle, provide directional control during handling maneuvers, and provide effective isolation of passengers and payload from road disturbances. Suspension is the term given to the system of springs, shock absorbers and linkages that connects a vehicle to its wheels. Suspension systems serve a dual purpose contributing to the cars handling and braking for good active safety and driving pleasure, and keeping vehicle occupants comfortable and reasonably well isolated from road noise, bumps, and vibrations.

Damper is the most important in suspension system. Damper function is the control of motion or oscillation, as seen with the use of hydraulic gates and valves in a vehicles shock absorber. Like spring rate, the optimal damping for comfort may be less than for control. Damping controls the travel speed and resistance of the vehicles suspension. An undamped car will oscillate up and down. With proper damping levels, the car will settle back to a normal state in a minimal amount of time. Most damping rate in modern vehicles can be controlled by increasing or decreasing the resistance to fluid flow in the shock absorber. Nowadays, there many types of suspension system can make car more comfortable in any road condition. It has five main types of vehicle suspension system like passive, semi-active, slow active, active and fully active suspension system, which depend on the operation mode to improve vehicle ride. A semi-active damper is capable of changing its damping characteristics whether through mechanically changing orifices or fluid with adjustable viscosity; a semi-active damper offers greater variation in damping rate with presence of the control algorithm used in the design which will governs the amount of damping needed.

1.2 PROBLEM STATEMENT

The problem of controlling MR damper rises from this damper constraint. The damper constraint indicates that the output of the disturbance rejection control namely target force that must be tracked by MR damper must be in the same sign with the real time damper velocity. MR damper cannot provide positive force at negative relative velocity of the damper and vice versa. The limitation of semi-active control strategy is that besides having the ability to attenuate the disturbances, it must produce the target force exactly in the same sign with the damper velocity. So, it is important to study the semi active suspension control system namely skyhook, groundhook, and hybrid. This project is useful for optimizing the appropriate tuning parameter to achieve the optimum vibration absorption in both body and wheel response.

1.3 OBJECTIVES

Objectives of this project are:

- To study the well known control strategy namely skyhook, groundhook, and hybrid.
- To demonstrate the semi active suspension system in a quarter car model by employing those controller structures.
- To perform or investigate the simulation and experimental work.

1.4 SCOPES

During finishing this project, all the simulation study will be done by using Matlab Simulink environment. The suspension system will be analyzed within quarter car model. And after that, an experimental work will be done by using linear quarter car test rig which is available at Universiti Teknikal Malaysia Melaka (UTeM) Autotronic Laboratory. Meanwhile, this project will utilizing the input data characterization from Zulazrin (2009) and force tracking control result from Zubir (2009).

CHAPTER II

2 LITERATURE RIVIEW

2.1 AUTOMOTIVE SUSPENSION

Automotive suspension system is one of the vehicle systems that receive many attentions due to its application on absorbing vibration. Since then, this system had been developed from time to time to increase its ability on responding over load vibration due to uneven road profile and vehicle situation characteristic. There are five type of suspension system that had been classified during this development which is:

2.1.1 PASSIVE SUSPENSION SYSTEM

Passive suspension system is a parallel arrangement between passive damper and spring which mean that this system unable to generate force, but only able to dissipate energy at a constant rate due to presence of constant velocity damper. This type of damper had been use for several years in conventional vehicle cause by low cost production.

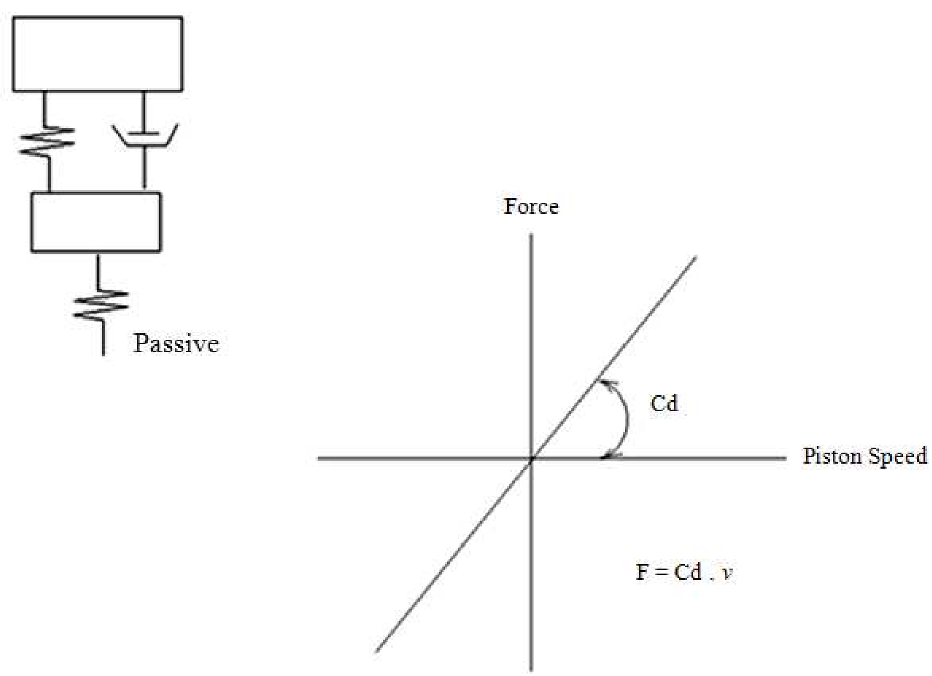

Figure 2- 1: Passive Suspension System

2.1.2 SEMI-ACTIVE SUSPENSION SYSTEM

Semi-active suspension system is a parallel arrangement between adjustable damper and spring. This type of suspension system unable to generate force, but able to dissipate energy at a variable rate with presence of adjustable damper; there are two type of adjustable damper which is variable orifice and variable fluid viscosity. Variable orifice damper type allows the changing at the size of valve port flow for creating various damping rate of damper fluid with applying current. While, variable fluid viscosity damper type gives a various damping rate by changing the fluid viscosity. The fluid that exhibits the changeability is Magneto Rheological (MR) fluid which will change its viscosity in presence of magnetic coil which can be generate by applying current. And also, this type of damper will be used in this project. This type of suspension system gets more attention in automotive industry due to its safety rather than fully active suspension system because when this system malfunction, it will working as passive suspension system.

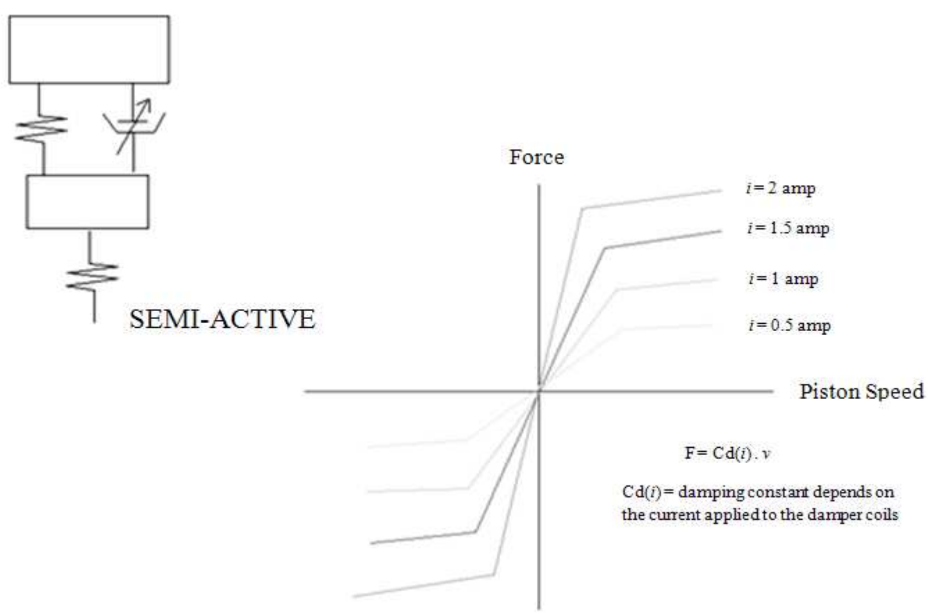

Figure 2- 2: Semi Active Suspension System

2.1.3 SLOW-ACTIVE SUSPENSION SYSTEM

Slow-active suspension system is a parallel arrangement between passive damper, spring and force generation device. This type of suspension system runs as passive suspension system when force generation devise is not working. Presence of force generation devise is able generate external force to remove unwanted motion of vehicle body movement. This type of suspension system need more space for arranging the passive suspension system with force generation devise correspondingly.

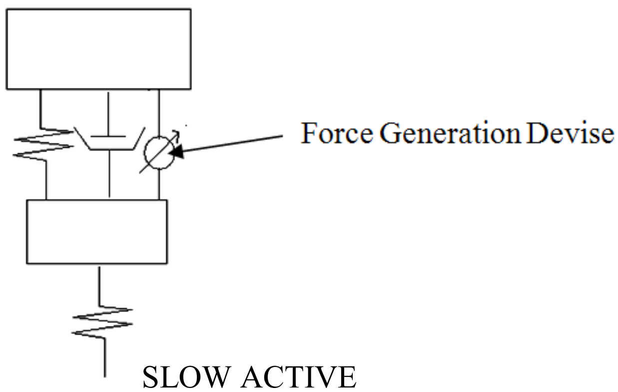

Figure 2- 3: Slow Active Suspension System

2.1.4 ACTIVE SUSPENSION SYSTEM

Active suspension system is a parallel arrangement between spring and force generation device. This type of suspension system can exhibit unwanted force when force generation device is malfunction.