PID CONTROLLER FOR SEMI-ACTIVE SUSPENSION SYSTEM USING MAGNETO-RHEOLOGICAL (MR) DAMPER

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This thesis work is dedicated to my wife, Logeswary, who has been a constant source of support and encouragement during the challenges of graduate school and life. I am truly thankful for having you in my life. This work is also dedicated to my parents, Rajan and Paruvathy, who have always loved me unconditionally and whose good examples have taught me to work hard for the things that I aspire to achieve.

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ABSTRACT

In order to maintain the high level of comfort that customer expect from vehicle and still maintain the high safety standards of automobiles, the car suspension system contribute significant impact. The main requirement of vehicle suspension is that, it should be able to minimize the vertical displacement and the acceleration of the body in order to increase the passenger comfort. A viable alternative to maintain the level of comfort is to use a semi-active suspension system with magneto-rheological (MR) damper which will reduce the inherent trade off between the ride comfort and road holding characteristic of the vehicle. Because the behaviour of semi-active devices is often highly nonlinear, one of the main challenges in the application of this technology is the development of appropriate control algorithms. In this study, the development of a semi-active suspension control of quarter car model using robust controller has been done. A mathematical modelling and computer simulation models of quarter car semi-active suspension controller algorithm have been developed within Matlab-SIMULINK. A high performance and robust controller design and developed using Matlab. There are two type of controller identified in this study which are inner loop and outer loop controller. The analysis and comparison made between passive and semi-active suspension with MR damper to provide effective damping by using robust controller.

ABSTRAK

Dalam usaha untuk mengekalkan tahap keselesaan dan keselamatan yang tinggi, sistem penggantungan untuk kenderaan merupakan suatu aspek yang sangat dititik beratkan dalam industry automobile. Ini kerana keselesaan dan keselamatan merupakan unsur yang amat dikehendaki oleh pengguna kenderaan. Kedua–dua aspek ini boleh dicapai melalui sistem peggantungan yang tahan lasak dan berkesan. Sistem penggantungan yang direka perlu mempunyai kemampuan untuk meminimumkan anjakan menegak dan mengurangkan pecutan rangka badan kenderaan untuk mencapai keselesaan yang dikehendaki. Satu alternatif yang berdaya maju untuk mengekalkan tahap keselesaan adalah dengan menggunakan sistem penggantungan separa-aktif dengan magneto-reologi (MR) peredam yang akan mengurangkan perdagangan yang wujud di luar antara keselesaan perjalanan dan jalan memegang ciri kenderaan. Disebabkan kelakuan peranti semi -aktif sering sangat tidak linear, salah satu cabaran utama dalam penggunaan teknologi ini ialah pembangunan algoritma kawalan yang sesuai. Dalam kajian ini, pembangunan kawalan untuk penggantungan separa-aktif bagi suku model kereta menggunakan pengawal teguh telah dilakukan. Pemodelan dan simulasi komputer matematik model kereta suku separa-aktif algoritma pengawal penggantungan telah dibangunkan dalam Matlab-SIMULINK . Terdapat dua jenis pengawal dikenal pasti dalam kajian ini yang gelung dalaman dan pengawal gelung luar. Analisis dan perbandingan dibuat antara penggantungan pasif dan semi-aktif dengan MR peredam untuk memberikan redaman berkesan dengan menggunakan pengawal.

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LIST OF SYMBOLS

α	-	MR yield stress
γ	-	Hysteresis parameter
η	-	Equilibrium rate
β	-	Hysteresis parameter
A	-	Hysteresis parameter
C_u	-	Damper constant at unsprung
c_1	-	Reproduce the roll-off occurring
c_0	-	Viscous at large damping
F	-	Force generated
F_d	-	Damping Force
F_c	-	Desired Damping Force
Hz		Hertz
k_0	-	Stiffness at large velocities
k_1	-	Stiffness due to accumulator
K_{cr}	-	Critical value of Proportional
K_s	-	Spring constant of Sprung(body)
K_u	-	Spring constant of Unsprung(tire)
M_s	-	Mass of Sprung(body)
M_u	-	Mass of Unsprung(tire)
n	-	Number of turns
P_{cr}	-	Critical value of Period
s, sec	-	Second
X_s	-	Displacement of Sprung(body)
X_u	-	Displacement of unsprung(tire)
X_r	-	Road Unevenness

x	-	Damper displacement
V, *Volt*	-	Voltage
y	-	Internal displacement of the damper
z	-	Evolutionary variables

CHAPTER 1

INTRODUCTION

1.1 Introduction

The vehicle suspension is used to eliminate unpleasant vibrations from various road conditions. There are three main types of vehicle suspension system have anticipated and effectively implemented. The systems are namely passive, semi-active and active systems. Though the passive suspension system featuring oil damper provides design simplicity and cost-effectiveness, performance limitations are inevitable due to the lack of damping force controllability. On the other hand, the active suspension system can provides high control performance in wide frequency range. However, this type may require high power sources, many sensors and complex actuators such as servo valves. Consequently, one way to resolve these requirements of the active suspension system is to adopt the semi-active suspension system. The semi-active suspension system offers a desirable performance, enhanced in the active mode without requiring large power sources and expensive hardware.

1.2 Research Background

There has been a sustained interesting magneto-rheological (MR) device due to the controllable interface provided by the MR fluid inside the devices that enables the mechanical device to interact with an electronic system, which can be used to continuously adjust the mechanical properties of the device. Some examples of devices in which MR fluids have been employed include dampers, clutches, brakes and transmissions.

The most popular of these devices are MR dampers, especially as automotive shock absorbers. The automotive shock absorber has been shown to be a very important contributor to the ride comfort and road handling of a vehicle. It can conclude that the success of MR damper in semi-active vehicle suspension applications is determined by two aspects which is the accurate modeling of the MR dampers and the other is the selection of an appropriate control strategy.

In addition ,theoretical and simulation researches have demonstrated that the performance of a semi-active control system is also highly dependent on the choice of control strategy .Therefore, some semi-active and passive control schemes have been discussed and compared the approaches ,such as PID controller into semi active control.

1.3 Research Objectives

i. To design and develop a controller for semi-active suspension system employing MR damper for a quarter car model.

ii. To investigate the performance of the controller for body displacement and body acceleration of semi-active system for various road condition.

1.4 Problem Statements

Traditionally, 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.

A passive suspension has the ability to store energy via a spring and to dissipate it via a damper. The parameters are generally fixed, being chosen to achieve a certain level of compromise between road holding and ride comfort. Once the spring has been selected based on the load-carrying capability of the suspension, the damper is the only variable remaining to specify. Low damping yields poor resonance control at the natural frequencies of the body (sprung mass) and axle (unsprung mass), but provides the necessary high frequency isolation required for a comfortable ride. Conversely, large damping results in good resonance control at the expense of high frequency isolation. Due to these conflicting demands, suspension design has had to be something of a compromise, largely determined by the type of use for which the vehicle is designed.

The other solution is using active control. However this method is expensive for a standard car because require high power source, many sensors and complex actuator such as servo-valves. Consequently, one way to resolve this matter is to adopt the semi-active suspension system, where this system offers a desirable performance generally enhanced in the active mode without requiring large power sources and expensive hardware.

1.5 Research Question

Can PID controller using MR damper the vibration vibrations of automotive suspension system from various road conditions?

1.6 Theoretical Frame Work

This study is to design a robust controller to control a semi-active suspension system using quarter car model with MR damper.

1.7 Scopes of Research

The scopes of this project are:

i. Literature Review of semi-active suspension, modelling techniques and controllers, and MR damper.
ii. Modelling of semi-active suspension system using MR damper of a quarter car model within Matlab SIMULINK environment.
iii. Design and simulate robust controller for semi-active suspension system with MR damper.

iv. Validation, verification and analysis of the controllers' performance for semi-active suspension system using MR damper in comparison with passive suspension system.

1.8 Research Methodology and Flowchart

The methodologies involved in this study are shown in Figure 1.1. The project starts by collecting reading materials such as books, journals and technical papers specifically on quarter car model, passive and semi-active suspension system, MR damper, intelligent controller.

Research has been done continuously throughout this study to get a better understanding on the concept of semi-active suspension system and its constraints. Besides, consultation sessions with the project supervisor and few colleagues who are doing similar research were also held periodically to discuss any arising issues and problems encountered pertaining to this study.

Based on the research conducted, semi-active with MR damper application was crucially analysed and its controller type were justified before use in simulation. The study on quarter car suspension system has been divided into two main parts which are (1) mathematical modelling and (2) simulation of the controller system.

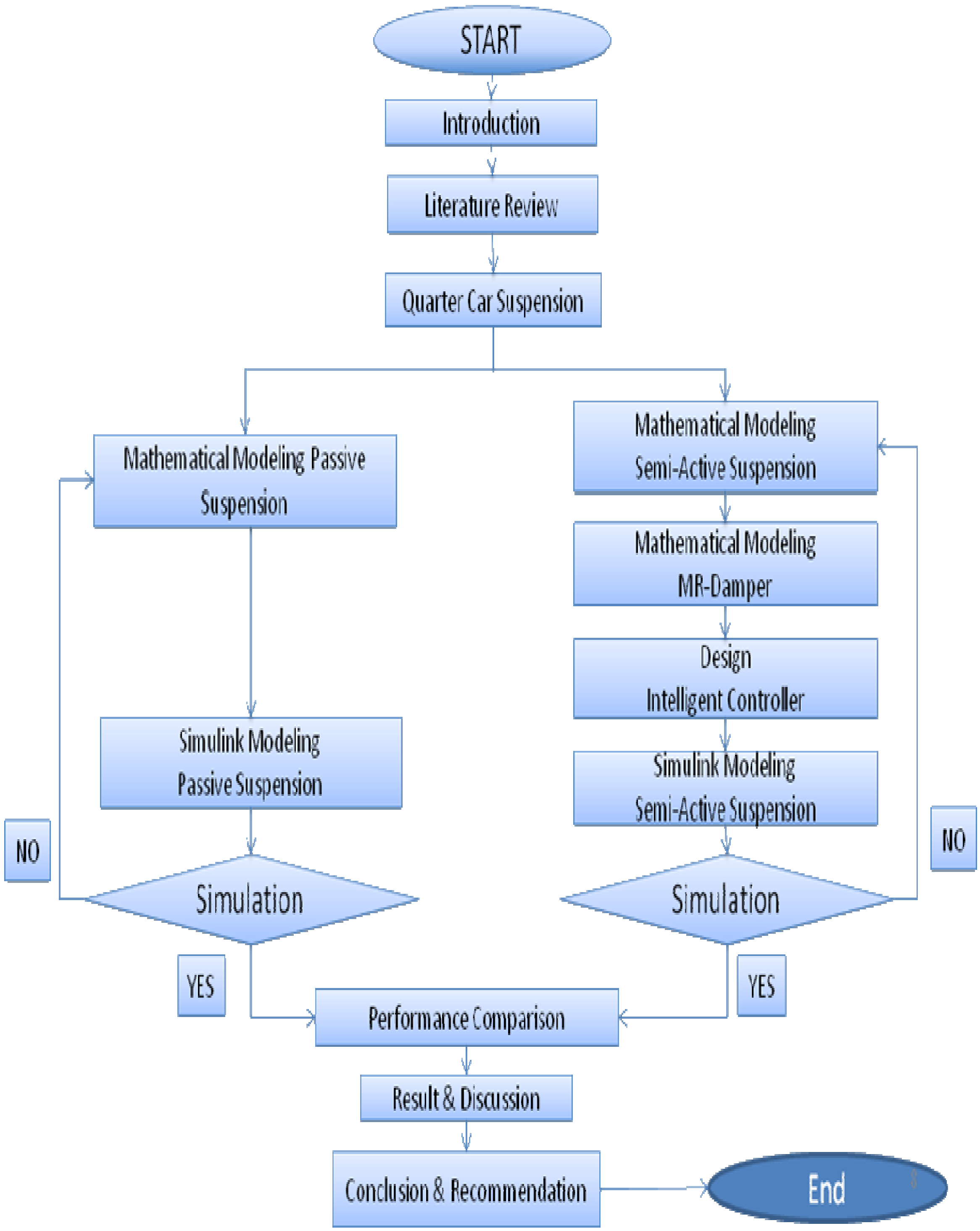

Figure 1.1: Flowchart of Methodology

1.9 Gantt Chart

NO.	ACTIVITIES	WEEKS															
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	Selection of project title	■	■														
2	Collecting reading materials			■	■	■	■	■									
3	Literature review of previous research				■	■	■	■	■	■	■	■	■	■	■	■	
4	Understanding the concept of semi-active vehicle suspension system with MR damper				■	■	■	■	■	■	■						
5	Familiarization with Matlab SIMULINK						■	■	■	■	■	■	■				
6	Simulation of vibration environment using data acquired by previous researcher										■	■	■	■			
7	Simulation of semi-active vibration controller												■	■	■		
8	Analysis of the results from the simulation of passive and semi-active													■	■	■	
9	Report writing											■	■	■	■	■	
10	Preparation for seminar presentation														■	■	

Figure 1.2 : Gantt Chart for Master Project 1

NO.	ACTIVITIES	WEEKS															
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
1	Literature review																
2	Experimental setup: Integration and development of data acquisition and instrumentation system																
3	Experiment on vibrating mechanical equipments (quarter car suspension)																
4	Analysis of the experimental results																
5	Report writing																
6	Preparation for seminar presentation and submission of draft thesis																
7	Seminar 2																
8	Submission of the thesis																

Figure 1.3 : Gantt Chart for Master Project 2

1.10 Thesis Outline

This thesis consists of seven chapters. Chapter 1 is the introduction chapter. This chapter presents the research background, statement of the problem, objectives and scopes of the study, research contributions, methodology of research, and the overall outline of this thesis

Chapter 2 presents the literature review on related subjects concerning this thesis. In this chapter, the classification of vehicle suspension system, the selection of damper types and review on published articles related to active suspension control strategies are described.

Chapter 3 presents the methodology, modelling and validation of quarter car model. In this chapter, the mathematical equation of 2DOF quarter car model is introduced. Then, the mathematical model with quarter car is presented in order to validate the simulation results. The development of a validated quarter car model based on the mathematical quarter car is described. This chapter also presented the development of force tracking control system. In this chapter, a mathematical formulation of MR damper dynamics is introduced. Then, the algorithm of force tracking control system is formulated. Finally, the evaluation of force tracking control performance is discussed in terms of the tracking ability of the pneumatic force to the desired force.

Chapter 4 describes the development of the proposed multiple PID controller. In this chapter, the algorithm formulation of the proposed controller and its benchmark are explained.

Chapter 5 presents the simulation analysis on the time domain of the proposed control structure is presented. Finally, the simulation model evaluation of the proposed controller is carried out using quarter with passive system.

Finally, Chapter 6 is the concluding chapter. This chapter summarizes the works done in this entire study. The directions and recommendations for future research works are also outlined.

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