REAL CODED GA FOR TUNING OF SEMI-ACTIVE RAILWAY VEHICLE SUSPENSION SYSTEM

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To my beloved mother and father

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ABSTRACT

To maintain a high level of comfort expected by passengers from transportation vehicle while maintaining a high safety standards railway vehicle suspension system contribute the most significant impact. The main requirement of a vehicle suspension is that, it should be able to minimize the vertical displacement and the acceleration of the body in order to improve 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 tradeoff between the ride comfort and road holding characteristic of the vehicle. Since the behavior 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 system. In this thesis, the development of a semi-active suspension control of half car model of railway vehicle using stability augmentation control system is studied. A mathematical modelling and computer simulation model of secondary half car semi-active suspension controller algorithm have been developed within Matlab-SIMULINK. The tuning of this controller was developed by using Genetic Algorithm (GA).

ABSTRAK

Untuk mengekalkan tahap keselesaan yang tinggi yang diharapkan oleh penumpang dari kenderaan pengangkutan di samping mengekalkan tahap keselamatan yang tinggi, sistem gantungan menyumbang dengan paling ketara. Keperluan utama sistem penggantungan kenderaan adalah, ia mestilah mampu untuk mengurangkan anjakan dan pecutan badan menegak / melintang untuk meningkatkan keselesaan penumpang. Satu alternatif yang berdaya maju untuk mengekalkan tahap keselesaan adalah dengan menggunakan sistem sgantungan separa-aktif dengan peredam magneto-reologi (MR) yang akan mengurangkan keseimbangan yang wujud antara keselesaan perjalanan dan ciri-ciri yang memegang jalan kenderaan. Oleh kerana kelakuan peredam separa-aktif kebiasaannya sangat tidak linear, salah satu cabaran utama dalam penggunaan teknologi ini ialah pembangunan sistem kawalan yang sesuai. Dalam tesis ini, pembangunan kawalan sistem gantungan separa-aktif model kereta separuh daripada kenderaan keretapi menggunakan kestabilan sistem kawalan pembesaran dikaji. Pemodelan dan simulasi komputer model matematik kereta separuh kedua, algoritma pengawal sistem gantunfgan separa-aktif telah dibangunkan dalam Matlab-SIMULINK. The penalaan pengawal ini telah dibangunkan dengan menggunakan Algoritma Genetik (GA).

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LIST OF SYMBOLS

y_c	Carbody displacement
θ_c	Carbody roll angle
y_r	Relative displacement
y_b	Bogie Displacement
n_i	Number of cycles
a_i	Mean acceleration
T_i	Fatigue time
T	Total fatigue time
a	Peak acceleration
W_z	Sperling's Ride Index
f	Oscillation frequency
$F(f)$	Frequency-dependent factor
B	Acceleration weighting factor
B_w	Horizontal comfort index
B_s	Vertical comfort index
V_r	Vertical ride index
V_l	Lateral ride index
m_c	Mass of car body
m_b	Mass of car bogie
k_1	Secondary lateral spring stiffness
k_r	Stiffness of bogie disturbance
k_2	Secondary vertical spring stiffness
b_1	Secondary lateral damping coefficient
b_2	Secondary vertical damping coefficient
h_1	Height between body centre of gravity and secondary lateral suspension
w	Width of body centre gravity and secondary vertical suspension

CHAPTER 1

INTRODUCTION

Rail transportation has been the most demanded transport option offering safety, speed, and comfort. In parallel with implementation of new technologies, the cruising speed has also increased. The effects of vibrations caused by rail disturbances on vehicle carbody and passengers are more important in high cruising speeds. Hence, safe and comfortable transportation of passengers and goods under high speeds has become an important engineering problem to solve.

The vehicle suspension is used to eliminate unpleasant vibrations from various road conditions. There are three main types of vehicle suspension system have been effectively implemented. The systems are namely passive, semi-active and active systems. Though a passive suspension system featuring oil damper and spring provides design simplicity and cost-effectiveness, performance limitations are inevitable due to the lack of damping force controllability. On the other hand, an 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 an active suspension system is to adopt a 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.

Today's vehicles rely on a number of electronic control systems. Some of them are self-contained, stand-alone controllers fulfilling a particular function while others are co-ordinated by a higher-level supervisory logic. Examples of such vehicle control systems include braking control, traction control, acceleration control, lateral stability control, suspension control and so forth. Such systems aim to enhance ride and handling, safety, driving comfort and driving pleasure. The thesis focuses on semi-active suspension control. The thrust of this work is to provide a comprehensive overview of modeling and design a vehicle semi-active systems based on smart damping devices. Isolation from the forces transmitted by external excitation is the fundamental task of any suspension system. The problem of mechanical vibration control is generally tackled by placing between the source of vibration and the structure to be protected, suspension systems composed of spring-type elements in parallel with dissipative elements. Suspensions are employed in mobile applications, such as vibrating machinery or civil structures. In the case of a vehicle, a classical car suspension aims to achieve isolation from the road by means of spring-type elements and viscous dampers (shock absorbers) and contemporarily to improve road holding and handling. The elastic element of a suspension is constituted by a spring (coil springs but also air springs and leaf springs), whereas the damping element is typically of the viscous type. In such a device the damping action is obtained by throttling aviscous fluid through orifices; depending on the physical properties of the fluid (mainly its viscosity), the geometry of the orifices and of the damper, a variety of force versus velocity characteristics can be obtained. This technology is very reliable and has been used since the beginning of the last century (Bastow, 1993).

1.1 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, and 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 Stability Augmentation controller into semi-active control.

1.2 Objectives

i. To design a controller for semi-active suspension system employing MR actuator for a secondary half car model of railway vehicle.
ii. To tune the controller to investigate the desired performance of controller for body displacement and body acceleration of semi-active system using Genetic Algorithm methods.

1.3 Problem Statements

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 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 stability 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 train 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.

1.4 Research Question

Can Stability augmentation controller effectively control a semi-active suspension system leading to passengers' comfort?

1.5 Theoretical Frame Work

This study is to design and tune a stability controller to control a semi-active suspension system using half car model with MR damper.

1.6 Scopes of Research

i. Modelling of semi-active suspension system using MR damper of a half car model within Matlab SIMULINK environment.
ii. Genetic algorithm is implemented to tune the controller parameters.

iii. Genetic algorithm to be implemented using Matlab and linked to SIMULINK.

1.7 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 railway vehicle model, passive, semi-active and active suspension system, MR damper, stability augmentation controller and evolutionary algorithm methods.

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 analyzed and its controller type were justified before used in simulation.

The study on a half-car railway vehicle suspension system has been divided into two main parts which are (1) mathematical modelling and (2) simulation of the controller system.

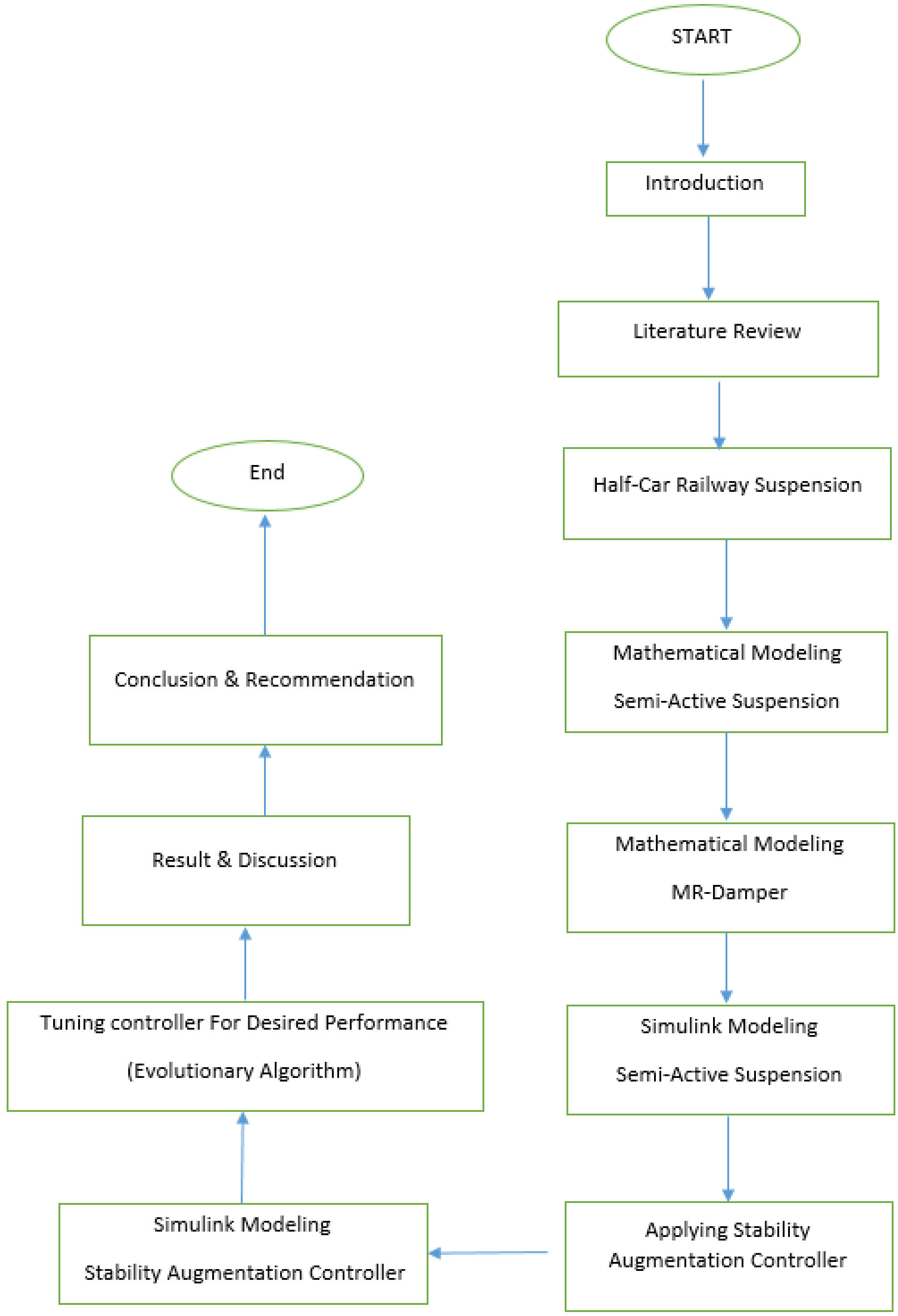

Figure 1.1 Flowchart of methodology

1.8 Thesis Outline

This thesis consists of six 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, stages, controllers, tuning methods for desired performance and review on published articles related to suspension control strategies are described.

Chapter 3 presents the modelling and validation of the half-car railway vehicle model. In this chapter, the mathematical equation of 3DOF half-car model is introduced. Other types of suspension systems will be described in detail. Then, the mathematical modeling of three different kinds of suspension system for half-car model and their SIMULINK model are presented in order to validate the simulation results. Two concepts of desired performance and their measurement methods will also be explained.

Chapter 4 describes the implementation of the proposed stability augmentation controller to achieve desired performance. In addition controller structure in SIMULINK and parameters are shown in SIMULINK. In this chapter, the fundamentals and algorithm of the proposed controller are explained.

Chapter 5 presents one real coded GA and explained in detail. After linking simulation model and GA code to tune the controller for the best performance is going to be done. In addition effects of GA parameters on the result will derived. At the end there is compresence part between two tuning method, sensitivity analysis and GA. Results for different inputs are presented and compared.

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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