COMPENSATOR SKYHOOK DAMPING CONTROL FOR RAILWAY VEHICLES

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DEDICATION

This thesis is dedicated to my father, who taught me that the best kind of knowledge to have is that which is learned for its own sake. It is also dedicated to my mother, who taught me that even the largest task can be accomplished if it is done one step at a time.

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ABSTRACT

The work in this thesis proposed a control method for active technology in trains using skyhook damping control algorithm. The main advantage of the method is the good improvement of passenger ride comfort on straight track such that it can be computed rapidly using a highly effective controller which show significant effect in compromising the tradeoff between ride quality vs track following. The skyhook damping proposed in this project is presented in quarter car model. Conventional skyhook damping uses high pass filter to achieve the tradeoff between ride quality and track following. Here lead-lag compensator that acted as filter is proposed. MATLAB simulations are carried out under some conditions to test the effectiveness of the proposed method, namely step response, rise time and percentage over shoot. The advantage of the proposed method over the conventional skyhook damping is expected to increase by a significant percent in the train speed and a relative percentage decrease in the steady state oscillations. It is predicted that the method can be very useful in the design of a practical high performance, low cost controller of active suspension railway system.

ABSTRAK

Kerja di dalam tesis ini mencadangkan kaedah kawalan bagi teknologi aktif menggunakan penyerap Skyhook algoritma kawalan. Kelebihan kaedah ini adalah ia dapat memperbaiki keselesaan penumpang yang menaiki keretapi tersebut di trek yang rata di mana ia boleh di gunakan secara efektif. Pengawal yang mempunyai efektif yang tinggi menunjukkan kesan yang baik di dalam tolak ansur antara kualiti penumpang dan ikutan trek. Penyerap skyhook yang dicadangkan didalam tesis ini dilakukan didalam model suku kenderaan. Penyerap Skyhook konvensional menggunakan Penapis Lalu Tinggi (HPF) untuk mendapatkan pertukaran antara keselesaan penumpang dan ikutan trek. Di sini, pemampan lead-lag(depan-belakang) yang berguna sebagai penapis telah dicadangkan. Simulasi Matlab dijalankan untuk mengkaji kebaikan kaedah yang dicadangkan iaitu respon unit langkah, masa naikan dan peratusan overshoot(terlebih tembakan). Kaedah ini dijangka dapat meningkatkan kadar efektif dan mengurangkan hayunan. Ia juga dijangka meningkatkan prestasi menggunakan kawalan yang murah untuk teknologi aktif bagi sistem keretapi.

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LIST OF ABBREVIATIONS

LQG	-	Linear Quadratic Gaussian
LQR	-	Linear Quadratic Regulator
MPC	-	Model Predictive Control
LMI	-	Linear Matrix Inequality
GA	-	Genetic Algorithms
MIMO	-	Multi-Input-Multi-Output
UTM	-	Universiti Teknologi Malaysia
Z-N	-	Ziegler–Nichols
C-C	-	Cohen–Coon
IMC	-	Internal Model Control
G-P	-	Gain-Phase Margin
P	-	Proportional controller
PI	-	Proportional Integral controller
PD	-	Proportional Derivative controller
PID	-	Proportional Integral Derivative controller

LIST OF SYMBOLS

dB	-	decibel
km	-	Kilometre
km/h	-	Kilometre per hour
ω	-	Angular velocity
u	-	Control input
x	-	State Vector
$\dot{x}$	-	Derivative Of The State Vector With Respect To Time
y	-	Output Vector
u	-	Input Or Control Vector
A	-	System Matrix
B	-	Input Matrix
C	-	Output Matrix
D	-	Feedforward Matrix
c_{pz}	-	Primary Damping
c_{rz}	-	Secondary Damping
k_{az}	-	Air Spring Change Of Area Stiffness
k_{pz}	-	Primary Spring Stiffness
k_{rz}	-	Secondary Reservoir Stiffness
k_{sz}	-	Air Spring Volume Stiffness
m_b	-	Vehicle Body Mass
m_t	-	Bogie Mass
m_{mp}	-	Mass Of Air Spring Mid-Point
z_b	-	Vertical Displacement For Bogie
z_{mp}	-	Vertical Displacement For Air Spring Mid-Point Mass
z_t	-	Random Track Input Displacement
z_v	-	Vertical Displacement For Vehicle Body
$\dot{Z}_v$	-	Vertical Velocity For Vehicle Body
$\ddot{Z}_v$	-	Vertical Acceleration Of Vehicle Body
$\dot{Z}_b$	-	Vertical Velocity For Bogie

f_{act}	-	Active Force Input
$\dot{z}_t$	-	Random Track Input Velocity
C_{sky}	-	Gain Of The Skyhook Damping
K_p	-	Proportional controller gain
K_i	-	Integral controller gain
K_d	-	Derivative controller gain
k_{dc}	-	DC gain
ζ	-	Damping ratio
ω_n	-	Natural frequency
ω_d	-	Damped natural frequency
M_p	-	Percent overshoot
π	-	Phi
S_p	-	Poles/Zeros location
Hz	-	Hertz

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CHAPTER 1

INTRODUCTION

1.1 Problem Background

The idea of active technology in rail automobiles has been analyzed theoretically and experimentally since the 1970s, but it has not yet finalized a convincing advance in practical application, as has been found, for instance, in the aircraft and automotive industries. The potential explanation for the failure to succeed in introducing and retaining active technology in rail automobiles is that it is costly. In relation to the passive solution, the active suspension system must prove to be at least as dependable and harmless. If, however, a definition can be identified that simultaneously handles good performance and reasonable costs, there is tremendous potential for future implementation. Active technology for railway automobiles extends the possibilities of enhancing the dynamic efficiency of the railway vehicle in comparison with the traditional passive approach. Of course, improvements in riding comfort, speed conduct and twisting capacity have a positive effect on the dynamic performance of the vehicle, which can, in turn, allow a greater vehicle speeds.

Active technology in rail automobiles may be used to accomplish one or many of the following objectives below.

a) Improved passenger trip easiness,

b) Maintaining good ride ease even if the vehicle's speed is improved,

c) Maintain good ride ease even though track conditions are poorer,

d) Cut wheel and rail wear to minimum with the aid of improved curve negotiation,

e) Maintain running constancy at very high vehicle speed.

For some scores of years now, active suspensions for railway automobiles have been under concern[1],While their applications are very limited in the operation of services[2]. However, it appears clear that they will realize widespread acceptance in due course, and on-going research investigations are very suitable for this purpose. Control may be useful either to enhance the secondary suspension performance (carbody to bogie), generally to improve the consistency of the ride, or to the primary suspension (bogie to wheelsets), and can operate in either direction in general (horizontal, vertical, roll, etc.)[3].

In an effort to show significant effect in compromising, the trade-off between ride quality vs track following, skyhook damping control concept is adopted. The skyhook damping proposed in this project is in a quarter-car model.

1.2 Problem Statement

Skyhook damping technique provides a deep improvement to the ride quality for straight track operation, but generates huge suspension deflections in reaction to long wavelength, deterministic characteristics such as curves and slopes, a feature that is not usually a major design issue for passive suspensions using conventional dampers.

Conventional skyhook damping uses high pass filter to achieve the balance between ride quality and track following. Here lead-lag compensator that acted as filter is proposed.

1.3 Research Objectives

The objectives of the research are:

(a) To design a PID controller and a filter for conventional skyhook damping;

(b) To design a lead lag compensator as filter for conventional skyhook damping;

(c) To analyze the various characteristics of the obtained mathematical model and the designed controller.

1.4 Scope of the study

This study is limited to solutions for active secondary suspensions, for which the concept of absolute or Skyhook damping is well known. A quarter-car model, which represents the active secondary suspension setup in railway vehicles, is used in this study.

1.5 Organization of the report

The chapters of this thesis are organized as follows. The first chapter addresses the background, problem statements, research objective, and scope of the study. The theory and literature review of this project will further be explored in chapter two. It also discusses some controllers that are used in active suspension technology. The methodology in designing the controller by the use of MATLAB software in order to simulate the available data are discussed in chapter three while chapter four discusses the results obtained. Finally, chapter five provides a conclusion of the accomplished tasks so far and the future work.

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