PD-STABILITY AUGMENTATION SYSTEM (PD-SAS) CONTROLLER FOR 3-DOF RAILWAY VEHICLE SUSPENSION MODEL

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DECLARATION

I declare that this project report entitled “PD-Stability Augmentation System (PD-SAS) controller for 3-DOF railway vehicle suspension model” is the result of my own work except as cited in the references

Signature :

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Date : 26.06.2019

APPROVAL

I hereby declare that I have read this project report and in my opinion this report is sifficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering.

Signature :

Name : MR.MOHD HANIF BIN HARUN

Date : 26.06.2019

DEDICATION

To my beloved mother and father

ABSTRACT

Nowadays, the railway vehicle system are widely use and with the rapid development of railway use, vibration control to maintain stability, safety and improvement the level of passenger discomfort become the crucial part of research. This study focus on the semi-active suspension system and the 3 Degree of freedom (DOF) are developed using Newton second law which consist of two vertical dampers and springs, and a set of lateral spring and damper in lateral direction. The stability augmentation system (SAS) and PD-SAS are introduced in this study in order to reduce the unwanted motion. The response of the vehicle performance are investigated under step and sinusoidal track irregularity. The response of semi-active system are compared with passive system. Matlab Simulink software has been used in order to investigate and analyse the performance of the railway vehicle model. The simulation results of the study clearly show that the semi-active system are able to improve the performance of the vehicle compared with the passive system .

ABSTRAK

Pada masa kini, sistem kenderaan keretapi digunakan secara meluas dan dengan perkembangan pesat penggunaan kereta api, kawalan getaran untuk mengekalkan kestabilan, keselamatan dan peningkatan tahap ketidakselesaan penumpang menjadi bahagian penting di dalam penyelidikan. Kajian ini menumpukan pada sistem penggantungan separa aktif dan 3 darjah kebebasan (DOF) yang diwujudkan menggunakan undang-undang kedua Newton yang terdiri daripada dua peredam menegak dan mata air, dan satu set spring sisi dan peredam pada arah sisi. Sistem pembesaran kestabilan (SAS) dan PD-SAS diperkenalkan dalam kajian ini untuk mengurangkan pergerakan yang tidak diingini. Tanggapan prestasi kenderaan dikaji menggunakan step dan sinusoidal input. Tindak balas sistem separuh aktif dibandingkan dengan sistem pasif. Perisian Matlab Simulink telah digunakan untuk menyiasat dan menganalisis prestasi model kereta api . Hasil simulasi kajian jelas menunjukkan bahawa sistem separa aktif mampu meningkatkan prestasi kenderaan berbanding dengan sistem pasif.

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DOF	Degree of freedom
MATLAB	Matrix laboratory
UTeM	Universiti Teknikal Malaysia Melaka
PID	Proportional, Integral and Derivative
PD	Proportional and Derivative
GUI	Graphical user interface
SAS	Stability Augmentation System

LIST OF SYMBOL

M_c	-	Mass of car body
M_b	-	Mass of bogie
k_1	-	Secondary lateral spring stiffness
k_2	-	Secondary vertical spring stiffness
k_r	-	Stiffness of bogie disturbance
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
θ	-	Roll angle of vehicle body
I_r	-	Roll axis moment of inertia
$\ddot{\Theta}_c$	-	Roll acceleration of vehicle body
$\ddot{y}_b$	-	Lateral acceleration of vehicle bogie
$\ddot{y}_c$	-	Lateral acceleration of vehicle body
y_c	-	Lateral displacement of vehicle body
y_b	-	Lateral displacement of vehicle bogie
F_d	-	Lateral MR damper
m	-	Meter
rad/sec	-	Radian per second

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CHAPTER 1

INTRODUCTION

1.0 Background

Nowadays, most of the people in the country prefer to choose the train especially to those who having a traffic problems in the cities and want to save on the cost of using the car. High-speed trains are environmentally friendly and they are safe to use. With the rapid development of railway use, vibration control to maintain stability, safety and improvement the level of passenger discomfort become an important part of research. Therefore, the suspension system plays an important role because of it can reduce the unwanted motion from a train on irregular tracks and also can improve passenger comfort during travel.

This research will study on the semi-active suspension system of the railway vehicle system in order to improve the stability of the railway vehicle, so that travelling could become more comfortable, provide a great rating of ride quality and avoid discomfort from passengers. Active and semi-active suspension systems is the most conventional suspension systems used to train trains have limitations in improving travel comfort and this system continually supply and modulate the flow of energy. In the previous study was carried out using passive suspension systems such as jingles, wheels, steel springs, rubber bushings and another mechanism. It is known as a passive system because they does not need the power source and can only store or dissipate energy.

Previously, use of active control technology in the railway industry as main suspension of railway train has becomes an attraction. Different solutions have been

studied over the years in different countries for specific issues resolution. This research concerns about the semi-active control applied on a suspension system of the railway vehicle using Stability Augmentation System (SAS) and PD-Stability Augmentation System (PD-SAS) control theory which can increase the performance of the vehicle and control the stability of the railway vehicle in order to improve the ride quality. The suspension system can be classified into two types which is Primary and Secondary Suspension system. Primary suspension is in between Axle Box and Bogie consisting of Spring and dampers while the Secondary Suspension system is in between Bogie and train body either through a bolster or bolster-less. Both suspensions system are placed in the three direction which is vertical, lateral and longitudinal directions.

This study is limited to lateral and roll analysis with its possible degree of freedom. In order to increase the stability to the high level of the train, the controller will be set up on the suspension system . SAS and PD-SAS controller are introduced. Train consists of vehicle body and two bogie frames and each bogie has two solid axle wheels. Wheel sets are connected to the frame bogie through the springs and dampers in longitudinal and side directions. To determine the mathematical equation, two vertical dampers and springs, and a set of lateral spring and damper in lateral direction. Therefore, the system has 3 degree of freedom (DOF). The mathematical model has been constructed by deriving the equations of motion of a rail vehicle frame bogie and wheelset. The control strategies were implemented in MATLAB/Simulink to investigate the performance of the railway vehicle system.

1.1 Problem statement

The use of trains is widely used worldwide as it has many advantages. Therefore, the use of train becomes the user's primary option to arrive at the destination. The suspension system is a very important component in the railway and has an influence on the stability of the vehicle's operation and safety. The stability of the trains is a problem that needs to be focus in order to increase the performance of the vehicle and make transport efficient. Vibration of the carbody in railway system mainly caused by track irregularity. This vibration need to be reduce or minimise in order to improve the ride comfort. It is impossible to change the new track because it require a high cost. Therefore, the controlable suspension system are introduce located at the secondary suspension system due to the abality of the system to reduce the unwanted motion.

1.2 Objectives

The objectives of this project are:

i. To analyse a 3-DOF half-car railway vehicle suspension system.
ii. To compare analytically two types of control strategies applied on secondary lateral suspension system.

1.3 Scope of project

There are two type of suspension system which is primary and secondary suspension system. This study only focus on secondary lateral suspension system. The half-car railway vehicle suspension parameters are selected to represent the parameters of railway vehicle suspension model.

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

In this chapter, the purpose of literature review is to increase the understanding about the project that need to be done. This chapter also provide the method used based on the previous study which has been done by researchers or engineer. The literature review is very important on this study in order to make sure that the method proposed can be used to implement the project. This chapter discusses the related research into suspension system for railway vehicles. Background research has been done for vehicle suspension system especially for railway and automotive vehicles. Undoubtedly, over the years until now, there are many automotive engineers still working on the development of the railway vehicle system with the aim of providing better ride comfort. Higher speeds usually generate increased forces and accelerations on the vehicle, which has a negative impact on ride comfort. Therefore, most of the previous study on the suspension system and vehicle stability has been stimulated in order to increase the efficiency of the train. Suspension system and control strategies are chosen to be deeply investigated.

2.1 History

Train vehicles transport consisting of a series of connected vehicles that generally running on rails also known as tracks to transport cargo or passengers. Basically train tracks consist of two running track. The profile irregularity of a railway line and their interaction with wheel is the major vibration sources for railway vehicle system -8io]kjm. This vibrations are arrested by suspension arrangement. Research on railway vibrations

was conducted by many researchers around the world over the years but this research is still an interesting field of science to be study. Suspension system was introduced very early in the development of railways that the interface between railway vehicle body and wheel needed some suspension system to reduce the vibration felt as the train moved along the track.

2.2 Suspension system in railway vehicle

Suspension system was recognised very early in the development of railways that the interface between vehicle body and wheel needed some sort of cushion system to reduce the vibration felt as the train moved along the line. Suspension system work to absorb road shock from the track in vertically or laterally and also avoid train to bounce at high speed which can lead to derailing. The purpose of suspension system is to improve the ride comfort, road handling and stability of vehicles. Spring are used to store the energy and slow down the acceleration while vehicle is moving and absorb shock energy from the track and convert it into potential energy of spring. There are three level of suspension system involve in railway vehicle which is primary, secondary, and tilting suspension system but freight wagons usually have just one suspension level which is primary suspension system (Qazizadeh, 2017).

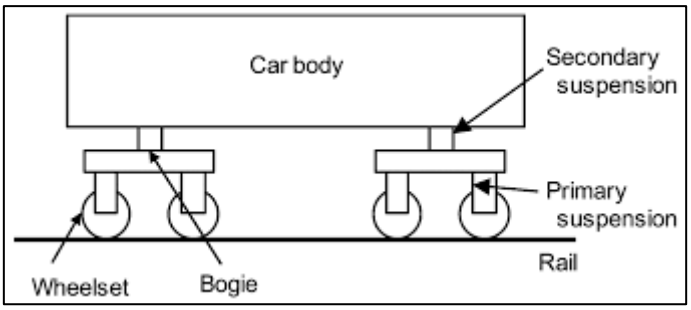

Figure 2.1 : Configuration of railway vehicle (Osamu Kondo and Yousuke Yamazaki, 2013).

2.2.1 Primary suspension system

The primary suspension is the rubber spring or coil and damper components placed between the bogie and the wheel set to supports the structural suspension of the carriage and entire train. Bogie are attached through bearing to support the railway vehicle body, improve ride quality by absorbing vibration and to reduce the generation of track irregularities. The primary suspension system has a beneficial effect on the stability limits of the bogie. The main function of primary suspension in railway vehicle is to reduce wheel-rail forces; provide acceptable curving; maintain wheelset stability; and also reduce wheel unloading on twisted tracks for preventing derailment. Railway vehicle need two suspension levels because without secondary suspension between bogie and carbody, the vibration level on the carbody would be very high for passengers so that primary suspension deals with wheel rail forces and stability issues while the secondary suspension improves the quality of ride comfort (Qazizadeh, 2017). Vibrations transmitted to the vehicle body can be reduce by focusing on reduction vibration at bogie. Vibration can be reduce with the increasing of primary damping coefficient so that the smaller amount of vibration is transmitted to the vehicle body.

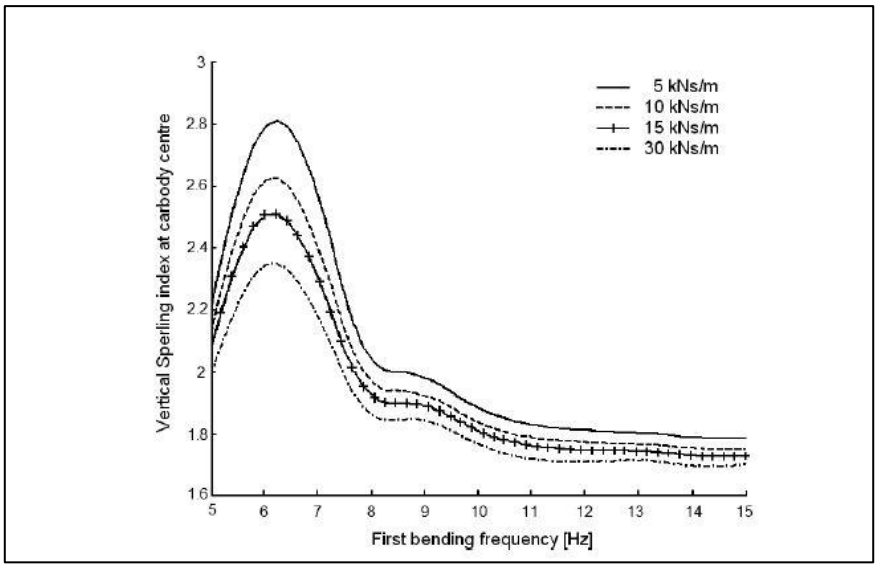

Figure 2.2 : Different primary damping coefficients (Zhou, Goodall et al., 2009).

2.2.2 Secondary suspension system

Secondary suspension system is the air-springs and viscous dampers interconnects the car body and bogie (Anneli orvanas, 2017). Secondary suspension system consist of air spring and vertical dampers placed between the vehicle body and usually two hydraulic dampers connected to each bogie to reduce the low-frequency vehicle vibrations (Anneli orvanas, 2017). Air spring can reduce the transmission of vibrations and also maintain the railway body at consistent height. The stiffness of the air spring is based on the amount of air in the bag. The secondary suspension is often also equipped with one anti-roll bar per bogie but sometimes known as stabiliser with the purpose of reducing the carbody roll. This anti-roll bar is normally transversely mounted on the bogie with vertical links connected to the carbody and can be regarded as a torsional springs. Emergency spring or bump stops is also one of the crucial element in the secondary suspension system that limit the relative vertical displacement between carbody and bogies. The bump stop is a rubber component with significant stiffness to give negative impact on ride comfort when the bump stops contact was occurs.