ACTIVE SUSPENSION SYSTEM USING STABILITY AUGMENTATION SYSTEM FOR PASSENGER VEHICLE

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DECLARATION

I declare that this project report entitled "Active Suspension using Stability Augmentation System for Passenger Vehicle" is the result of my own work except as cited in the references.

Signature : ....

Name : ....

Date : ....

APPROVAL

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

Signature : ....

Name of Supervisor: MOHD HANIF HARUN

Date : 16/6/2017

DEDICATION

I dedicate this report to my loving parent, Mr Azmi Bin Mohd Yusop and Mrs Norhajira Binti Khalid support me to write this report and do the simulations. My deepest respect and thanks go to my family for all they have done for me in which I will never forget. Their patience and encouragement have been invaluable. I am deeply indebted to them. After this, I promise to be a good son. This is only the beginning of our family future success and prosperous. Not to forget, special thanks to brothers and sisters for giving me a real support, pray, and support me in ups and downs. Special thanks also to Prof. Madya Dr Azma Putra and JKPSM because have been guide us along we do final year project from the beginning until the end of study. Special thanks also to all lecturer that have been share their knowledge to us while us doing final year project. Thanks also to our supervisor that have guide us along we do final year project and share his experience with us. Thanks also to my group that under our supervisor have been help me and guide me. Thanks also to people that help me along this final year project officially or unofficially.

ABSTRACT

This study presents the use of active suspension system using stability augmentation system in reducing the effects of road surface to the vehicle ride comfort. A control oriented half vehicle simulation model was developed in Matlab and verify with CARSIM 8 software simulation. The vehicle model with active suspension and stability augmentation have been developed in Matlab/Simulink. An investigation of a suitable active control algorithm that can improved vehicle ride comfort was proposed in reducing unwanted vertical motion of passenger vehicle when passing a step or bump. The proposed algorithm known as stability augmentation system (SAS) that is able to reduce the effect of road disturbance, maintains load-levelling and load distribution during vehicle maneuvers in an ideal case for control algorithm parameters tuning is presented. Active suspension based on desired force from the controller and relative velocity between sprung mass and unsprung mass of the vehicle model and shown to be able to consistently provide the actual force to reduce the vibration of the vehicle body. The vehicle is tested at different speeds of 40km/h and 100km/h. Comparison of the simulation results demonstrates the improvement of the vehicle ride comfort.

ABSTRAK

Kajian ini membentangkan akan penggunaan sistem suspensi aktif dengan menggunakan sistem pembesaran kestabilan bagi mengurangkan kesan permukaan jalan terhadap keselesaan pemanduaan kenderaan. Simulasi model separuh kenderaan berorientasikan kawalan telah dicipta dan bagi mengesahkan dengan simulasi perisian CARSIM 8. Model kenderaan dengan penggantungan aktif dan kestabilan pembesaran telah dibangunkan dengan menggunakan Matlab/Simulink. Penyiasatan algoritma kawalan aktif sesuai kerana boleh meningkatkan keselesaan pemanduan kenderaan telah dicadangkan dalam mengurangkan pergerakan menegak yang tidak diingini kenderaan penumpang apabila melalui permukaan bertangga atau beralun. Algoritma yang dicadangkan adalah sistem pembesaran kestabilan yang mampu mengurangkan kesan gangguan permukaan jalan, mengekalkan badan kenderaan stabil dan pengagihan semasa pergerakan kenderaan berdasrkan permukaan jalan mengikut parameter kawalan algoritma telah di bentangkan. Suspensi aktif akan menghasilkan daya mengikut kuasa yang dikehendaki dari sistem kawalan dan halaju relatif antara badan kenderaan dan sistem suspensi dan terbukti mampu untuk mengurangkan getaran badan kenderaan. Kenderaan itu juga akan di uji pada kelajuan yang berbeza pada kelajuan 40km/j dan 100km/j. Perbandingan hasil keputusan simulasi menunjukkan peningkatan keselesaan pemanduan kenderaan.

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TABLE OF CONTENT

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

MR	Magnetorheological
ER	Electrorheological
PID	Proportional-Integral-Derivative
PI	Proportional Integral
PD	Proportional Derivative
LPV	Linear Parameter-Varying
FEBC	Frequency Estimation-Based Controller
SAS	Stability Augmentation System
DOF	Degree of Freedom

LIST OF SYMBOLS

m	-	Mass
k	-	Spring stiffness
c	-	Damping coefficient
l	-	Length
z	-	Displacement
$\dot{z}$	-	First derivative of z
$\ddot{z}$	-	Second derivative of z
M_b	-	Mass of vehicle body
M_{wr}	-	Mass of wheel rear
M_{wf}	-	Mass of wheel front
K_{sf}	-	Front suspension spring stiffness
K_{sr}	-	Rear suspension spring stiffness
K_{tf}	-	Tire spring stiffness front
K_{tr}	-	Tire spring stiffness rear
C_{sf}	-	Front suspension damping coefficient
C_{sr}	-	Rear suspension damping coefficient
I_θ	-	Pitch moment of inertia
l_f	-	Length of front vehicle from center gravity of the vehicle body
l_r	-	Length of rear vehicle from center gravity of the vehicle body

CHAPTER 1

INTRODUCTION

1.1 Background

Suspension system is an important part to support sprung mass and stabilize vehicle body from moving upward and downward, from uneven road surface. Spring will absorb unwanted forces from the road and reduce jolting, meanwhile damper prevent bouncing upward and downward of the vehicle. That is fundamental operation for passive suspension. Nowadays, there are three types of suspension system were built by the automotive industry. Which are passive, semi-active and active suspension systems. The producing of semi-active and active suspension is to improve the function of passive suspension and driving comfort on the uneven terrain. Besides that, passive suspension cannot control the spring stiffness and damper coefficient, in order to decrease the displacement of sprung mass vibration (Chen, et al., 2014).

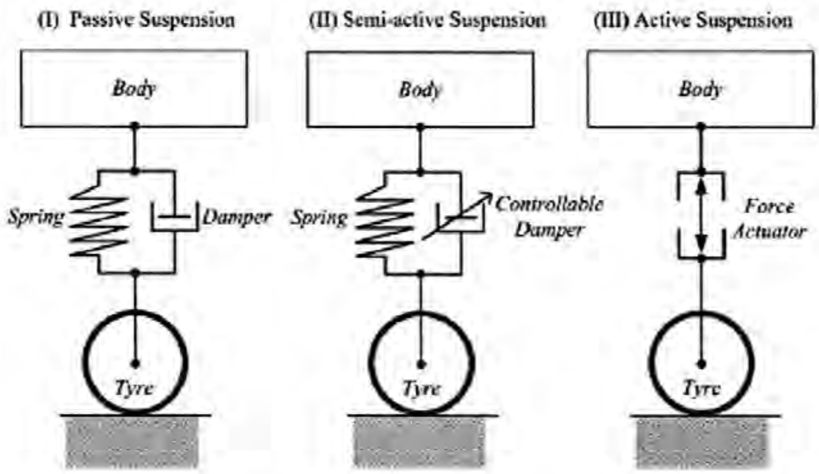

Figure 1.1 Type of suspension system (Chen, et al., 2012)

Passive suspension has a limitation to reduce the motion of the car, only certain ground surface. For example if the vehicle with passive suspension is driving on the bump surface continuously, the vibration of vehicle will not reduce and it will bounce until the tire with flat surface. By this phenomena of continuously bouncing, driver and passengers comfort and also ride quality of the vehicle body will be worse. Other than that, passive suspension cannot stabilize the vehicle body during the cornering. For an example, if the vehicle make cornering to the left, the suspension on the left side car will be moving downward. Passive suspension does not have control system to push the left side of the car moving upward, if the suspension system on the left and the right side are in the same position as the result stability of the car body during cornering will be improve.

The effect of the suspension system can be analyse by using simulation, experimental or both. In this project the effect of suspension system, to the ride comfort of the vehicle will be analyse using Matlab/Simulink. The parameter of sedan car has been taken as a model for the simulation. The simulation will be analyse on two type of suspension, one with passive suspension and the other is active suspension with stability augmentation controller. This project will use equation of motion for 4 degree of freedom half car pitch plane for sedan car with passive suspension. The advantage of magnetorheological damper can control the movement suspension by control damping coefficient according to the vertical force of the ground to the vehicle (Naik and Singru, 2009). The other benefit of semi-active suspension, it use less current to control the suspension distance in order to decrease vehicle motion from bounce upward and downward. Moreover, semi-active can be work as passive suspension if the control cannot be use or not function (Luo, et. al., 2010), the vehicle motion still can be reduce.

1.2 Problem Statement

Vibration from the vehicle body could make driver and passengers feel not comfort and loose stability of the vehicle body. If the vehicle stability does not control, while vehicle want to make cornering it will increase vehicle body roll. If the roll of the vehicle body increase, the probability to accident is high. Ground terrain also will affect the vehicle stability, because passive suspension only can absorb the vibration at certain ground surface, depend on the passive suspension parameter. If the vehicle move on the long bump surface, the vehicle body will be continue bounce and will stop until the wheel move on the flat road surface. Passive suspension cannot control the damper coefficient and/or spring stiffness to absorb vibration, this will effect the vehicle body motion(Campos, et al., 1999). Passive suspension does not have sense that can detect the vehicle motion in order to produce force to stabilize the motion.

Suspension system with stiff and harsh will affect the passenger comfort, while suspension system softer it will affect the road handling of the vehicle. This problem can be solve by using active suspension system, it can control the movement of the suspension. This system can reduce the vehicle body vibration and improve road handling. However, active suspension require high current to operate the system in order to stabilize vehicle body motion. It also use high cost for the maintenance, because the active suspension is fully control system.

If the system controller for the active suspension failure, the suspension work will be unstable (Luo et al., 2010). This is study is to improve ride comfort of vehicle during bouncing by using active suspension. Besides that, control strategies of active suspension with stability augmentation system controller will be developed to reduce the vibration of the vehicle body.

1.3 Objective

The objectives of this project are as follows:

i. To improve ride comfort of vehicle.

ii. To develop a control strategy for active suspension with stability augmentation system.

1.4 Scope of Project

The scopes of this project are:

i. The vehicle parameter of D-class sedan car half car model is selected.

ii. This study only focus on ride analysis of the car model.

1.5 Summary

Passive suspension cannot be adjusted or controlled the movement of the suspension to stabilize the vehicle body motion. Active suspension system with stability augmentation system have been used in this project to study the effect of the stability control on the suspension system. Since, active suspension system can control the vehicle body movement upward and downward or reduce the vehicle body displacement. So, the vibration of the vehicle motion can be reduce, as it can produce force to control vehicle body stability.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter presents, the advantage of active suspension, vehicle stability test simulation, type of semi-active damper, and followed suspension controller in active suspension technology. An overview of current works and research among the researchers is also presented.

2.2 Vehicle Suspension System

Suspension have been use in the vehicle system, to support the weight of the vehicle and also reduce vibration in the vehicle body. Suspension can be divide into two type, dependent and independent suspension system. Dependent suspension usually use in commercial vehicle, for example lorry and bus. Dependent suspension is common use in commercial vehicle because it can support high weight or load. The example of dependent suspension is leaf spring, the combination of flat plate can support large area and weight of vehicle load. The disadvantage of dependent, it will affect the other side tire if the tire rolling on the bump road surface. The advantage of independent suspension, the other tire will not bounce if the tire on the other driving drive on the bump surface. The main of the suspension system are spring, shock absorber, strut and tire of the vehicle. Besides that, there type of suspension system, that use in the vehicle suspension. The suspension system are passive, semi-active and active suspension system.

2.2.1 Passive Suspension System

Passive suspension are common use in the vehicle suspension system, because of simple and low cost of production than semi-active and active suspension system. However, passive suspension can control the movement of the suspension system according to the ground terrain (Chen, et al., 2014). Vehicle passive suspension with low hard suspension will reduce the vehicle passenger comfort. Besides that, if the vehicle use soft suspension it will give ride comfort but poor road handling (Ikenaga, et al, 2000). Passive suspension is the suspension that did not have any controller that can adjust the movement of the spring and shock absorber.

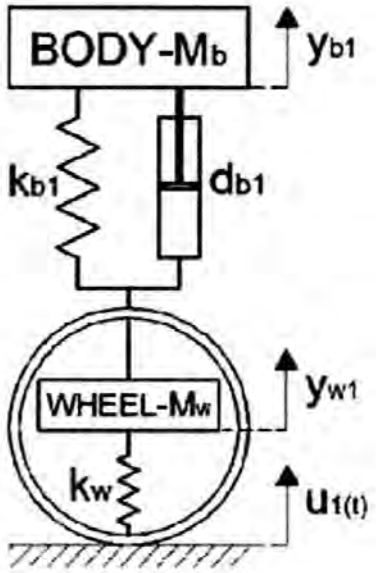

Figure 2.1 Schematic diagram for passive suspension (Paulides J. J. H. and Lomonova E. A., 2006)

2.2.2 Semi-active Suspension System

Suspension provide good handling and braking for safety driving and also reduce bump and vibration from the ground terrain. Semi-active suspension provide better vehicle stability than active and passive suspension. Semi-active suspension can act as passive suspension if the controller not function. But, active damper would be unstable if the controller cannot be use (Luo, et al., 2010). Besides that, (Chen, et al., 2014) wrote that semi-active can provide suspension control of spring stiffness and damping coefficient. Other than that, semi-active suspension time to react with the vehicle body vibration is less than 100 milliseconds. Semi-active suspension can provide harder and softer damping limit according to the ground terrain (Qazi, et al, 2013).

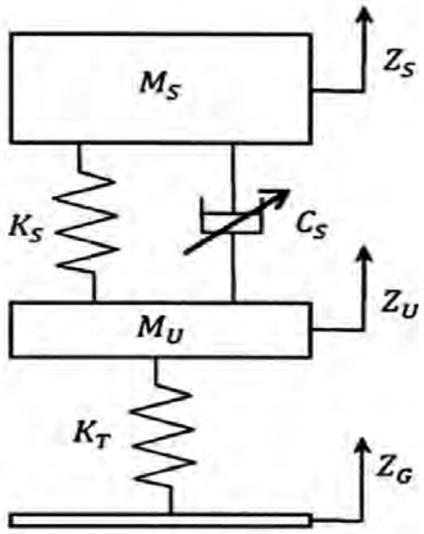

Figure 2.2 Schematic diagram for semi-active suspension (Raj A. and Rajamohan V., 2016)

2.2.3 Active Suspension System

Active suspension function is to isolate the vehicle body from wheel vibration by the ground terrain. Besides that, fully active suspension system are control by electronic system to control the vehicle body condition. Then, the vibration from the ground terrain will be directly control motion by electronic device of active suspension system. The suspension system is good to isolate the vehicle body motion. However, the installation and maintenance of the active suspension are quite expensive (Turnip, et al., 2008). Other than that, if the electronic control system in the suspension does not work, the active suspension will be unstable because of electronic system cannot control the movement of the suspension (Luo, et al., 2010).