DEVELOPMENT OF ACTIVE SUSPENSION FOR PASSENGER CAR

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

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This report is submitted in partial fulfillment of the requirements for the award of a Bachelor of Mechanical Engineering (Automotive)

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DECLARATION

“I hereby declare that the work in this report is my own except for summaries and quotations which have been duly acknowledged”

Signature: ……………………………..
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Date: ……………………………..

Special thanks

My family

My FYP supervisor

My seminar panels

My course mate

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ABSTRAK

Dalam projek ini, suspensi aktif untuk kereta penumpang telah dibangankan dan disimulasikan dengan menggunakan perisian Matlab/SIMULINK untuk perningkatan pretasi pemanduan. Suspensi kenderaan adalah satu sistem yang mampu menyerap tenaga potensi daripada gangguan jalan dan menghapusnya melalui peredam. Untuk suspensi pasif, kekakuan pegas yang rendah akan membawa kepada yang baik dalam prestasi pemanduan kenderaan tetapi mengabaikan pengendalian kenderaan manakala kekakuan pegas yang tinggi adalah kurang baik dalam keselesaan pemanduan kenderaan tetapi meningkatkan pengendalian kenderaan. Oleh itu, terdapat kompromi antara prestasi pemanduan dan pengendalian. Dalam usaha untuk meningkatkan prestasi pemanduan, satu-satunya penyelesaian yang mungkin adalah menggunakan suspensi aktif di mana penggerak hidraulik dipasang selari dengan spring dan peredam dalam sistem suspensi kenderaan. Tujuan untuk projek ini adalah menghasilkan kenderaan model dalam perisian Matlab/SIMULINK dan menghasilkan beberapa jenis strategi kawalan dalam pembangunan suspensi aktif. Model kereta suku dan model kereta lengkap digunakan dalam pembangunan suspensi aktif dengan beberapa jenis strategi kawalan yang dicadangkan. Perisian Matlab/SIMULINK digunakan untuk membandingkan pretasi antara suspensi pasif dan aktif. Daripada seksyen keputusan, gerakan menegak, gerakan pitch, and gerakan roll badan kenderaan yang tidak diingini telah dikurangkan dan keseimbangan badan kenderaan telah ditambahkan. Sebagai kesimpulan, pengabaian bagi gerakan menegak, gerakan pitch, and gerakan roll badan kenderaan yang tidak diingini di mana menggunakan beberapa strategi kawalan yang dicadangkan di dalam suspensi system kenderaan telah meningkatkan keselesaan penumpang dan pemandu di dalam kereta.

ABSTRACT

In this project, the active suspension for passenger car was developed and simulated by using Matlab SIMULINK software for improvement of ride performance. Vehicle suspension is a system that capable to absorb the potential energy from road disturbance and dissipated it via damper. For passive suspension, the low spring stiffness will lead to good in ride performance but sacrifice the vehicle handling whereas high spring stiffness results in poor in ride comfort but improve the vehicle handling. Thus, there is compromise between ride and handling performance. In order to enhance the ride performance, the only possible solution is to adopt an active suspension whereby a hydraulic actuator is installed parallel with spring and damper in vehicle suspension system. The objectives of this project are to develop the vehicle model in Matlab/SIMULINK software and develop several control strategies for active suspension development. The quarter car and full vehicle ride model is adopted in development of active suspension with proposed types of control strategies. The Matlab/SIMULINK software is used to compare the performance between passive and active suspension. From the result section, the unwanted vehicle body heaves, pitch, and roll motion were reduced and the stability of vehicle body was increased. In conclusion, the rejections of unwanted vehicle body heave, pitch, and roll motion which is using proposed control strategies in vehicle suspension system was improved the comfortable of passengers and driver in vehicle.

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LIST OF SYMBOLS

A_p	=	Piston Area, m^2
C_{d1}	=	Discharge Coefficient
C_{d2}	=	Discharge Coefficient
C_s	=	Suspension Damper Constant, Ns/m
C_{sf}	=	Front Suspension Damper Constant, Ns/m
C_{sfl}	=	Front Left Corner Suspension Damper Constant, Ns/m
C_{sfr}	=	Front Right Corner Suspension Damper Constant, Ns/m
C_{sr}	=	Rear Suspension Damper Constant, Ns/m
C_{srl}	=	Rear Left Corner Suspension Damper Constant, Ns/m
C_{srr}	=	Rear Right Corner Suspension Damper Constant, Ns/m
C_{tm}	=	Leakage Coefficient
$\dot{F}_A$	=	Rate of Actuator Force, N/s
F_d	=	Damper Force, N
F_{df}	=	Front Damper Force, N
F_{dfl}	=	Front Left Corner Damper Force, N
F_{dfr}	=	Front Right Corner Damper Force, N
F_{dr}	=	Rear Damper Force, N
F_{drl}	=	Rear Left Corner Damper Force, N
F_{drr}	=	Rear Right Corner Damper Force, N
F_s	=	Spring Force, N

F_{sf}	=	Front Spring Force, N
F_{sfl}	=	Front Left Corner Spring Force, N
F_{sfr}	=	Front Right Corner Spring Force, N
F_{sr}	=	Rear Spring Force, N
F_{srl}	=	Rear Left Corner Spring Force, N
F_{srr}	=	Rear Right Corner Spring Force, N
F_z	=	Hydraulic Actuator Resultant Force, N
I_ϕ	=	Roll Axis Moment of Inertia, kgm^2
I_θ	=	Pitch Axis Moment of Inertia, kgm^2
K	=	Voltage to Position Conversion Factor, V/m
K_d	=	Derivative Gain of PID Controller
K_i	=	Integral Gain of PID Controller
K_p	=	Proportional Gain of PID Controller
K_s	=	Spring Stiffness, N/m
K_{sf}	=	Front Wheel Spring Stiffness, N/m
K_{sfl}	=	Front Left Corner Wheel Spring Stiffness, N/m
K_{sfr}	=	Front Right Corner Wheel Spring Stiffness, N/m
K_{sr}	=	Rear Wheel Spring Stiffness, N/m
K_{srl}	=	Rear Left Corner Wheel Spring Stiffness, N/m
K_{srr}	=	Rear Right Corner Wheel Spring Stiffness, N/m
K_t	=	Tire Stiffness, N/m
K_{tf}	=	Front Tire Stiffness, N/m
K_{tfl}	=	Front Left Corner Tire Stiffness, N/m
K_{tfr}	=	Front Right Corner Tire Stiffness, N/m
K_{tr}	=	Rear Tire Stiffness, N/m

K_{trl} = Rear Left Corner Tire Stiffness, N/m

K_{trr} = Rear Right Corner Tire Stiffness, N/m

L_f = Distance between Front Axle of Vehicle and Center of Gravity of Sprung mass, m

L_r = Distance between Rear Axle of Vehicle and Center of Gravity of Sprung mass, m

M_ϕ = Hydraulic Actuator Resultant Roll Torque, Nm

M_s = Sprung Mass, kg

M_θ = Hydraulic Actuator Resultant Pitch Torque, Nm

M_u = Wheel Mass, kg

M_{uf} = Front Wheel Mass, kg

M_{ufl} = Front Left Corner Wheel Mass, kg

M_{ufr} = Front Right Corner Wheel Mass, kg

M_{ur} = Rear Wheel Mass, kg

M_{url} = Rear Left Corner Wheel Mass, kg

M_{urr} = Rear Right Corner Wheel Mass, kg

P_s = Supply Pressure, Pa

P_L = Pressure Induced by Load, Pa

ϕ = Roll Angle, rad

$\dot{\phi}$ = Roll Rate, rad/s

$\ddot{\phi}$ = Roll Acceleration, rad/s^2

θ = Pitch Angle, rad

$\dot{\theta}$ = Pitch Rate, rad/s

$\ddot{\theta}$ = Pitch Acceleration, rad/s^2

u_1 = Spool Valve Position, m

u_2 = Bypass Valve Area, m

V = Input Voltage Command, V

w	=	Spool Valve Width, m
W	=	Track Width, m
Z_s	=	Vehicle Body Vertical Displacement, m
$\dot{Z}_s$	=	Vehicle body Vertical Velocity, m/s
$\ddot{Z}_s$	=	Vehicle Body Vertical Acceleration, m/s^2
Z_u	=	Wheel Vertical Displacement, m
$\dot{Z}_u$	=	Wheel Vertical Velocity, m/s
$\ddot{Z}_u$	=	Wheel Vertical Acceleration, m/s^2
Z_{sf}	=	Vehicle Body Front Vertical Displacement, m
$\dot{Z}_{sf}$	=	Vehicle Body Front Vertical Velocity, m/s
$\ddot{Z}_{sf}$	=	Vehicle Body Front Vertical Acceleration, m/s^2
Z_{sr}	=	Vehicle Body Rear Vertical Displacement, m
$\dot{Z}_{sr}$	=	Vehicle Body Rear Vertical Velocity, m/s
$\ddot{Z}_{sr}$	=	Vehicle Body Rear Vertical Acceleration, m/s^2
Z_{sfl}	=	Vehicle Body Front Left Corner Vertical Displacement, m
$\dot{Z}_{sfl}$	=	Vehicle Body Front Left Corner Vertical Velocity, m/s
$\ddot{Z}_{sfl}$	=	Vehicle Body Front Left Corner Acceleration, m/s^2
Z_{sfr}	=	Vehicle Body Front Right Corner Vertical Displacement, m
$\dot{Z}_{sfr}$	=	Vehicle Body Front Right Corner Vertical Velocity, m/s
$\ddot{Z}_{sfr}$	=	Vehicle Body Front Right Corner Vertical Acceleration, m/s^2
Z_{srl}	=	Vehicle Body Rear Left Corner Vertical Displacement, m
$\dot{Z}_{srl}$	=	Vehicle Body Rear Left Corner Vertical Velocity, m/s
$\ddot{Z}_{srl}$	=	Vehicle Body Rear Left Corner Vertical Acceleration, m/s^2
Z_{srr}	=	Vehicle Body Rear Right Corner Vertical Displacement, m
$\dot{Z}_{srr}$	=	Vehicle Body Rear Right Corner Vertical Velocity, m/s
$\ddot{Z}_{srr}$	=	Vehicle Body Rear Right Corner Vertical Acceleration, m/s^2

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LIST OF ABBREVIATIONS

AC	Alternative Current
AFC	Active Force Control
AMD	Active Mass Damper
CO	Carbon Monoxide
DOF	Degrees of Freedom
ECU	Electronic Control Unit
EGR	Exhaust Gas Recirculation
FBD	Free Body Diagram
HC	Hydrocarbon
PI	Proportional-Integral
PID	Proportional-Integral-Derivative
PMDC	Permanent Magnet Direct Current
FYP	Final Year Project

CHAPTER I

INTRODUCTION

1.1 OVERVIEW

Vehicle suspension system is a tool which is designed to provide safety and comfortable while driving. The disturbance usually occurred by three vertical movements during driving which are vertical displacement, vertical velocity, and vertical acceleration (Fenchea, 2008). In order to satisfy the comfortable of driver and passenger in vehicle, a suspension system should support the vehicle, provide directional control and provide effective isolation of passengers from road disturbances. A soft suspension is good in ride performance, whereas a stiff suspension is good in condition where insensitivity to apply loads.

Usually the type of suspension which is used for vehicle is passive suspension. It is store the potential energy from the road disturbances via a spring and dissipates it via damper. The stiffness of the spring and parameter of the damper are fixed for certain level of compromise between road holding, load carrying and comfort.

Meanwhile, an active suspension system able to store, dissipate, and introduce the potential energy from road disturbances to system. The stiffness of the spring may vary depending upon operating conditions by hydraulic actuator which installed to the suspension system. The Electronic Control Unit (ECU) controls the hydraulic actuator to give external force to the suspension system (Acker et al., 1991).

1.2 PROBLEM STATEMENTS

Passive suspension has limitations due to the fixed suspension parameters. Low spring stiffness leads to good ride performance but sacrifices the vehicle handling whereas high spring stiffness causes poor ride performance but provides better vehicle handling. Therefore, in automotive industry, there is compromise between ride and handling performance. To provide one of the possible solutions to this problem, a hydraulic actuated active suspension using active force control is proposed. The proposed active suspension will be able to enhance the ride performance of the passenger vehicle.

1.3 OBJECTIVES

The objectives of this project are as follow:

1. To develop quarter car and full car model
2. To develop several control strategies for active suspension in order to improve vehicle ride.

1.4 SCOPES

The scopes of this project are as follow:

1. Development of mathematical model and Matlab/SIMULINK of quarter car and full car to represent dynamic behavior of the vehicle in vertical direction.
2. Development of mathematical model and Matlab/SIMULINK of hydraulic actuator.
3. Development of PID, Fuzzy PID with AFC for enhancement of vehicle ride performance.