I/We* have read this thesis

and from my/our* opinion this thesis

is sufficient in aspects of scope and quality for awarding

Bachelor of Mechanical Engineering (Automotive)

Signature	: …………………….
Name of Supervisor	: Mohd Hanif bin Harun
Date	: 13 May 2010

**Line which is irrelevant* →

SIMULATION STUDY ON ACTIVE SEAT SUSPENSION FOR A PASSENGER CAR

MUHAMAD SUFFIAN EFFENDI BIN MD YUSUF

This report is presented as
a requirement for a degree undergraduate in
Bachelor of Mechanical Engineering (Automotive)

Faculty of Mechanical Engineering
Universiti Teknikal Malaysia Melaka

APRIL 2010

"I declare this report is on my own work except for summary and quotes that I have mentioned its sources"

Signature	:………………..
Name of Author	: Muhamad Suffian Effendi Md Yusuf
Date	: 20/05/2010

To my family

for

their love

ACKNOWLEDGEMENTS

Praise is to Allah S.W.T to Whom seek help and guidance and under His benevolence we exist and without his help this project could not have been accomplish.

I would like to take this opportunity to express my gratitude to my supervisor En. Mohd Hanif bin Harun his constant guidance and encouragement during the past fourteen weeks. He always appreciates whatever little progress I have achieved, and continuously gives me much inspiration by sharing his precious knowledge and experience. I shall always remember the fun we have had together.

Finally, but most importantly of all, my parents Tifah bte Masran and should receive my greatest appreciation for their enormous love. They always respect what I want to do and give me their full support. The support from my siblings is also highly appreciated.

Muhamad Suffian Effendi Md Yusuf

UTeM

April 2010

ABSTRACT

The goal of this project is to propose control mechanism of the active seat suspension for a passenger car in order to improve riding comfort of the vehicle. This analysis incriminates Newton Second Law Theory for vertical force, pitching moment and also rolling moment. For study for this model it only have ride model. This ride model after that will be tested by using software MATLAB Simulink for simulation test. For this model its only 10 DOF needed. The data after that will compare from active suspension and passive suspension between their performance and motion from the simulation and authentic with data from the true source.

ABSTRAK

Matlamat projek ini ialah untuk mencadangkan pemasangan mekanisma kawalan terhadap sistem gantungan aktif terhadap bangku kenderaan penumpang dengan tujuan untuk penambahbaikkan dalam pemanduan kenderaan. Analisa ini melibatkan teori Newton kedua terhadap daya menegak sistem gantungan dan juga tapak cagak momen terhadap kecuraman dan momen golekkan. Untuk mempelajari model ini hanya medel tunggangan diperlukan. Model tunggangan ini kemudian akan diuji menggunakan perisian komputer MATLAB Simulink untuk diuji di bawah keadaan yang hampir nyata dengan keadaan sebenar dan prestasinya disiasat. Dalam model ini 10 darjah kebebasan diperlukan. Data yang diperoleh daripada ujian dibandingkan perlaksanaan dan pergerakkannya dalam simulasi dan disahkan dengan data yang diperoleh daripada pelbagai sumber, antaranya daripada sumber ilmiah dan industri.

TABLE OF CONTENT

LIST OF TABLE

LIST OF FIGURE

LIST OF SYMBOLS

SYMBOL	TITLE	UNIT
rs	Seat Rolling Angle	*rad*
$\dot{r}s$	Seat Roll Rate At Body Centre Of Gravity	$rads^{-1}$
$\ddot{r}s$	Seat Roll Acceleration At Body Centre Of Gravity	$rads^{-2}$
rc	Vehicle Rolling Angle	*rad*
$\dot{r}c$	Vehicle Roll Rate At Body Centre Of Gravity	$rads^{-1}$
$\ddot{r}c$	Vehicle Roll Acceleration At Body Centre Of Gravity	$rads^{-2}$
ps	Seat Pitching Angle	*rad*
$\dot{p}s$	Seat Pitch Rate At Body Centre Of Gravity	$rads^{-1}$
$\ddot{p}s$	Seat Pitch Acceleration At Body Centre Of Gravity	$rads^{-2}$
pc	Vehicle Pitching Angle	*rad*
$\dot{p}c$	Vehicle Pitch Rate At Body Centre Of Gravity	$rads^{-1}$
$\ddot{p}c$	Vehicle Pitch Acceleration At Body Centre Of Gravity	$rads^{-2}$
C_{fl}	Vehicle Front Left Damper Coefficient	Nsm^{-1}
C_{fr}	Vehicle Front Right Damper Coefficient	Nsm^{-1}
C_{rl}	Vehicle Rear Left Damper Coefficient	Nsm^{-1}
C_{rr}	Vehicle Rear Right Damper Coefficient	Nsm^{-1}
Cs_{fl}	Seat Front Left Damper Coefficient	Nsm^{-1}
Cs_{fr}	Seat Front Right Damper Coefficient	Nsm^{-1}
Cs_{rl}	Seat Rear Left Damper Coefficient	Nsm^{-1}
Cs_{rr}	Seat Rear Right Damper Coefficient	Nsm^{-1}
Dfl	Disturbance Force At Front-Left Unsprung Mass	*N*
Dfr	Disturbance Force At Front-Right Unsprung Mass	*N*

Drl	Disturbance Force At Rear-Left Unsprung Mass	N
Drr	Disturbance Force At Rear-Right Unsprung Mass	N
F	Force	N
$Fdsfl$	Seat Front-Left Damper Force	N
$Fdsfr$	Seat Front-Right Damper Force	N
$Fdsrl$	Seat Rear-Left Damper Force	N
$Fdsrr$	Seat Rear-Right Damper Force	N
$Fdcfl$	Vehicle Front-Left Damper Force	N
$Fdcfr$	Vehicle Front-Right Damper Force	N
$Fdcrl$	Vehicle Rear-Left Damper Force	N
$Fdcrr$	Vehicle Rear-Right Damper Force	N
$Fssfl$	Seat Front-Left Spring Force	N
$Fssfr$	Seat Front-Right Spring Force	N
$Fssrl$	Seat Rear-Left Spring Force	N
$Fssrr$	Seat Rear-Right Spring Force	N
$Fscfl$	Vehicle Front-Left Spring Force	N
$Fscfr$	Vehicle Front-Right Spring Force	N
$Fscrl$	Vehicle Rear-Left Spring Force	N
$Fscrr$	Vehicle Rear-Right Spring Force	N
Fv	Vertical Force	N
I_{ps}	Seat Sprung Mass Pitch Inertia	kgm^{-2}
I_{rs}	Seat Sprung Mass Roll Inertia	kgm^{-2}
I_{pc}	Vehicle Sprung Mass Pitch Inertia	kgm^{-2}
I_{rc}	Vehicle Sprung Mass Roll Inertia	kgm^{-2}
K_{fl}	Vehicle Front-Left Spring Coefficient	Nm^{-1}
K_{fr}	Vehicle Front-Right Spring Coefficient	Nm^{-1}
K_{rl}	Vehicle Rear-Left Spring Coefficient	Nm^{-1}
K_{rr}	Vehicle Rear-Right Spring Coefficient	Nm^{-1}
Ks_{fl}	Seat Front-Left Spring Coefficient	Nm^{-1}
Ks_{fr}	Seat Front-Right Spring Coefficient	Nm^{-1}
Ks_{rl}	Seat Rear-Left Spring Coefficient	Nm^{-1}
Ks_{rr}	Seat Rear-Right Spring Coefficient	Nm^{-1}
Kt_{fl}	Tire Front-Left Spring Coefficient	Nm^{-1}

Kt_{fr}	Tire Front-Right Spring Coefficient	Nm^{-1}
Kt_{rl}	Tire Rear-Left Spring Coefficient	Nm^{-1}
Kt_{rr}	Tire Rear-Right Spring Coefficient	Nm^{-1}
Kp	Proportional Gains Respectively	
Ki	Integral Gains Respectively	
Kd	Derivative Gains Respectively	
m_s	Seat Mass	kg
m_c	Vehicle Mass	kg
m_w	Wheel Mass	kg
Mp	Pitch Moment	Nm
Mr	Roll Moment	Nm
Ts	Seat Width	m
Tc	Vehicle Track Width	m
Wsd	Seat Body Length From CG to Front Mounting	m
Wsb	Seat Body Length From CG to Rear Mounting	m
Wcd	Seat Body Length From CG to Front Tire	m
Wcb	Seat Body Length From CG to Rear Tire	m
Zc	Sprung Mass Displacement At Vehicle Body CG	m
$\dot{Z}c$	Sprung Mass Velocity At Vehicle Body CG	ms^{-1}
$\ddot{Z}c$	Sprung Mass Acceleration At Vehicle Body CG	ms^{-1}
$Zcfl$	Front-Left Vehicle Displacement	m
$Zcfr$	Front-Right Vehicle Displacement	m
$Zcrl$	Rear-Left Vehicle Displacement	m
$Zcrr$	Rear-Right Vehicle Displacement	m
$\dot{Z}cfl$	Vehicle Velocity At Front-Left Corner	ms^{-1}
$\dot{Z}cfr$	Vehicle Velocity At Front-Right Corner	ms^{-1}
$\dot{Z}crl$	Vehicle Velocity At Rear-Left Corner	ms^{-1}
$\dot{Z}crr$	Vehicle Velocity At Rear-Right Corner	ms^{-1}
$\ddot{Z}cfl$	Vehicle Acceleration At Front-Left Corner	ms^{-2}
$\ddot{Z}cfr$	Vehicle Acceleration At Front-Right Corner	ms^{-2}
$\ddot{Z}crl$	Vehicle Acceleration At Rear-Left Corner	ms^{-2}
$\ddot{Z}crr$	Vehicle Acceleration At Rear-Right Corner	ms^{-2}
Zs	Sprung Mass Displacement At Seat Body CG	m

$\dot{Z}s$	Sprung Mass Velocity At Seat Body CG	ms^{-1}
$\ddot{Z}s$	Sprung Mass Acceleration At Seat Body CG	ms^{-1}
$Zsfl$	Front-Left Seat Displacement	m
$Zsfr$	Front-Right Seat Displacement	m
$Zsrl$	Rear-Left Seat Displacement	m
$Zsrr$	Rear-Right Seat Displacement	m
$\dot{Z}sfl$	Seat Velocity At Front-Left Corner	ms^{-1}
$\dot{Z}sfr$	Seat Velocity At Front-Right Corner	ms^{-1}
$\dot{Z}srl$	Seat Velocity At Rear-Left Corner	ms^{-1}
$\dot{Z}srr$	Seat Velocity At Rear-Right Corner	ms^{-1}
$\ddot{Z}sfl$	Seat Acceleration At Front-Left Corner	ms^{-2}
$\ddot{Z}sfr$	Seat Acceleration At Front-Right Corner	ms^{-2}
$\ddot{Z}srl$	Seat Acceleration At Rear-Left Corner	ms^{-2}
$\ddot{Z}srr$	Seat Acceleration At Rear-Right Corner	ms^{-2}
$Zmfl$	Sprung Mass Displacement At Front-Left Seat Mounting	m
$Zmfr$	Sprung Mass Displacement At Front-Right Seat Mounting	m
$Zmrl$	Sprung Mass Displacement At Rear-Left Seat Mounting	m
$Zmrr$	Sprung Mass Displacement At Rear-Right Seat Mounting	m
$\dot{Z}mfl$	Sprung Mass Velocity At Front-Left Seat Mounting	ms^{1}
$\dot{Z}mfr$	Sprung Mass Velocity At Front-Right Seat Mounting	ms^{1}
$\dot{Z}mrl$	Sprung Mass Velocity At Rear-Left Seat Mounting	ms^{1}
$\dot{Z}mrr$	Sprung Mass Velocity At Rear-Right Seat Mounting	ms^{1}
$\ddot{Z}mfl$	Sprung Mass Acceleration At Front-Left Seat Mounting	ms^{-2}
$\ddot{Z}mfr$	Sprung Mass Acceleration At Front-Right Seat Mounting	ms^{-2}
$\ddot{Z}mrl$	Sprung Mass Acceleration At Rear-Left Seat Mounting	ms^{-2}
$\ddot{Z}mrr$	Sprung Mass Acceleration At Rear-Right Seat Mounting	ms^{-2}
$Zwfl$	Sprung Mass Displacement At Front-Left Tire	m
$Zwfr$	Sprung Mass Displacement At Front-Right Tire	m
$Zwrl$	Sprung Mass Displacement At Rear-Left Tire	m
$Zwrr$	Sprung Mass Displacement At Rear-Right Tire	m
$\dot{Z}wfl$	Sprung Mass Velocity At Front-Left Tire	ms^{1}
$\dot{Z}wfr$	Sprung Mass Velocity At Front-Right Tire	ms^{1}

$\dot{Z}wrl$	Sprung Mass Velocity At Rear-Left Tire	ms^{1}
$\dot{Z}wrr$	Sprung Mass Velocity At Rear-Right Tire	ms^{1}
$\ddot{Z}wfl$	Sprung Mass Acceleration At Front-Left Tire	ms^{-2}
$\ddot{Z}wfr$	Sprung Mass Acceleration At Front-Right Tire	ms^{-2}
$\ddot{Z}wrl$	Sprung Mass Acceleration At Rear-Left Tire	ms^{-2}
$\ddot{Z}wrr$	Sprung Mass Acceleration At Rear-Right Tire	ms^{-2}

NOMENCLATURE

DOF	Degree of Freedom
FBD	Free Body Diagram
PID	Proportional-Integral-Derivative
CG	Centre of Gravity

CHAPTER 1

INTRODUCTION

1.1 Background

Suspension is a system encircles spring and shock absorber to absorb any vibration from road roughness and on-board source. It is for giving comfortable to the driver and passenger.

The suspension systems support the vehicle body, decrease the road surface induced vehicle vibrations, help to improve ride comfort and road holding. Springs and dampers are main components of the suspensions that are parallel to each other and placed between the vehicle body and axles. The optimum design of these elements is the main goal of the manufacturers. Two important factors of ride comfort and road holding which are conflicting each other have to be compromised. Hard springs result in better road holding whereas ride comfort gets worse. On the other hand, resonance of the linear and angular motions of the vehicle body is another source of the uncomfortable ride. Addition of active systems has the potential of improving ride comfort. A good vehicle suspension system has to reduce the sprung mass displacement together with acceleration and provide adequate suspension deflection to maintain tires on contact. This helps to improve ride comfort and vehicle maneuverability. Thus, the improvement of the active vehicle suspensions systems has attracted more interest and been the subject of the research and development in last decades. The reason is commercial as well as being scientific. The main aim of the commercial activity is the desire of the automotive manufacturers to improve the performance and quality of their products. On the other hand, researchers and control system designers have claimed that the active control of the vehicle suspension system is possible when the developments in actuators, sensors and electronics have been considered. In the last twenty years, many studies have been published on active and semi-active suspension systems.

1.2 Objective

The objectives of this project are to propose control mechanism of the active seat suspension for a ground vehicle in order to improve riding comfort of the vehicle.

1.3 Scope

MATLAB Simulink Software will be chosen as a computer design tools used to simulate the dynamics behavior and evaluate the performance of the control structure. The research methodology implemented in this project take the following steps of works: literature review on related fields, study some previous works and the latest development on active seat suspension, development of equation of motion, simulation and comparison with the passive system.

1.4 Problem Statement

Normally in a vehicle have a vibration. Source of vehicle vibration is generally is divided into two classes:

- Road roughness
- On-board source

G.M Alan *etc*. (2005) said effect from the vibration can transfer from vehicle seat to human body. Its affect not only comfort, working efficiency and performance but can affect at health and safety when driving. Injury statistics from the Mine Safety and Health Administration (MSHA) showed incidences of exposure to whole-body vibration (WBV) and it also support by S.J Kooster (2004).

Operators of mine vehicles are in particular subject to high levels of vibrations under very constraining conditions. The vehicle operator often is more confined to a less space than in normal cars or vehicles and the seats are not equipped with a suspension system.

In the vehicles, an effective vehicle handling requires a significant torque on the front an axle which creates vibrations in the driver's seat. Improving the ergonomics of the seat can lessen the adverse effects of vehicle vibration. Adding a secondary suspension mechanism to the driver's seat of vehicles is another solution that was found to reduce the vibration induced by the seat.

1.5 Thesis Outline

Table 1.5.1: Gantt chart of Project Outline for PSM 1

NO	ITEM	WEEK(S)	JULY '09				AUG '09				SEPT '09				OCT '09			
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	Project Title Discussion	1																
2	Introduction	2																
3	Literature Review	3																
4	Research Methodology	4																
5	Report Writing	3																
6	Report Submission	1																

Target
Actual

Table 1.5.2: Gantt chart of Project Outline for PSM 2

NO	ITEM	WEEK(S)	JAN '10				FEB '10				MAR '10				APR '09			
			01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16
1	PSM 2 Discussion	1																
2	Build Simulation (using MATLAB)	4																
3	Simulation (MATLAB)	3																
4	Result Discussion	2																
5	Report Writing	4																
6	Report Submission	1																

Target
Actual

1.5.1 Chapter Summary

Chapter 1: This chapter explains about the objective and scope of this project. In this chapter also have the problem about the conventional and newer system.

Chapter 2: This chapter describes about the previous study about the seat suspension system.

Chapter 3: This chapter shows the system in mathematical modeling 10DOF full ride model.

Chapter 4: Result and discussion is briefly explained in this chapter

Chapter 5: Conclusion.