UNIVERSITI TEKNIKAL MALAYSIA MELAKA

IMPROVEMENT OF RIDE QUALITY FOR PASSENGER VEHICHLE USING THE MAGNETORHEOLOGICAL DAMPER

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree in Mechanical Engineering Technology (Automotive Technology) with Honours.

by

MOHD ARIF BIN YAAKUB
B071110304
920526-01-5963

FACULTY OF ENGINEERING TECHNOLOGY
2015

DECLARATION

I hereby, declared this report entitled "Improvement of Ride Quality of Passenger vehicle using Magnetorheological Damper" is the results of my own research except as cited in references.

Signature	:	…………………………………………….
Author's Name	:	MOHD ARIF BIN YAAKUB
Date	:	19 JANUARY 2015

APPROVAL

This report is submitted to the Faculty of Engineering Technology of UTeM as a partial fulfillment of the requirements for the degree of Bachelor in Mechanical Engineering Technology (Automotive Technology) with Honours. The member of the supervisory is as follow:

………………………………

(Mohammad Hafiz Bin Harun)

ABSTRAK

Kualiti pemanduan adalah perkara yang paling penting dalam kenderaan penumpang. Tanpa apa-apa keselesaan pada pemanduan, kenderaan cenderung untuk bergetar dan memberi masalah kepada kestabilan kenderaan. Getaran berlaku kerana penggantungan kenderaan gagal menyerap tenaga dari jenis permukaan jalan yang berbeza. Kegagalan ini akan berlaku getaran yang tidak diingini kepada kenderaan dan hasilnya, banyak masalah akan berlaku. Terdapat banyak penyelidikan telah dilakukan untuk membuat kualiti pemanduan adalah lebih baik dan satu daripadanya adalah penyelidikan mengenai sistem penggantungan. Laporan ini mengkaji tingkah laku kenderaan perjalanan menggunakan peredam magnetorheological. Peredam Magnetorheological adalah sistem penggantungan separa-aktif. 7 tahap persamaan kebebasan telah dibangunkan merujuk kepada model kereta penuh.Untuk penyelidikan ini, strategi kawalan yang digunakan adalah strategi kawalan hibrid, yang merupakan gabungan strategi kawalan cangkuk Skyhook dan Ground. Dalam kajian ini, perisian Matlab Simulink digunakan.

ABSTRACT

Ride quality is the most important for the passenger vehicle. Without any comfort on ride, the vehicles tend to vibrate and give a problem to vehicle stability. The vibrations occur because the suspension failed to absorb force from different type of road surface. This failure causes the unwanted vibration to the vehicle and as a result, many problems will occur. There are many research that have been done to create the better ride quality and one of it is research on the suspension system. This report studied is about the ride vehicle behaviour using magnetorheological damper. Magnetorheological damper is the semi-active suspension system. The 7 degree of freedom equation was developed by reference to the full car model. For this research, the control strategies used is hybrid control strategy, which is combination of the Skyhook and Ground hook control strategies. In this research, the Matlab Simulink software is used.

DEDICATION

To my beloved parents and family.

ACKNOWLEDGEMENT

I would like to thank God because I completely this final year project without facing any big problem. I am indebted to my supervisor, Encik Mohammad Hafiz Bin Harun for his effort in assisting me during the project period. I have learned and get a lot information from him about this project tittle. He also providing many helpful suggestions and comments for complete this project. I specially thank my parents for their continuous support throughout the project. A word of thanks is given to my friends for their constructive and helps in completing this project.

TABLE OF CONTENT

TABLE OF CONTENT

LIST OF FIGURES

LIST OF ABBREVIATIONS

MR	-	Magnetorheological Damper
ER	-	Electroheological Damper
HMMWV	-	High Mobility Multipurpose Wheeled Vehicles
LQG	-	Linear Quadratic Gaussin
LQR	-	Linear Quadratic Regulator

LIST OF SYMBOLS

SYMBOL	MEANING
Fd	Desired damper force
$\dot{Z}_b$	Sprung body velocity
$\dot{Z}_w$	Unsprung body velocity
$\dot{Z}_b$	Damper velocity
Ksky	Skyhook coefficient
Fg	Ground hook damping force
Kgrnd	Ground hook coefficient
F_b	Force acting at the vehicle body
a	Acceleration of the vehicle
m_b	Vehicle mass
$\ddot{Z}_b$	Body acceleration of the vehicle
Fsfl	Front left spring force
Fdfl	Front left damper force
Fsfr	Front right spring force
Fdfr	Front right damper force
Fsrl	Rear left spring force
Fdrl	Rear left damper force
Fsrr	Rear right spring force

$Fdrr$	Rear right damper force
$\sum M_p$	Sum of pitch moment
I_r	Pitch inertia
$\ddot{\theta}$	Pitch angular acceleration
W	Distance between centre of front to the centre of rear tire or wheelbase
M_r	Roll moment of the vehicle
I_r	Roll inertia
$\ddot{\beta}$	Roll angular acceleration
L	Track width of the vehicle
Fu	Sum of force
$\ddot{Z}u$	Tire acceleration
Mu	Tire mass
Ft	Force of the tire
Fs	Force of the spring
Fd	Force of the damper
$Ftfl$	Front left tire force
$Fsfl$	Front left spring force
$Fdfl$	Front left damper force
$Mufl$	Front left unsprung mass
$\ddot{Z}ufl$	Front left unsprung mass vertical acceleration
$Ftfr$	Front right tire force
$Fsfr$	Front right spring force

$Ksfl$	Front left suspension stiffness
$Zufl$	Front left unsprung mass vertical displacement
$Zsfl$	Front left sprung mass displacement
$Csfl$	Front left suspension damping coefficient
$\dot{Z}ufl$	Front left unsprung mass vertical velocity
$\dot{Z}sfl$	Front left sprung mass velocity
$Ktfl$	Front left tire stiffness
$Zrfl$	Front left road profile
$Ksfr$	Front right suspension stiffness
$Zufr$	Front right unsprung mass vertical displacement
$Zsfr$	Front right sprung mass displacement
$Csfr$	Front right suspension damping coefficient
$\dot{Z}ufr$	Front right unsprung mass vertical velocity
$\dot{Z}sfr$	Front right sprung mass velocity
$Ktfr$	Front right tire stiffness
$Zrfr$	Front right road profile
$Ksrl$	Rear left suspension stiffness
$Zurl$	Rear left unsprung mass vertical displacement
$Zsrl$	Rear left sprung mass displacement
$Csrl$	Rear left suspension damping coefficient
$\dot{Z}url$	Rear left unsprung mass vertical velocity
$\dot{Z}srl$	Rear left sprung mass velocity

Ktrl	Rear left tire stiffness
Zrrl	Rear left road profile
Ksrr	Rear right suspension stiffness
Zurr	Rear right unsprung mass vertical displacement
Zsrr	Rear right sprung mass displacement
Csrr	Rear right suspension damping coefficient
$\dot{Z}urr$	Rear right unsprung mass vertical velocity
$\dot{Z}srr$	Rear right sprung mass velocity
Ktrr	Rear right tire stiffness
Zrrr	Rear right road profile

CHAPTER 1
INTRODUCTION

The objective and scope for this project is clearly states in this chapter. The introduction of vehicle dynamic and ride quality are also discusses in this chapter for the more understanding about this project. There is some discussion on the sub-title of ride quality that is problem of ride quality that affected on vehicle and human.

1.1 Objective

- To developed an equation for magnetorheological damper for passenger vehicle.
- To developed a control algorithm for magnetorheological damper that can improve the ride quality of passenger vehicle.

1.2 Scope Of Project

- Development the 7-DOF of vehicle ride vehicle dynamic equation
- Development the 7-DOF of ride vehicle dynamic using the Matlab simulink software.
- Development a control algorithm of magnetorheological damper.

1.3 Problem Statement

Ride comfort is also one of the criteria that must be considered in automotive industry. From the criteria, people are attracted to experience the quality of good vehicle ride and controlling. The important of ride comfort is to improve vehicle stability, provide comfortable aspect to the drivers and give the maximum safety for vehicle and driver. For the driver, especially in term of healthy, the vehicle with a very good ride quality is the best choice to make.

Base on the research, a poor ride quality can cause bad injuries to the back bone and serious back pain. It also makes the bone joint feel uncomfortable when riding the vehicle. So with this good ride quality, the kind of pain can be avoided.

When the vehicle is driven on the different type of road, there is some vibration that can cause the joining part become easily worn out. If the vehicle use magnetorheological damper as the suspension system, it can reduce the vibration and make the joining part in a vehicle is long lasting.

1.4 Vehicle Dynamic

Vehicle dynamic is the branch of engineering that relates tyre and aerodynamic forces to overall vehicle acceleration, velocities and motions due to Newton’s Laws. It encompasses the behaviour of the vehicle as affected by tyre, driveline, chassis characteristics and aerodynamic. This subject is complex because it involves large number of variable.

In general, vehicle dynamics described in terms of its handling, performance and simulations. The quality of handling is focused on the vehicle commands response and ability to stable against external disturbance. A performance characteristic refers to the ability of vehicle to accelerate, develop drawbar bull to overcome obstacle and decelerate.

1.5 Ride Quality

Today, technology has combined the ride and handling features in the same vehicle to reach the high levels of comfort. This level of comfort are difficult to reconcile with a low angular inertia, low center of gravity, body roll resistance, steering feel and many more characteristics that make a car handle well. Some of modern vehicle now are provided with many electronic system that can improve the handling stability, provided comfortable driving and increase the passenger safety and health. This feature can see on the vehicle such as EBD, ABS, VSC (vehicle stability control) and others.

Ride are related to the vibration of the vehicle on the irregular surface and its effect on passenger and goods. Therefore, the theory of vehicle dynamic is concerned with the study of handling, performance and ride relationships with the vehicle design under various operating conditions. The performance of the vehicle that response to force imposed is by accomplished the motion in accelerating, braking, cornering and ride. The study of vehicle dynamics must involve the study of how the force is produced.

The ride quality is measured in terms of the level of isolation from road inputs in the suspension transfers to vehicle without any problem on vehicle control. Ride is the major component of the vehicle comfort and the problems will occur when the vehicle’s suspension failed to absorb force from the tire on the different type of road surfaces. This failure is the main problem for every cars and vehicle that makes the unwanted vibration. It also can cause the problems to vehicle stability and passenger comfort.

CHAPTER 2

LITERATURE REVIEW

There are many history of suspension system used in vehicle and how the passive suspension system is developed until it becomes the semi-active suspension system. This chapter has discusses of literature review about the semi active system. A history about the Magnatorheological Damper that use in the semi active suspension system also consist in this chapter.

2.1 Magnetorheological Fluid

Lately, the magnetorheological (MR) dampers received more attention as semi-active system actuator because of their fast response to applied magnetic field and have a compact size. In 1948, Jacob Rabinow was the first person that observed the effect of magnetorheological damper. Researcher began in late 1980s and 1990s to get serious about developing the commercial viability of MR fluids, especially when others technologies began to made their practically used and real possibility. Sensors technology, microprocessors, processing speed and increasing electronic content have make control possibilities that did not exist in Rabinow's time.

MR fluid is defines as the magnetically induced fibrillation of micrometer-sized, which magnetic particles suspended in a low viscosity fluid. With the effect of magnetic field, the particles of MR fluid associated themselves with respect the magnetic field and form into columns or chains that make the viscosity of the MR fluid change. Without any magnetic field produce, the MR fluid has the properties of a Newtonian fluid.

MR fluid is composed of oil and varying percentages of iron particles that have been coated with an anti-coagulant material. When inactive, MR fluid behaves as ordinary oil, but it uncovered to a magnetic field, micron size iron particles that are distributed throughout the fluid align themselves along magnetic flux line (James Poynor, 2001). The changes in physical property of MR fluid are resulted from the chain-like structures between paramagnetic MR particles in the low permeability solvent.

At the normal state, MR fluid shows the isotropic Newtonian behaviour because the MR particles move freely as shown in Figure 2.1. But, when the magnetic field applied to the MR fluid, it shows anisotropic Bingham behaviour and resist to flow or external shear force because the MR particles make a chain structure as shown in Figure 2.2. From this property, torque or force of application devices can be easily controlled by the intensity of the magnetic field.

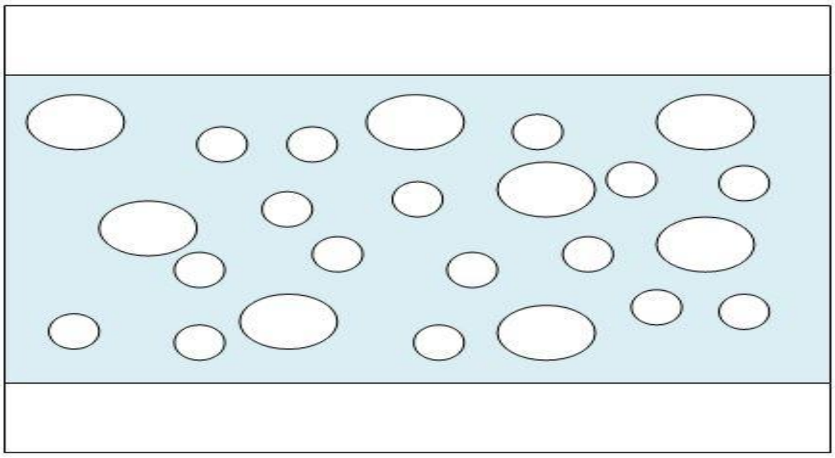

Figure 2.1: No magnetic field applied

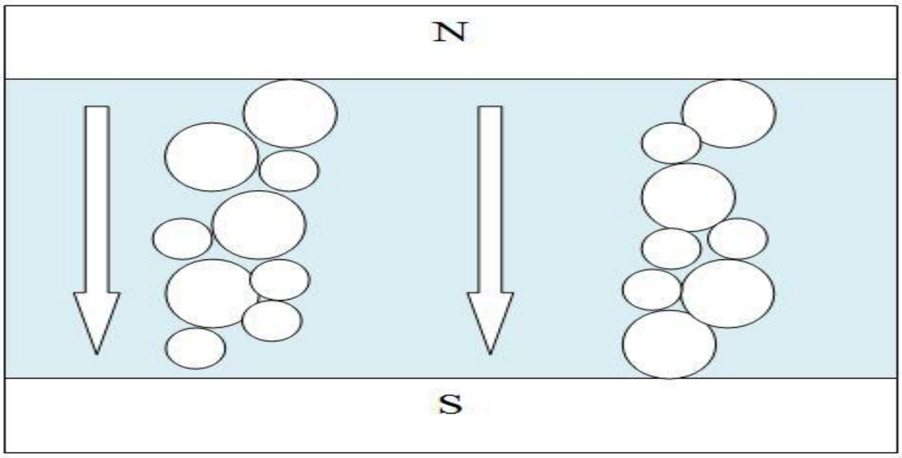

Figure 2.2: With the magnetic field applied

MR fluid have many attractive features, including high yield strength, low viscosity and stable hysteretic behaviour over a broad temperature range (Carlson, 1994). Anyway, the barrier of their widespread commercial and the principle handicap of fluids is received in many areas but still relative high cost.

Controllable fluid such as magnetorheological (MR) and electrorheological (ER) have recently attracted wide interest because of their quick response, reversible behaviour change when subjected to magnetic fields or electric. In the past decades, diverse ER and MR damping have been developed for research and industrial applications (Stanway Sproston and El-Waheed, 1996). These devices usually work according to one or three flow modes. The mode operations are valve mode, squeeze mode and shear mode. The valve mode usually use widely among these three modes. The device operated in valve mode when the MR fluid is used to impede the flow of MR fluid from one reservoir to another as Figure 2.3. For device that operate squeeze mode has a thin film on order of 0.02 inches of MP fluid that sandwich between paramagnetic pole surfaces as shown in Figure 2.4. A device that use the shear mode has a thin layer between 0.005 to 0.015 inches of MR fluid that sandwich between two paramagnetic pole surface as shown in Figure 2.5.