SUPERVISOR DECLARATION

"I hereby declare that I have read this thesis 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 : ....
Supervisor I : EN. MOHD HANIF BIN HARUN
Date : 21/6/2011

Signature : ....
Supervisor II : ....
Date : ....

SEMI ACTIVE SUSPENSION SYSTEM DESIGN FOR
HEAVY DUTY TRUCK

MOHD SALMIZI BIN MAT NOR

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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: ....
Author: ....
Date: ....

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ABSTRACT

The study present a semi active control system in designing a controller for semi active. The mathematical model of a heavy duty truck were developed and the performance of semi active system were compared with passive system. This semi active control system was proposed to reduce the rolling and pitcing the truck body. It was proved by the result that semi active control system can improve the rolling and pitching of the truck.

The 9 DOF truck model and MATLAB Simulink were created. It is includes the degree of freedom for roll, pitch and vertical motion of the sprung mass and also vertical motion off unsprung mass. The pitch motion is due to the longitudinal acceleration and roll motion is due to the lateral acceleration.

ABSTRAK

Kajian menunjukkan sistem kawalan semi aktif dalam membina satu alat kawalan berdasarkan teori pembolehubah struktur. Satu model matematik tentang kenderaan berat di bina dan keputusan prestasi bagi semi aktif dan pasif dibandingkan. Tujuan alat kawalan semi aktif ini adalah untuk mengurangkan beberapa daya yang bertindak pada badan kenderaan berat. Ini dapat dibuktikan dengan keputusan kajian dimana alat kawalan semi aktif dapat meningkatkan daya pada badan kenderaan berat.

Satu model kenderaan berat dan MATLAB model dibina. Ia berdasarkan daya yang bertindak pada badan kenderaan berat. Ia termasuklah daya yang ada pada beban tergantung dan beban tidak tergantung. Daya yang bertindak ke tepi adalah berdasarkan pecutan ke depan dihasilkan oleh kenderan berat.

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CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION TO THE SEMI ACTIVE SUSPENSION

Demand for better ride comfort, road handling and controllability of passenger cars have motivated automotive industries to use active and semi active suspension in middle top range vehicles due to their effectiveness in order to increase the car comfort anf stability. For this project I am using Matlab SIMULINK to design mechanism of the semi active suspension of heavy duty truck for full car model. The block diagrams are drawn in Simulink based on the full car model according to the parameters. The block diagrams will drawn from the car model which was consider on body, damper, spring, actuator and wheel and describes of the semi active truck suspension, including control system design and performance evaluation.

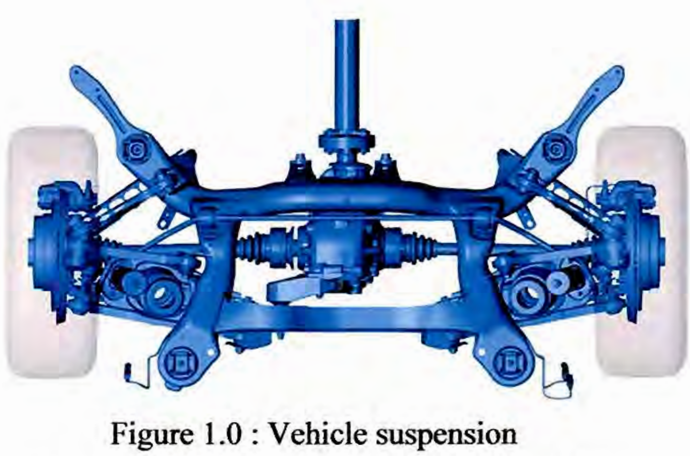


Figure 1.0 : Vehicle suspension

(Source : http://www.mercedes-benz.com.hk)

Suspension is a system that connect a vehicle to its wheels by using spring and shock absorber. It can absorb any vibration from road roughnes or load from the vehicle. Suspension system was created to give a good handling and allows the vehicle to corner with minimum roll or loss of traction between the tires and the road, keep the driver or passengger comfortable from any vibration, road noise and bumps. 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. In a typical suspension system for a vehicle with front engine and front wheel drive the weight of the vehicle give an initial compression to the coil springs. When the tires and wheels move in the road, the springs compress and expand to absorb most of the shock.

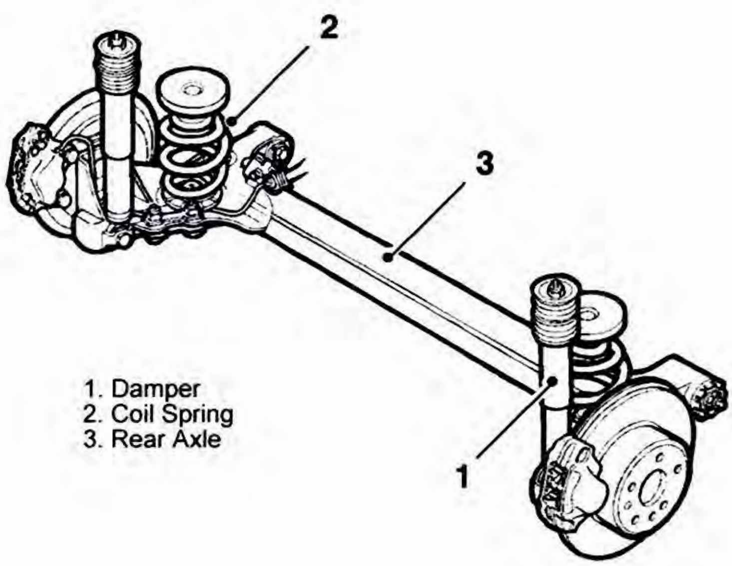


Figure 1.1 : Front suspension
(Source : http://www.miracerros.com/mustang/t_front)

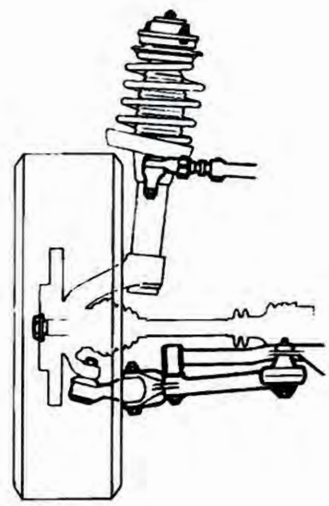


Figure 1.2 : Rear suspension

(Source : http://www.saabcentral.co)

The suspension at the rear wheels is more simple than the front wheels which require multiple joint so the wheels can move up and down while swinging from side to side for steering. Shock absorber is mounted separately at each wheel to restrain spring movement and prevent prolonged spring oscillations. The shock absorber contains a piston that moves in a cylinder as the wheel moves up and down with vehicle body. As the piston moves, the fluid was force through an orifice, imposing a restraint on the spring. Spring loaded valves open to permit quicker flow of the fluid if fluid pressure rises high enough when rapid wheel movements take place.

Figure 1.3 : Semi active suspension

(Source : http://www.sae.org/automag/techbriefs)

Most automotive vehicles use gas filled shock absorbers in which the air space above the fluid is filled with a pressurized gas such as nitrogen. The gas pressure on the fluid reduces the creation of air bubbles and foaming. Most automobiles and many light trucks have coil springs at the rear. These may mount on the rear drive axle on various types of control or suspension arms in an independent suspension system. Some rear drive vehicles have leaf springs at the rear. Leaf springs have been around since the early Egyptians. Ancient military engineers used leaf springs in the form of bows to power their siege engines, with little success at first. The use of leaf springs in catapults was later refined and made to work years later. Springs were not only made of metal, a sturdy tree branch could be used as a spring, such as with a bow.

Figure 1.4 : Leaf Spring
(Souece : http://image.off-roadweb.com)

The suspension system is classified as a passive, semi active and active suspension system. It is according to the ability to add or extract energy. The semi-active suspension has no force actuator, it is possible to continuously vary the rate of energy dissipation using a controllable damper.

1.2 OBJECTIVE OF THE PROJECT

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 takes the following steps of works: literature review on related fields, study some previous works and the latest development on heavy duty truck, development of equation of motion, simulation and comparison with the passive system.

The objective of this project is :

1. To create 9 DOF mathematical model of heavy duty truck
2. To design a suitable controller to improve ride handling of heavy duty truck
3. To compare the semi active suspension system with the passive system in MATLAB simulink environment

1.3 SCOPE OF THE PROJECT

1. The simulation is performed in Matlab Simulink
2. The simulation is to predict the performance of heavy duty truck ride handling
3. The parameters are taken from the real commercially available heavy duty truck

1.4 STRUCTURE AND LAYOUT OF REPORT

This project work towards developing semi active suspension and passive suspension for quarter car, using Matlab Simulink is presented in five chapters. As the development progress can be divided in to 5 main categories.

The first chapter introduces the semi active suspension system and objective of this project.

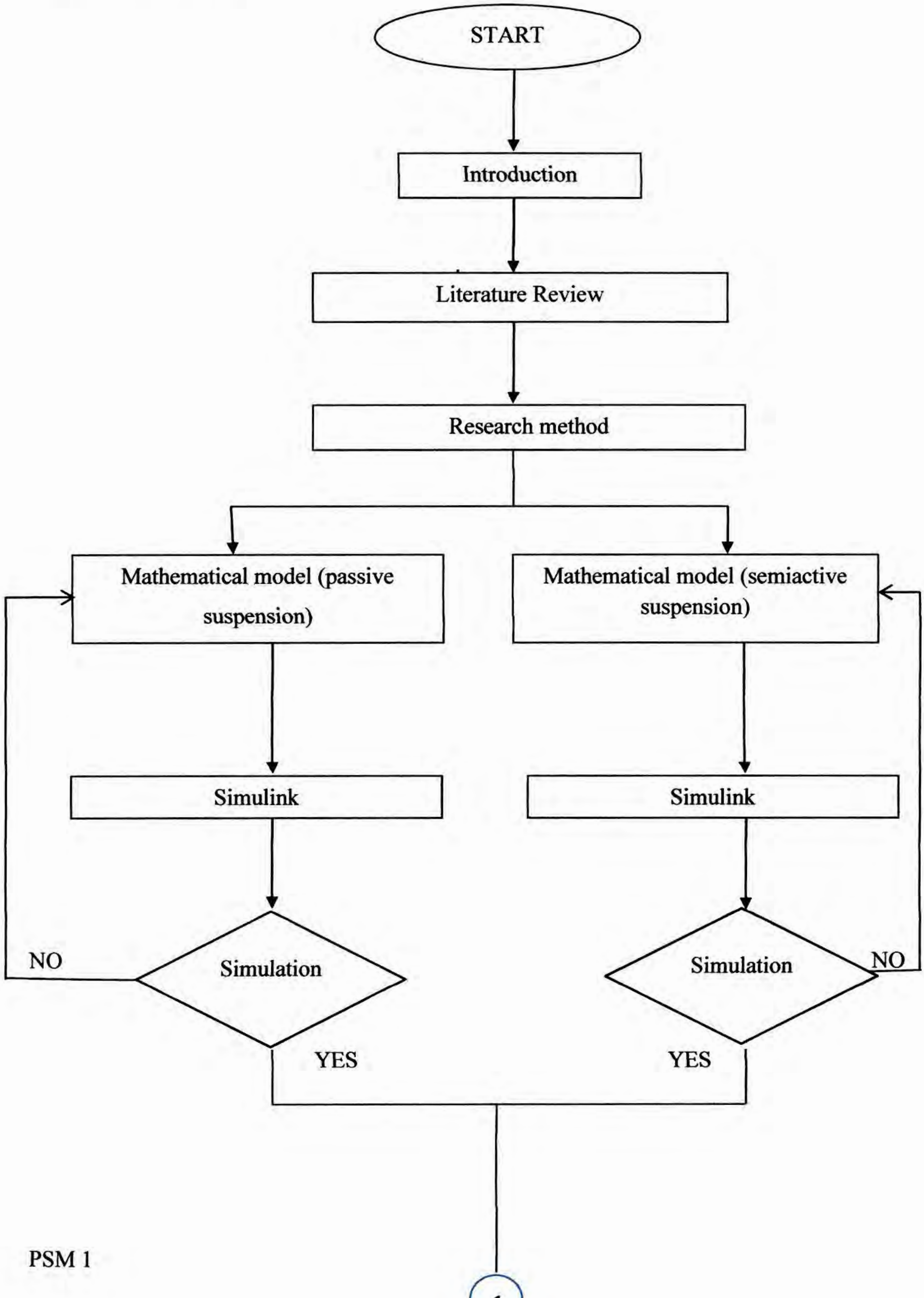
The second chapter reports on the review of literature on passive and semi active suspension system that inspires the scope of the present report.

Chapter three proposes a method of design of the system in software by using Simulik software.

Chapter four, deals with result and discussion of semi active suspension system's operation and design. Application of this suspension is also discussed.

A compressive summary of the project efforts and the conclusions derived from this project work is presented in chapter five. Constraints and future research potential of the passive and semi active suspension system are also presented.

1.5 FLOW CHART



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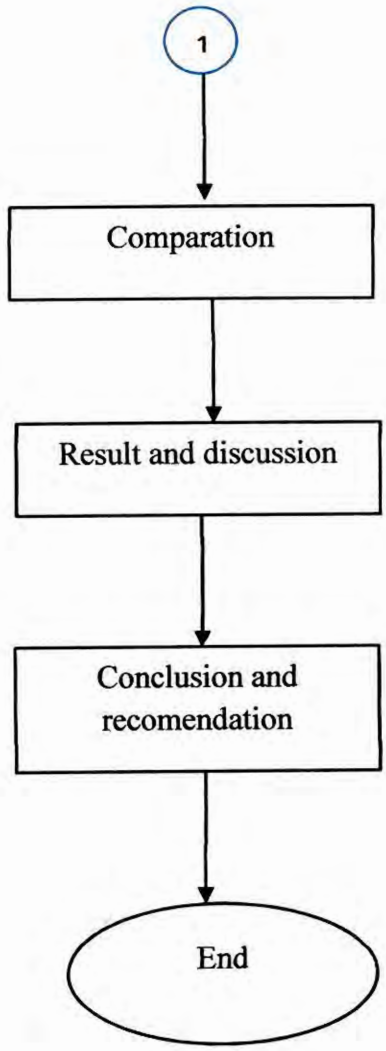
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Comparation
Result and discussion
Conclusion and recomendation
End

CHAPTER II

LITERATURE REVIEW

2.0 Introduction

The suspension of a car is actually part of the chassis, which comprises all of the important systems located beneath the car's body. Traditional vehicle suspension consists of combinations of springs and dampers. The roll trade-off of suspension systems has been a long standing challenge for vehicle dynamicists. Achieving better ride performance almost invariably leads to increased roll of the vehicle. To the car engineer this roll leads to undesirable handling characteristics. To the heavy vehicle engineer the increased roll leads to higher risk of roll-over due to the translation of the center of gravity (COG) of the vehicle. The problems with heavy vehicle roll overs have been well study. Roll overs occur when the overturning moment on the vehicle, due to lateral acceleration and displacement of COG, exceed the restoring forces that the tyres can supply. A static balance is no longer possible and the COG must accelerate outwards. The less stable the vehicle, the more likely it will be involved in a roll over accident. This indicates that it is difficult for a driver to anticipate the roll over limit of the vehicle. Studies have shown that avoidance of roll over can only be achieved in most cases by improving the stability of the vehicle. Such components only have the ability to only dissipate energy and are called passive. These passive suspensions are reaching the limit of development due to fundamental conflicts in the demands of ride, road holding and handling. Active suspensions have been developed to reduce this trade off. These suspensions are able to supply power, usually using hydraulic actuation. This leads to such systems typically having high power consumption and often a high level of complexity. The required bandwidth is also high as the aim is to control both the body and wheel motion. A semi-active roll control system of the type considered in this paper would provide the vehicle with a switchable roll stiffness. The low roll stiffness setting would be used when lateral forces on the vehicle are small. This would facilitate good ride performance. The vehicle would switch to the higher roll stiffness configuration when large lateral forces are present. By changing only the roll stiffness of the vehicle, the vertical bounce stiffness is unaffected under all conditions, hence the ride is only modified in response to roll-plane roughness. Such a system could be implemented with minimal power consumption. The increase in weight could be low with careful design. The justification of the cost would depend on the achievable performance gain.

2.1 History of suspension system

By the early 19th century, most British horse carriages were equipped with springs' wooden springs in the case of light one horse vehicles to avoid taxation, and steel springs in larger vehicles. These were made of low carbon steel and usually took the form of multiple layer leaf springs. The British steel springs were not well suited for use on America's rough roads of the time, and could even cause coaches to collapse if cornered too fast. In the 1820s, the Abbot Downing Company of Concord, New Hampshire developed a system whereby the bodies of stagecoaches were supported on leather straps called "thoroughbraces", which gave a swinging motion instead of the jolting up and down of a spring suspension. Automobiles were initially developed as self-propelled versions of horse drawn vehicles. However, horse drawn vehicles had been designed for relatively slow speeds and their suspension was not well suited to the higher speeds permitted by the internal combustion engine. In 1901 Mors of Germany first fitted an automobile with shock absorbers. With the advantage of having a dampened suspension system in his 'Mors Machine', Henri Fournier was able to win the prestigegous Paris-Berlin race on June 20th 1901. Fourniers superior time was 11 hrs 46 min 10 sec, while the best competitor was Léonce Girardot in a Panhard at the time 12 hrs 15 min 40 sec. In 1920, Leyland used torsion bars in a suspension system. In 1922, independent front suspension was pioneered on the Lancia Lambda and became more common in mass market cars from 1932.

2.2 Suspension system

The suspension system can be categorized into passive, semi-active and active suspension system according to external power input to the system or a control bandwitdh. A passive suspension system is a conventional suspension system consists of a non-controlled spring and shock-absorbing damper. The semi-active suspension has the same elements but the damper has two or more selectable damping rate. An active suspension is one in which the passive components are augmented by actuators that supply additional force. Beside these three types of suspension system, a skyhook type damper has been considered in the early design of the active suspension system. In the skyhook damper suspension system, an imaginary damper is placed between the sprung mass movements can be reduced without improving the tire deflection. However, this design concept is not feasible to be realized.

2.2.1 The passive suspension system

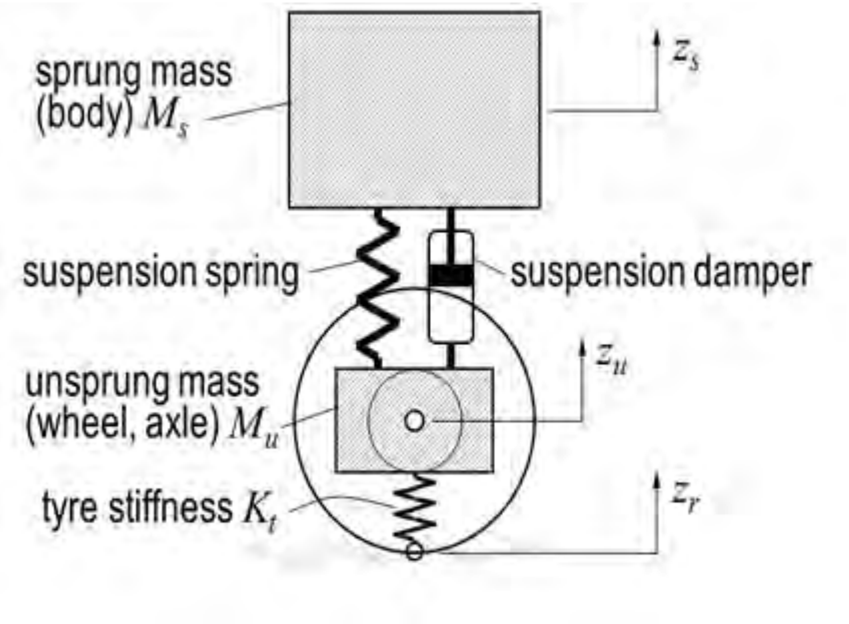

Figure 2.1: Passive suspension system

In early semi-active suspension system, the regulating of the damping force can be achieved by utilizing the controlled damper under dampers under closed loop control, and such is only capable of losing energy. Two types of dampers are used in the semi-active suspension namely the two state damper and the continuous variable dampers. The two state dampers switched rapidly between states under close-loop control . In order to damp the body motion, it is necessary to apply a force that is proportional the body velocity. Therefore, when the body velocity is in the same direction as the damper velocity, the damper is switched to the high state. When the body velocity is in the opposite direction to the damper velocity, it is switched to the low state as the damper is transmitting the input force rather than dissipating energy. The disadvantage of this system is that while it controls the body frequencies effectively, the rapid switching , particularly when there are high velocities across the dampers, generates high-frequency harmonics which makes the suspension fell harsh, and leads to the generations of unacceptable noise.

2.2.2 The semi active suspension system

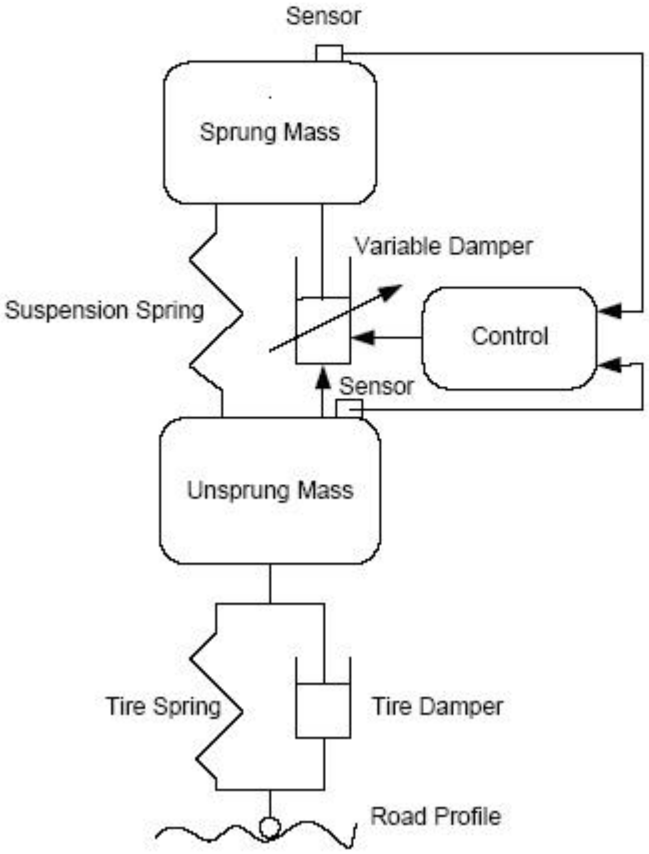

Figure 2.2: Semi active suspension system

The continuous variable dampers have a characteristic that can be rapidly varied over a wide range. When the body velocity and damper velocity are in the same direction, the damper force is controlled to emulate the skyhook damper. When they are in the opposite directions, the damper is switched to its lower rate, this being the closest it can get to the ideal skyhook force. The disadvantage of the continuous variable damper is that is difficult to find devices that are capable in generating a high force at low velocities and a low force at high velocities and low force at high velocities, and be able to move rapidly between the two. Karnopp (1990) has introduced the control strategy to control the skyhook damper. The control strategy utilized a fictitious damper that is inserted between the sprung mass and the stationary sky as a way to suppress the vibration motion of the spring mass and as a tool to compute the desired skyhook force. The skyhook damper can reduce the resonant peak of the spring mass quite significantly and thus achieves a good ride quality. But, in order to improve both the ride quality and handling performance of a vehicle, both resonant peaks of the spring mass and the unsprung mass need to be reduced. It is known that the skyhook damper alone cannot reduce both resonant peaks at the same time.

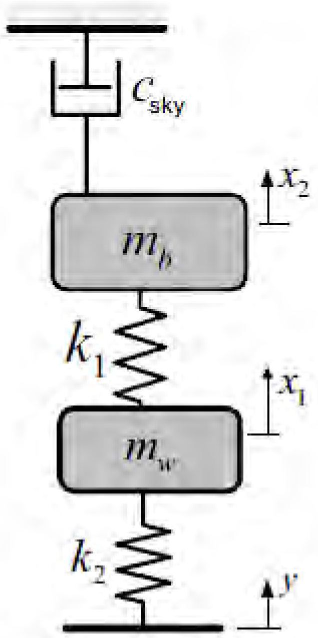

Figure 2.3: Skyhook damper

More recently, the possible applications of electroheological (ER) and magnetorheological (MR) fluids in the controllable damper were investigated by Yao *et al*. (2002) and Choi and Kim (2000). However since MR damper cannot be treated as a viscous damper under high electric current, a suitable mathematical model is needed to be developed to describe the MR damper.