MODELLING, SIMULATION AND EXPERIMENTAL VERIFICATION OF A SEMI ACTIVE ABSORBER SYSTEM

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Thesis submitted in partial fulfilment of the requirements
for the award of the degree of
Bachelor of Mechatronic Engineering

Faculty of Manufacturing Engineering
UNIVERSITI MALAYSIA PAHANG

SEPTEMBER 2013

UNIVERSITI MALAYSIA PAHANG

BORANG PENGESAHAN STATUS TESIS♦

JUDUL: **MODELLING, SIMULATION AND EXPERIMENTAL VERIFICATION OF A SEMI ACTIVE SUSPENSION SYSTEM**

SESI PENGAJIAN: **2012/2013**

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CHAPTER 1

INTRODUCTION

1.1 PROJECT MOTIVATION

Shock absorber is one of the important elements in a car that contributes to both driving safety and comfort. It is a device that controls unwanted spring motion through a process known as dampening. Shock absorber slow down and reduce the magnitude of vibratory motions by changing the kinetic energy into heat energy that can be transferred through a hydraulic fluid. The existence of vehicle dampers, or called shock absorber is difficult to estimate with accuracy, the existence of shock absorber rises as the production of the vehicle. First suspension system was invented by the Truffault before 1900 with using the concept of scissor action friction disc system using bronze discs. Over recent years interest has grown in suspension systems which can improve comfort and stability compared with passive system. The improvements are achieved by making the suspension system can make their own decision by electronic control. This system will be adjusted automatically when it goes from one road condition to others. The main objective for this is to obtain a good isolation of the body.

The production of the damper is probably around 50-100 million units per annum with a retail value well in excess of one billion dollar per annum. A typical European country has a demand for over 5 million units per year on new cars and over 1 millions replacement units. The need for dampers arises because of the roll and pitches associated with vehicle maneuvering, and from the different roughness of roads. In the mid nineteenth century, road quality was generally very poor. During that time in order to improve the comfort the better horse drawn carriage at that period therefore had soft suspension, achieved by using long bent leaf spring.

Development of the dampers has occurred tremendously. Although there will keep continue to be differences between each other but now the suspension system reach at a level of a mature products. Fully active suspension system offers some advantage between others but it is not very suitable for passenger cars due to higher money consumption. Nowadays, it is very clear that different country was producing their own technology in suspension system; we believe that Germans have different driving expectations to other Europeans. Most German manufacturers like Audi and BMW therefore differentiate themselves from other manufacturers through high performance ride control. Yet in markets like the US, France or Japan, ride performance is not significant criteria of differentiation.

1.2 PROJECT BACKGROUND

The vehicle suspension system provides the driver with driving comfort and safety. Driving comfort can be defined as reducing the disturbance factor such as vibration, noise, and climatic condition as low as possible, while driving safety can be defined as result of harmonious suspension design in terms of wheel suspension, springing, steering and braking and is reflected in an optimal dynamic behavior of the vehicle. Suspension system act as medium to transmits all forces between the body and the road. Suspension system can be divided into three main parts which are spring, damper and wishbones. For this project it will focus on damper system only. Damper function is to slow down the oscillations of body and wheel, this oscillation is produce from the dissipation of energy by the spring. For the good damper it must contain the criteria where it can split between the body and the wheel also called as sprung mass when the absorber experience factor that can give effect to the absorber such as road disturbances. In this modern technology there are three types of vehicle suspension system used which are passive, semi active and active. All system normally used hydraulic or pneumatic operation but recently a new system was found which used electromagnetic in suspension system.

People require high quality for everything. Certainly, the comfort in the moving vehicles is people's concern so it is desirable to have high performance suspension system for vehicles. In the environment of a moving vehicle, passenger often feels uncomfortable due to the vibration of the vehicle body. Vibration control techniques have classically been categorized into two areas, namely passive and active controls. In a passive system the parameters are synthesized through off-line design techniques and no on line feedback actions are used. Since passive systems produce fixed designs, the control will not be optimal when the system or the operating condition changes. Active approach is a vibration control technique that can adapt for system variations and can be much more effective than passive system. Based on vibration control techniques, technology nowadays has grown in suspension systems which can offer improved and stability over the performance provided by conventional passive systems. The improvements are achieved by making the suspensions has a brain which can alter their characteristics based on the road structure.

In order to get the functionality and to reduce cost, this project will use semi active system. These enable the suspension system to adapt to various driving condition suitable with driver's need. Driver can manually adjust the absorber suitable with their needs.

1.3 PROBLEM STATEMENT

Problem statement is the collection of an issue currently existing which needs to be solved in this project. This problem provides the context for the research study and generates the questions which this research aims to answer it.

In the future, active suspension system will replace conventional passive suspension system since vehicle stability and passenger safety are important aspect for the driver. Passive absorber system is a fixed design that lack of capability to diminish force and oscillation experienced by the spring from being transferred to the sprung mass. The passive suspension systems may lead to a compromise between ride and handling. For example a low damped suspension will cause more comfortable ride but can significantly reduce the stability of the vehicle. As we know vehicle suspension system is a device to transmit and also filter all forces between the body and the road. In order to give better performance for this project, semi active components are introduced. These characteristic enable the suspension system to adapt to various driving condition. Other than that by using semi active system user also has option to select the firmness of the suspension based on the road condition.

In order to exhibit variable characteristic in a suspension system, there are two components in the suspension system need to be changed either by mechanically or chemically. For this project it will focus only to the shock absorber or damper. The damper provides the driver with both driving safety and comfort. Its task is to freeze the body and wheel oscillations. To improve ride quality, it is necessary to separate between the body and road disturbances while to improve ride stability it is important to make the tire fixed to the ground.

Specific vehicle models need to be used in order to analyze the effectiveness of the suspension system on vehicle dynamics, for this project it will use Proton Wira car as a reference. A full vehicle model needs to present the nonlinear kinematics of wheels and axles, the effect of suspension geometry and has to include the drive train the steering mechanism and the tire dynamics resulting in a high number of degrees of freedom. The full vehicle suspension system is represented as a linear seven degree of freedom (DOF) system. It consists of a single sprung mass (car body) connected to four unsprung masses (front-left, front right, rear left and rear right wheel) at each corner. The sprung mass is free to bounce, pitch and roll while the unsprung masses are free only to bounce vertically with respect to the sprung mass. The full vehicle suspension model is represented as a linear seven degree of freedom system. Full vehicle suspension system consists of a single sprung mass (car body) connected to four unsprung masses m1, m2, m3, and m4 (front left, front right, rear left, rear right wheels) at each corner. The suspensions between the sprung mass and unsprung masses are modeled as linear viscous dampers and spring elements while tires are modeled as simple linear springs without damping components. For this project, in order to achieve accuracy we will focus on physical models of suspension system in quarter car model to be exact only to the rear tire. This aims to describe correctly the roll and pitch motion of the car and the connected inertia forces.

Suspension system is closely related to four main problems which are comfort, safety, energy and lastly maintenance. In this project we are choosing to look through in comfort problem. Driving comfort can be defined as minimization the unnecessary factor such as vibration, noise and climatic conditions down as low as possible to the vehicle. There are two key factors that will look through in this comfort condition which are motion and vibration. The acceleration of the body is an obvious quantity for motion and vibration of the car body can be used for determining a quantitive value for driving comfort. There are several factors that can affect the comfortness which are drop test, ride motions, longitudinal acceleration transients and lastly lateral acceleration transients. In this project it will more specified on the ride motions. A Ride motion is depend on the road roughness. This project will focus on the movements of the vehicle in different road roughness.

Different road roughnesses have different displacement amplitude. Displacement amplitude is a measurement of distance of the movement of a particle from its equilibrium position.

As the conclusion, our research problem is to modeling and simulation of semi active suspension system which is damper for a rear tire to solve comfort problem when experience different road condition.

1.4 PROJECT OBJECTIVES

Research objective set the purpose and focus the research on what we are going to achieve by this project. It is similarly to the purpose or aim for the project. These are the objectives that must be achieved from this research, there are:

(i) Modeling passive and semi active suspension system using MATLAB.
(ii) To identify the factor that makes the suspension systems become variable.
(iii) To design (CATIA) and fabricate semi active suspension system.
(iv) To distinguish the performance between passive and semi active suspension system.

1.5 PROJECT SCOPES

Project scope will identify and minimize the scope of the project. So that, it will make the project become more focus. In this project scope, it will clearly clarify condition where it is included and excluded from this project. The scope of this project covers several issues such as:

(i) This project valid only to the condition where ride motions are different in response to road roughness other condition is ignored.
(ii) This project only acceptable to normal passenger car which is Proton Wira suspension system, other brand of car will not be taken into account.
(iii)The scope of this project only valid to the rear wheel position.

1.6 REPORT ORGANIZATION

This report contains six sections which briefly describes the detailed information about the research. All chapters are preceded by a brief synopsis of the chapter and key words.

(i) Introduction
This is the beginning section which states the purpose and goals of the thesis. In this chapter, briefly describes the information in term of background, problem statement, objectives, scopes and others. This chapter is important because it is used to give general idea about this project.
(i) Literature review
In this chapter, published information in a particular subject area will be discussed. Literature review provides background for your topic using previous research.
(ii) Methodology
This chapter discussed about the procedures used in making experiments or projects. It will mention the research platform setup, the steps taken to conduct either simulation or experiment.

(iii)Result and discussion

Result obtains from experiment are shown in this chapter. The results are shown in terms of graphs, figures and tables. Then, the results will be analyzed and compared with the purpose of the simulations or experiments.

(iv)Conclusions and recommendations

This chapter summarized the overall of this project and to determine that the results verify the hypothesis or not. Recommendations for future study and the improvement in this field also stated in this chapter.

(v) References

In this chapter citation of a text that has been used in the creation of the thesis was stated.

CHAPTER 2

LITERATURE REVIEW

This chapter briefly describes the review on existing technology used in shock absorber. This chapter comprises two sections: The first section describes the comprehensive review on existing related technology. The second section describes the review on method, equipment, and technology previously used in the same area.

2.1 HISTORY OF SHOCK ABSORBER

The first production of shock absorber is hard to be identified when it was begin. But the production of the shock absorber arises rapidly by following the evolution of the motor car itself. The evolution of the shock absorber technology can be arranged in such ways, based on its history: dry friction (snubbers) (figure 2.1), blow-off hydraulics, progressive hydraulics, adjustable (manual alteration), slow adaptive (automatic alteration), fast adaptive (semi active) and lastly followed by electro fluidic (magneto rheological) [1]. In 1913, the first car that used shock absorber is Silver Ghost the company called Rolls Royce used discontinued rear dampers on the Silver Ghost [1]. From 1910 to 1925 mostly all the motor car used dry snubbers technology [1]. From 1985, the evolution of shock absorber become more widely increase on this period of time the technology was changed from passive to active suspension by fast auto adjusting dampers [1]. In this millennium era, from about 2000 the introduction of magnetorheological technology was founded, but at this time this technology only exists on high price vehicles only [1]

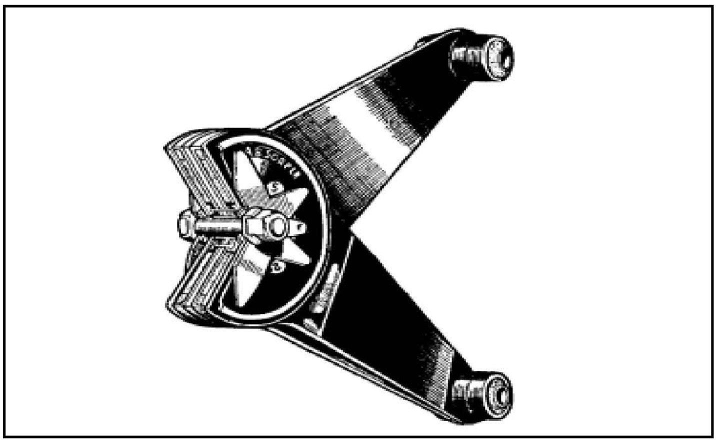


Figure 2.1: The Andre-Hartford scissor-action dry friction damper.

2.2 INTRODUCTION

The comfort and safety aspect for the driver depends on the suspension system of the vehicle as the suspension system carries the vehicle body and transmits all forces between body and road [2].The vehicle suspension systems basically consists of wishbones, the spring and the shock absorber to transmit and also filter all forces between body and road [3]. The spring function is to carry the body mass and to isolate the body from road disturbances and thus contributes to drive comfort while damper contributes to both driving safety and comfort [3]. The damper function is to slow down the movement of body and wheel oscillations; it directly refers to drive safety as a non-bouncing wheel is the condition for transferring road-contact forces [3].

Nowadays, people require high quality for everything. In the contact of vehicles, two factors that always take into consideration are driving safety and comfort. Driving safety is the result of a harmonious suspension design in terms of wheel suspensions, steering and braking and it is reflected in an optimal dynamic behavior of the vehicle [3]. Tire load variation is an indicator for the road contact and can be used to determining a measurable value for safety [5]. While driving comfort is a results from keeping the unnecessary condition that the vehicle experience such as vibrations, noise, and climatic control [3]. For driving comfort condition, two factors that can give measureable value for driving comfort are motion and vibration of the car body due to acceleration of the body [5]. In the condition of a moving vehicle, passengers often feel uncomfortable due to the vibration of the vehicle body [4].In order to solve this problem, effective vibration control of vehicle suspension systems is very important [4]. Based on figure 2.2 below, the ride quality and the drive stability are two conflicting criteria [5], it is impossible to increase both the criteria at the same time. As can be seen from the diagram, the fixed setting of a passive suspension system is always a compromise between comfort and safety for any condition that might change the suspension bump velocities in order to solve this conflict semi active or active suspension system try to solve or at least reduce this conflict [5].The mechanism of semi active suspension system is the improvement of the damping and/or stiffness of the spring to the actual needs [5]. While active suspension system is different characteristic which need extra force input in addition to possible existing passive systems and therefore need much more energy [5].

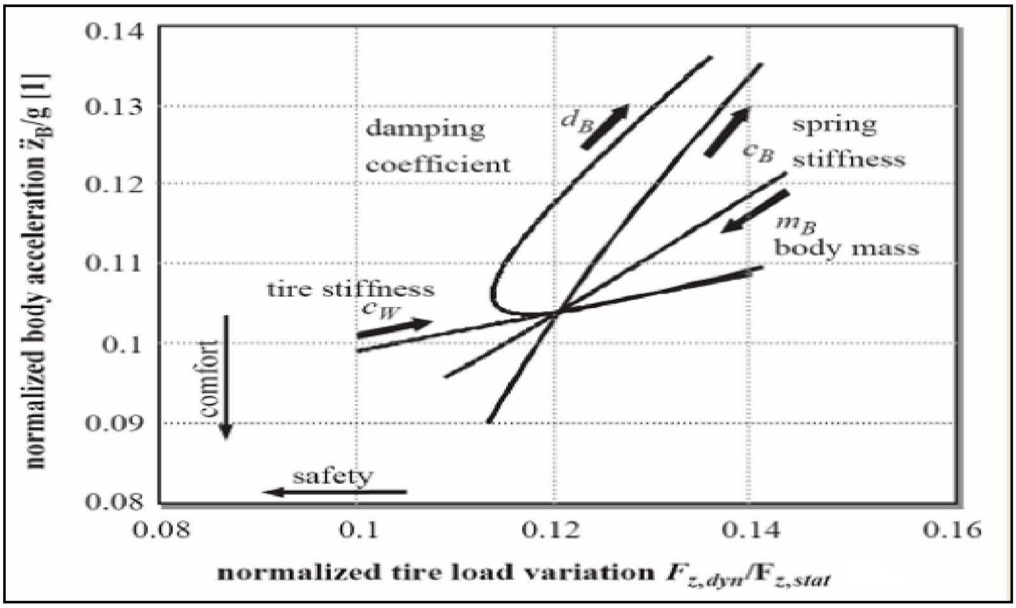


Figure 2.2: Conflict diagram

2.3 BASIC TYPES OF SHOCK ABSORBER

Basically damper can be divided into two main types which are dry friction with solid elements and hydraulic with fluid elements [1]. Dry friction with solid elements consists of scissor (figure 2.3) and snubber (figure 2.4), while hydraulic with fluid elements also can be divided into two main elements which are using lever-arm (figure 2.5) and telescopic (figure 2.6) [1].

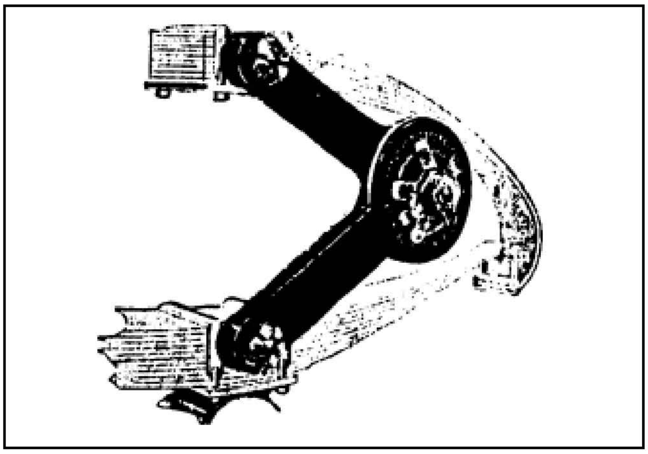


Figure 2.3: Dry-friction scissors damper on three quarter elliptic leaf springs (from Simanaitis, 1976)

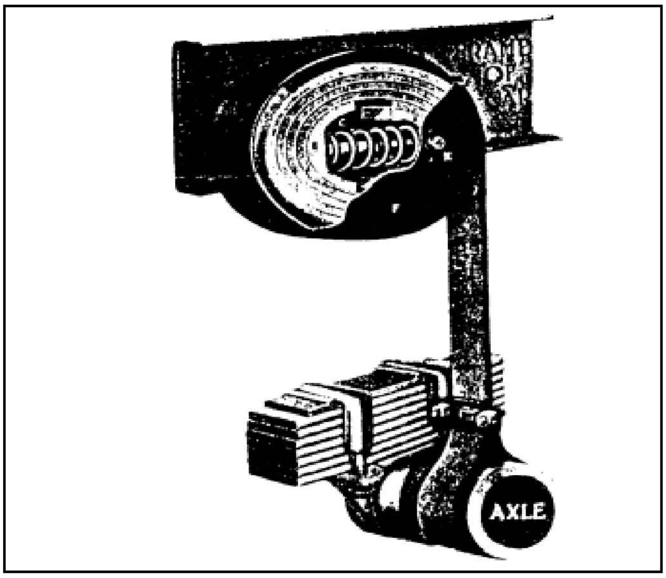


Figure 2.4: The Gabriel Snubber (1915) used a leather strap around sprung metal or wooden blocks to give restraint in rebound only (from Simanaitis, 1976)

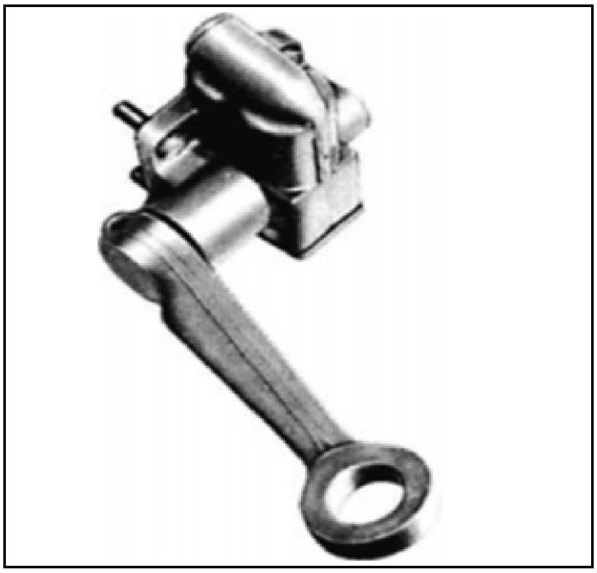


Figure 2.5: The simple lever-arm damper can be reinforced to carry suspension loads by lengthening the bearing rod.

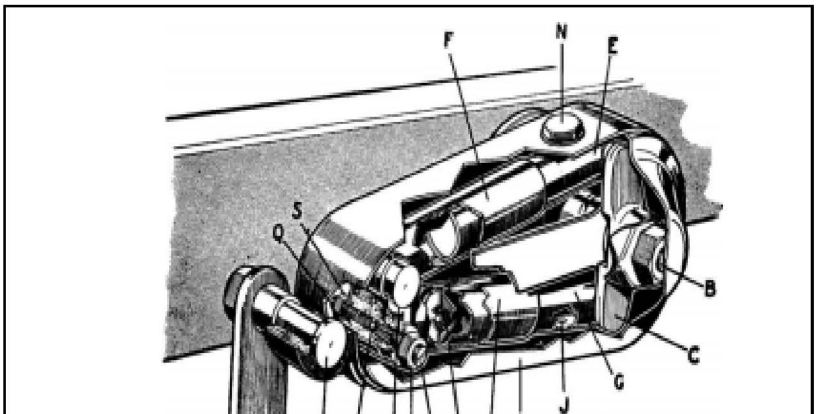


Figure 2.6: The Armstrong double telescopic lever arm damper.

Nowadays, only the hydraulic type of damper still used in this modern time. The basic hydraulic varieties are lever arm and telescopic [1]. The concept of lever arm is by using a lever to operate a vane [1]. Telescopic is most common used in this modern area, it can be divided into two main types which are either double-tube or gas-pressurized single-tube [1].

2.4 VEHICLE MODEL

Vehicle model can be divided into two parts.

2.4.1 Full Vehicle Model.

The full vehicle suspension system can be represented as linear seven degree of freedom (DOF) system [6]. It consists of a single sprung mass which is car body connected to four unsprung masses which are front-left, front-right, rear left and rear right wheels at each corner [6]. The sprung mass is free to bounce, pitch, and roll while the unsprung masses are free only to bounce vertically with respect to the sprung mass [6]. All other motions are neglected for this model. Hence this system consists of seven degree of freedom [6].The model of a full suspension system is shown in figure 2.7 below is represented by a linear seven degree of freedom, in this cases the lateral dynamics of the vehicle are ignored [6]. For the vehicle modeling full-car will be used as a good example of the entire car [6]. The equations of motion for this system are shown in figure 2.8 below.

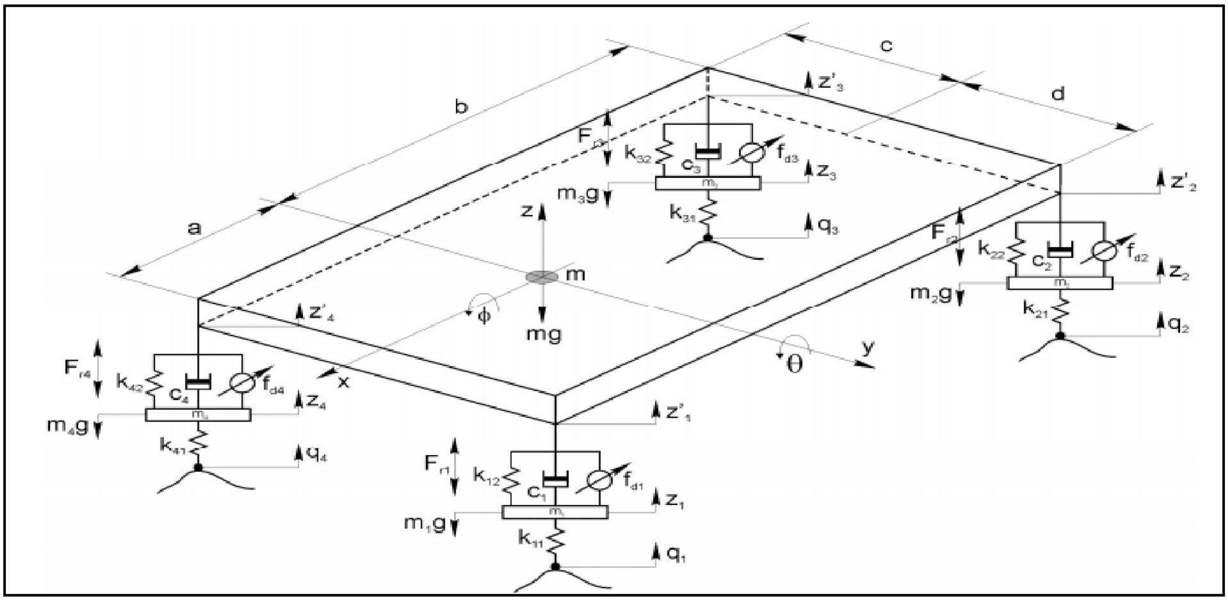


Figure 2.7: Full car model.

$$
\begin{cases}
m_1\ddot{z}_1 = k_{11}\left(q_1 - z_1\right) + k_{12}\left(z_1' - z_1\right) + c_1\left(\dot{z}_1' - \dot{z}_1\right) + f_{d1} + F_{r1} + m_1 g; \\
m_2\ddot{z}_2 = k_{21}\left(q_2 - z_2\right) + k_{22}\left(z_2' - z_2\right) + c_2\left(\dot{z}_2' - \dot{z}_2\right) + f_{d2} + F_{r2} + m_2 g; \\
m_3\ddot{z}_3 = k_{31}\left(q_3 - z_3\right) + k_{32}\left(z_3' - z_3\right) + c_3\left(\dot{z}_3' - \dot{z}\right)_3 + f_{d3} + F_{r3} + m_3 g; \\
m_4\ddot{z}_4 = k_{41}\left(q_4 - z_4\right) + k_{42}\left(z_4' - z_4\right) + c_4\left(\dot{z}_4' - \dot{z}_4\right) + f_{d4} + F_{r4} + m_4 g; \\
m\ddot{z} = k_{12}\left(z_1 - z_1'\right) + k_{22}\left(z_2 - z_2'\right) + k_{32}\left(z_3 - z_3'\right) + k_{42}\left(z_4 - z_4'\right) + c_1\left(\dot{z}_1 - \dot{z}_1'\right) + c_2\left(\dot{z}_2 - \dot{z}_2'\right) + \\
\quad + c_3\left(\dot{z}_3 - \dot{z}_3'\right) + c_4\left(\dot{z}_4 - \dot{z}_4'\right) - f_{d1} - f_{d2} - f_{d3} - f_{d4} - F_{r1} - F_{r2} - F_{r3} - F_{r4} + mg; \\
J_X\ddot{\varphi} = -\left[k_{32}\left(z_3 - z_3'\right) + c_3\left(\dot{z}_3 - \dot{z}_3'\right) + k_{42}\left(z_4 - z_4'\right) + c_4\left(\dot{z}_4 - \dot{z}_4'\right)\right]c + \\
\quad + \left[k_{12}\left(z_1 - z_1'\right) + c_1\left(\dot{z}_1 - \dot{z}_1'\right) + k_{22}\left(z_2 - z_2'\right) + c_2\left(\dot{z}_2 - \dot{z}_2'\right)\right]d + \\
\quad + \left(f_{d1} + f_{d2}\right)d - \left(f_{d3} + f_{d4}\right)c - \left(F_{r1} + F_{r2}\right)d + \left(F_{r3} + F_{r4}\right)c; \\
J_Y\ddot{\theta} = -\left[k_{12}\left(z_1 - z_1'\right) + c_1\left(\dot{z}_1 - \dot{z}_1'\right) + k_{42}\left(z_4 - z_4'\right) + c_4\left(\dot{z}_4 - \dot{z}_4'\right)\right]a + \\
\quad + \left[k_{22}\left(z_2 - z_2'\right) + c_2\left(\dot{z}_2 - \dot{z}_2'\right) + k_{32}\left(z_3 - z_3'\right) + c_3\left(\dot{z}_3 - \dot{z}_3'\right)\right]c + \\
\quad + \left(f_{d2} + f_{d3}\right)b - \left(f_{d1} + f_{d4}\right)a - \left(F_{r2} + F_{r3}\right)b + \left(F_{r1} + F_{r4}\right)a.
\end{cases}
$$

Figure 2.8: Equation of motion.

Where $m_1 \ldots m_4$ are the wheel masses (unsprung); m is the chassis mass (sprung); $k_{11} \ldots k_{41}$ are the tire stiffness coefficients; $k_{12} .. k_{42}$ are the suspension stiffness coefficients; $c_1 \ldots c_4$ are the damping coefficients; a, b, c and d are the distances of the chassis barycentre from suspension ;$q_1 \ldots q_4$ are the road profiles;$z_{1'} .. z_{4'}$ are the chassis vertical position; z is the chassis barycentre vertical position; J_x is the chassis moment of inertia around X axis; J_y is the chassis moment of inertia around Y axis ; φ is the chassis roll angle in radians; Θ is the chassis pitch angle in radians; $F_{r1} \ldots F_{r4}$ are the frictional forces due to rubbing pistons seals with the cylinder walls inside the actuators $F_{d1} \ldots F_{d4}$ are the hydraulic forces provided by actuators they are positive when the actuators under compression.[6].

2.4.2 Quarter Vehicle Model.

To minimize the scope of research the quarter vehicle model was used. Physical models for the investigation of vertical dynamics of suspension system usually applied on the quarter cat model [3]. This analysis was done only to the quarter-car model to explain correctly the roll and pitch motion of the car and the connected inertia forces [3].An example of quarter car model was shown in figure 2.9 below. The sprung and unsprung mass are z_b and z_w respectively. The damper produce force F_d while spring produce force F_s, the dynamic tyre load is F_{zdyn}, F_c describes the friction of the damper and ΔF_u is the additional force of the active or semi active components, body mass m_b,tire stiffness c_w and damping coefficient d_b are usually not constant [3]. Using the road displacement as r and the force F_b, which describe the body weight and the forces resulting from driving maneuvers, as inputs and using the body acceleration $\dot{z}_b$, the tire acceleration $\dot{z}_w$ and the suspension deflection $(z_w\text{-}z_b)$ as outputs,the equation for quarter car model can be derived as shown on figure 2.10 below [3].

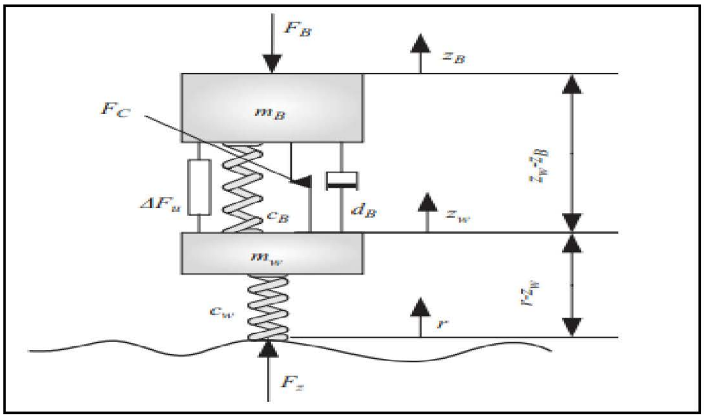


Figure 2.9: The quarter car model.

$$m_B\ddot{z}_B = c_B(z_W - z_B) + F_D - F_B + \Delta F_u,$$

$$m_W\ddot{z}_W = c_W(r - z_W) - c_B(z_W - z_B) - F_D - \Delta F_u.$$

Figure 2.10: Quarter car model equation.

2.5 OPERATING SPEEDS AND STROKES

The suspension bump velocities may be estimated under the following condition [1].

- Drop test
- Ride motions
- Longitudinal acceleration transients
- Lateral acceleration transients

2.5.1 Drop Test

Drop test can be defined a situation where the vehicle is released to fall freely from height h_D which is higher than the position at which the wheels touch the ground [1]. The wheels may initially be in the full droop position where the position of vehicle leaves the ground [1]. When the vehicle landing on the ground or when the vehicle is below that point at which the wheel and the ground touch together the springs and dampers will stimulate, and there will be relatively little further speed increase, unless the position of the drop is from very low initial position[1] . For a simple high drop analysis the impact speed V_1 can be obtained from the formula below in figure 2.11 [1].

$$\boxed{\tfrac{1}{2}mV_1^2 = mgh_D}$$

Figure 2.11: Simple high drop analysis

Where m is the mass and g is the gravitational field strength leading to formula shown in figure 2.12 below [1].

$$\boxed{V_1 = \sqrt{2gh_D}}$$

Figure 2.12: Impact speed formula.

2.5.2 Free Drop Release

Free drop release can be defined as the condition where the vehicle body to be temporarily fixed, a wheel may be suddenly released so that the suspension is forced into droop motion under the action of the main suspension spring [1]. In a real situation it might occur if one wheel suddenly passes over a wide hole, if the suspension was previously in a normal position, the free force on the wheel equals the normal suspension force about mg/4 [1]. This will give free extension velocity of 2 m/s or more, large in damper terms [1]. Figure 2.13 below shows the speed at which the car will experience on the car if the springs instantly be removed [1].

$$\boxed{V_R = \frac{mg}{\sum C_D} = \frac{g}{2\zeta}\sqrt{\frac{m}{\sum K}} = \frac{g}{2\zeta\omega_{NH}}}$$

Figure 2.13: Speed when damper is removed

Where K is the spring stiffness, C_D are the effective values at the wheels and the natural heave frequency in rad/s is ω_{NH} [1].

2.5.3 Ride Motions

The normal suspension system responses occur at the natural heave frequency f_{NH} of the vehicle, around 1.4 Hz for a passenger car [1]. For a sinusoidal motion on displacement, the velocity and acceleration are also changed into sinusoidal [1]. The amplitude of this characteristic are called the displacement amplitude, the velocity amplitude and the acceleration amplitude [1]. The term amplitude means the displacement amplitude increase twice at the distance between extreme positions and is called the stroke [1]. Figure 2.14 below shows that the velocity amplitude V_{SB} depends on the heave displacement amplitude Z_H [1].

$$\boxed{V_{SB} = \omega_{NH} Z_H = 2\pi f_{NH} Z_H}$$

Figure 2.14: Formula for suspension bump velocity.

Where φ_{NH} is the radian natural frequency (rad/s) of the body in heave [1].

2.5.4 Longitudinal Acceleration Transients

Variations of longitudinal acceleration cause angular pitch motions and occur by sudden application that can stop the vehicle such as removal of engine power or brake action, with a step change of A_x [1]. In the real situations this can easily demonstrated with applying brakes that kept firmly on as the vehicle [1]. Considering a longitudinal deceleration A_x on a simple vehicle having wheelbase L with centre of mass at the midpoint, centre of mass height H_G and suspension stiffness wheel rate K_w at each wheel. Angular pitch angle Θ radians gives a suspension bump displacement as shown in figure 2.15 below.

$$z_{SB} = \frac{1}{2}L\theta$$

Figure 2.15: Suspension bump displacement.

Hence the restoring pitch moment M_p as shown in figure 2.16 below [1].

$$M_P = 2K_W z_{SB} L = K_W L^2 \theta$$

Figure 2.16: Pitch moment

And the pitch angular stiffness K_p as shown in figure 2.17 below [1].

$$K_P = K_W L^2$$

Figure 2.17: Angular stiffness

A longitudinal acceleration A_x gives longitudinal load transfer moment as shown in figure 2.18 below [1].

$$\boxed{M_{AX} = mA_X H_G}$$

Figure 2.18: Longitudinal load transfer.

With an associated pitch angle as shown in figure 2.19 below [1].

$$\boxed{\theta = \frac{M_{Ax}}{K_P} = \frac{mH_G}{K_W L^2} A_X}$$

Figure 2.19: Associated pitch angle

And a suspension deflection formula as shown in figure 2.20 below [1].

$$\boxed{z_S = \frac{1}{2} L\theta = \frac{mH_G}{2K_W L} A_X}$$

Figure 2.20: Suspension deflection formula.

Hence the natural frequency f_{NP} of pitch motion formula shown in figure 2.21 below [1].

$$f_{NP} = \frac{1}{2\pi}\sqrt{\frac{K_P}{I_{PB}}}$$

Figure 2.21: Natural frequency

Heave frequency for almost vehicle at around 1Hz, hence the estimated suspension bump velocity for this amplitude and frequency $V_{SB,AX}$ shown in figure 2.22 below [1].

$$\begin{aligned} V_{SB,Ax} &= \omega_{NP} z_{SB} \\ &= 2\pi f_{NP}\left(\frac{mH_G}{2K_W L}\right)A_X \end{aligned}$$

Figure2.22: Estimated suspension bump velocity

Where ω_{NP} is natural frequency of the body in pitch and z_{SB} is the displacement of the suspension in bump [1].

2.5.5 Lateral Transient (Roll)

Lateral transient can be analyzed in a similar way to longitudinal motions, sudden changes of lateral acceleration cause roll motions [1]. A lateral acceleration causes a suspension roll angle as shown in figure 2.23 below [1].

$$\boxed{\phi_S = k_{\varphi S} A_y}$$

Figure 2.23: Suspension roll angle.

$k_{\varphi s}$ is the suspension roll angle gradient of about 0.014 rad/ms^{-2}(0.80°/ms $^{-2}$,8°/g, 0.14 rad/g). The corresponding suspension deflection z_s shown in figure 2.24 below [1].

$$\boxed{z_S = \tfrac{1}{2}\phi_S T}$$

Figure 2.24: Suspension deflection

With Θ_s in radians and a track (tread) T of about 1.5m. For a roll natural frequency f_{nr} the suspension velocity amplitude shown in figure 2.25 below [1].

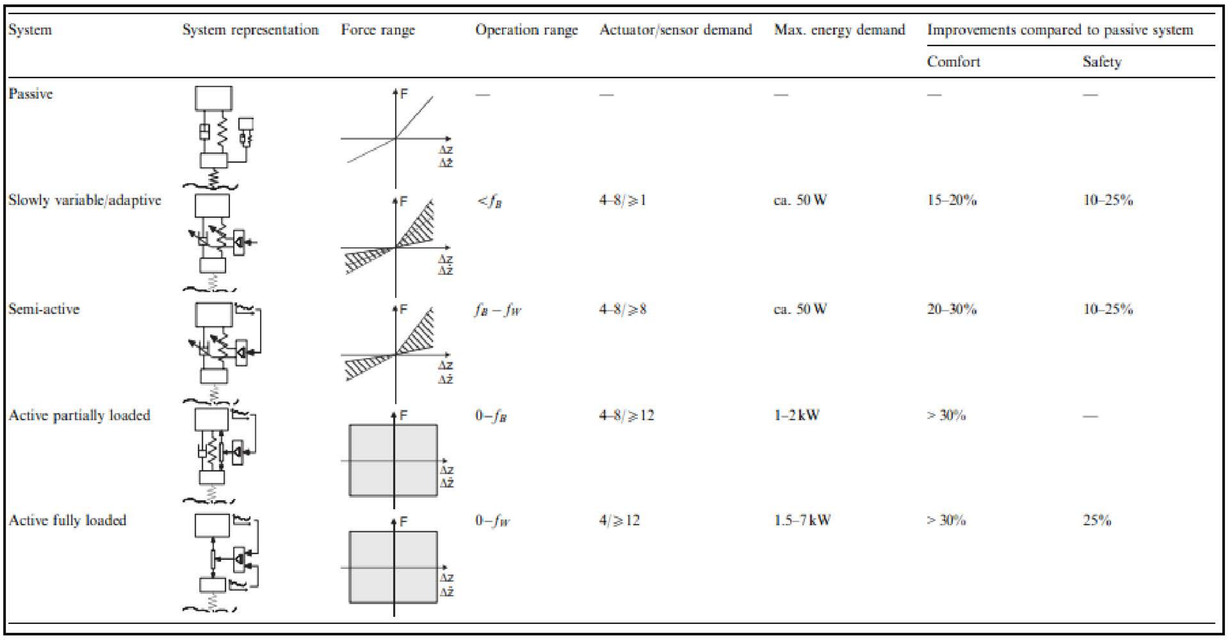
$$V_{SB,Ay} = 2\pi f_{NR} z_{SB} = \pi f_{NR} \phi_S T$$

Figure 2.25: Suspension velocity amplitude

In a real situation, for a passenger car a natural roll frequency of 1.5Hz and a suspension deflection of 10 mm/ms^{-2} (100 mm/g)[1]. Entering a normal corner of lateral acceleration 3m/s^2(0.3g), the suspension deflection is about 30mm and velocity 0.30 m/s[1]. An extreme corner gives 80 mm stroke and 0.60 m/s, depending on the time for steering wheel movement [1].

2.6 CLASSIFICATION OF SUSPENSION SYSTEM

Suspension systems are classified into three types which are passive system, semi active system and active system. The classification of the suspension system was shown in figure 2.26 below [3].



System	System representation	Force range	Operation range	Actuator/sensor demand	Max. energy demand	Improvements compared to passive system	
						Comfort	Safety
Passive			—	—	—	—	—
Slowly variable/adaptive			$<f_B$	4–8/≥1	ca. 50 W	15–20%	10–25%
Semi-active			$f_B - f_W$	4–8/≥8	ca. 50 W	20–30%	10–25%
Active partially loaded			$0–f_B$	4–8/≥12	1–2 kW	> 30%	—
Active fully loaded			$0–f_W$	4/≥12	1.5–7 kW	> 30%	25%

Figure 2.26: Classification of suspension system.

2.6.1 Passive System

Passive system is a conventional shock absorber that the parameters are synthesized through off-line design technique and no online feedback actions are used [4]. Passive systems are designs that have permanent designs that the control cannot be adjusted when the system or the operating condition changes such as different ride motion [4]. Two main parameters in vehicle are ride and handling [7]. In a passive suspension system it may results in good vehicle handling but at the same time has the disadvantage of causing passenger to experience harsh ride [7]. A harsh ride is the parameter that we want to avoid since it may cause damage to the vehicle [7]. On the other hand, passive suspension system can reduce the stability of the vehicle [7]. Ride can be defined as energy input measured at the driver seat [7]. This energy input will relate to the comfort, performance and safety, in a traditional measurement in military vehicle it must be limited to 6 watts rms [7].To meet the right requirement the parameters that need to be adjusted are increased course speed, increase the suspension travel, lowered the primary springs rates and lowered the selectively damping rates [7]. While handling can be defined as a parameter that shows the better a wheel can follow the undulations in terrain and the better it can transmit driving, braking and cornering movement [7]. Excessive body motions in turn can unfavorably distribute tire force and adversely affect the handling [7].

2.6.2 Semi Active Suspension System

Suspension system of machines and structures is the important mechanism to reduced noise and vibration, nowadays it becoming more complex and more important than ever [9]. Among others, the semi active suspension system is known to be good choice for practical application because it combines the advantage of passive and active suspension system [8]. Semi active suspension systems provide a good solution to the passive system such as not requiring high power actuator or supplies [9]. Although the performance of semi active suspension system is a little bit low than the active suspension system but in terms of cost it far less than the active suspension system [9]. Semi active control laws, which are often developed by modifying active control laws require an accurate and yet complex mathematical model will be used in order to change the system parameters [9]. Potential customer benefits of the semi active suspension systems include [7];

- An adjustable ride, optimized for comfort or handling performance
- Suspension will semi automatically adjust according to road condition
- User has the option to select the firmness of the suspension
- There is no change in size from traditional suspension system

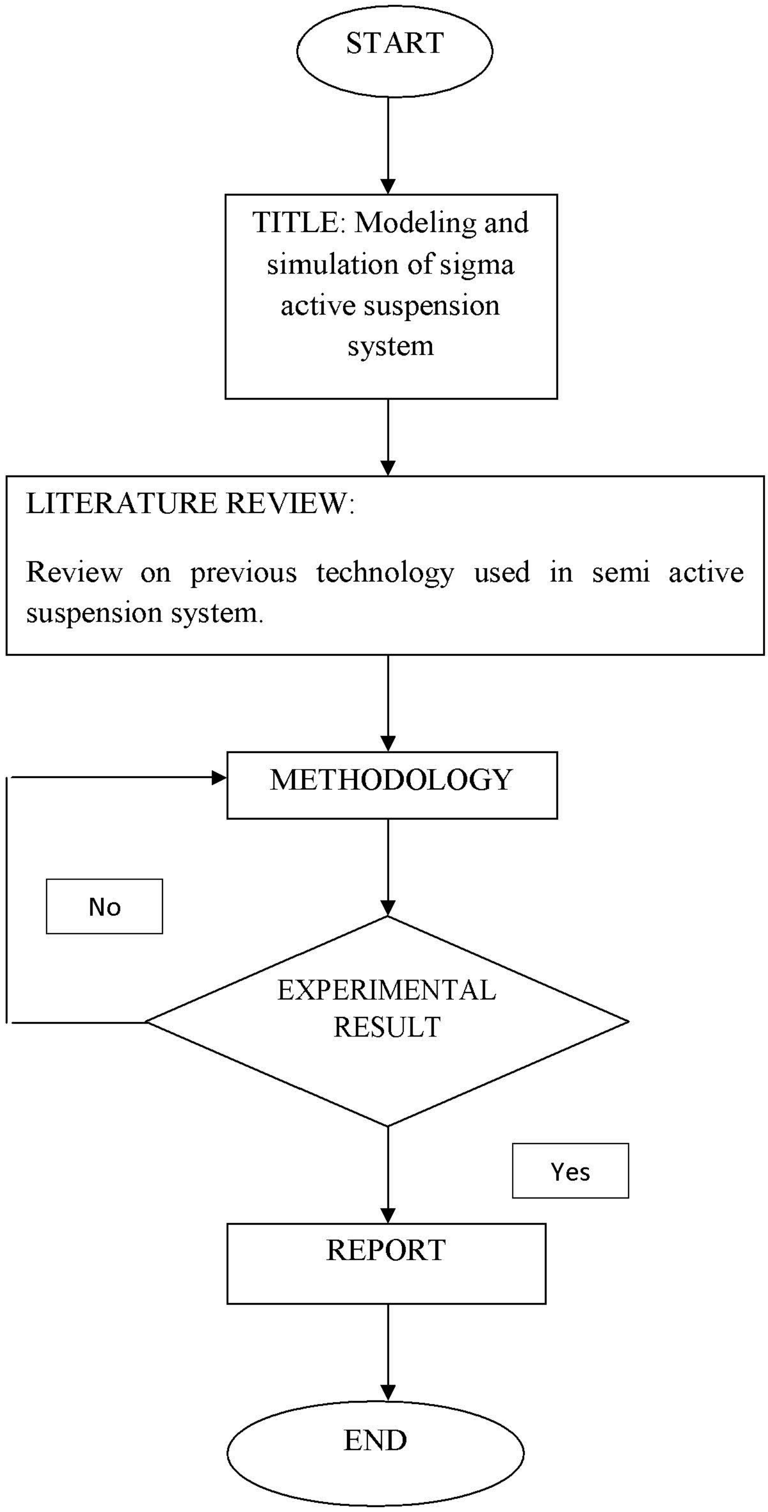
2.6.3 Active Suspension System

Active suspension system also known as Computerized Ride Control can be defined as a independent system in which it has the capability to adjust itself continuously based on desired or suitable situation [7]. In scientific term, it artificially extends the design parameters of the system by constantly monitoring and adjusting itself thereby changing its character on an ongoing basis, in other word this system use feedback as an input to make them response [7]. With advanced sensors and microprocessors feeding it information all the time and by changing its character to respond to varying road conditions, active suspension system offers improvement in handling, road feel, responsiveness and safety [7]. Basic components for active suspension system are computer, adjustable shocks and spring, a series of sensor and an actuator or servo atop at each shock and spring [7]. The most important component in this system is computer; it will function as a brain for this system in order to make a decision for this system. The components may vary depend on the manufacturer to manufacturer but these are the basic part that make up an active suspension system. Active suspension system can modify its character like adjusting shock stiffness, a spring rate and the like to improve ride performance, drivability and responsiveness. Controlling an active suspension system require a lot of feedback from sensor, a set of sensor situated in different location in vehicle in order to be processed by one or more controllers in order to calculate the control forces that should be actuated by hydraulic actuators [7]. Sensors, controllers and actuators usually communicate through a shared bus [7]

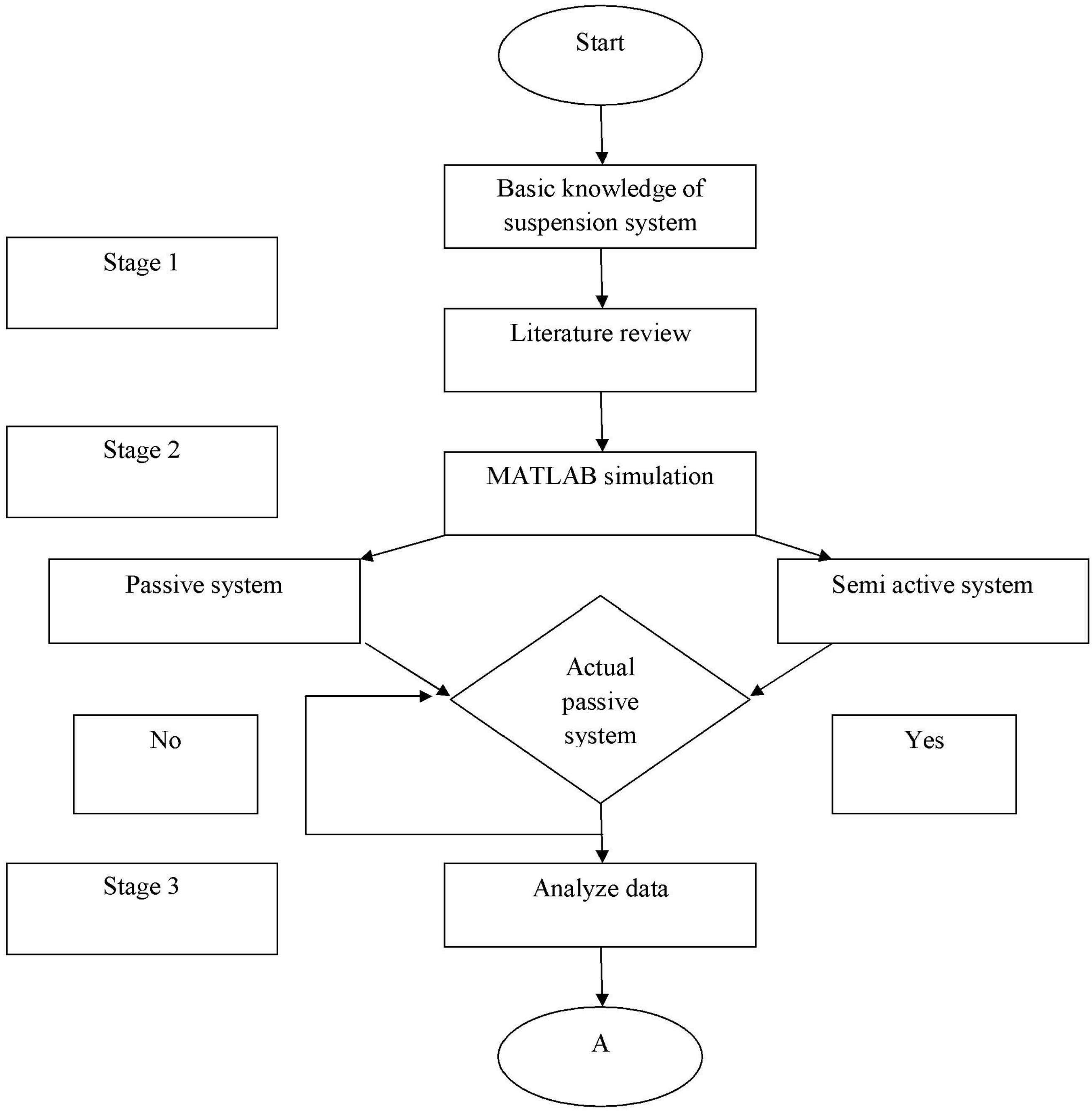
CHAPTER 3

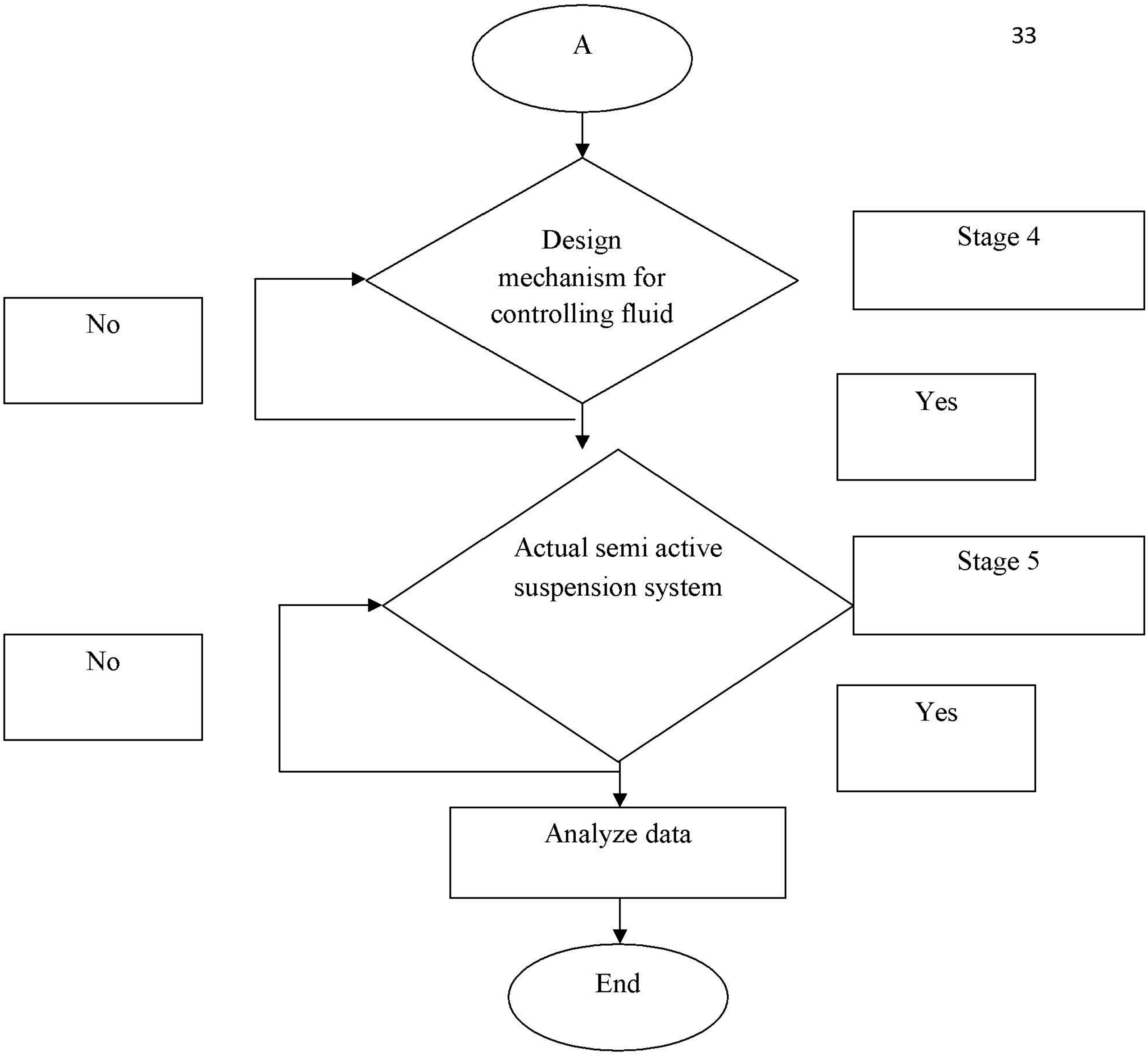
METHODOLOGY

3.1 PSM FLOW CHART



3.2 METHODOLOGY FLOW CHART





3.3 INTRODUCTION

Research methodology is a method used to collect information and data for the purpose of research project. This section describes the method used to start the research. The flow chart shows process occurs starting from the selection of the topic until the end of the research. Methodology is one of the important parts in order to achieve the research objective. There are five methodology stage applied in this project, there are;

3.3.1 Stage One

Stage one is the basic step in order to conduct a project. Stage one is a collection of information based on the previous research. On this stage we can look through and make comparison based on previous method used by other people and come out with better solution. This review is to know the principle of suspension system, factor effecting suspension system, previous research on suspension system as well as their limitation and how to improve the system. Stage one also called as literature review. A literature review is an evaluative report of studies found in the literature related to your selected area. The review should describe, summarize, evaluate and clarify this literature. It should give a theoretical basis for the research and help in determine the nature of your own research. The sources of literature review for this project are journal, textbook and online article. The literature review for this project covers several issues such as history of shock absorber, introduction of shock absorber, basic type of shock absorber, vehicle model, operating speeds and strokes and lastly classification of suspension system.

3.3.2 Stage Two

Second stage is simulation using software, this simulation accomplished by using MATLAB software. Developed by Math Works, MATLAB allows matrix manipulations, plotting of functions and data, implementation of algorithms, creation of user interfaces, and interfacing with programs written in other languages, including C, C++, JAVA and FORTRAN. MATLAB is powerful software that covers wide range of applications, including signal processing and communications, image and video processing, control systems, test and measurement, computational finance, and computational biology. Simulation using this software applied for passive and semi active system, this is to ensure that the real problem is valid if we compared with simulation using software. Simulation for this project use road profile factor as a manipulative variable. Different road roughness characteristics have been taken into account according to the ISO classification. The profiles are differentiating by several classes such as A for very good, B is good and lastly C is average. In a real situation the classification of road roughness distinguish by the different speed of the suspension system such as 60, 90 and 120km/h. While the responding variable for this project is bounce acceleration of the centre of gravity. Theoretically the acceleration of the centre of gravity for passive is higher than semi active system.

3.3.3 Stage Three

Next, in stage three experiments for the passive system was conducted in order to make a comparison and to investigate the factor that affecting the performance of passive system. Passive system in this contact is an experiment conducted using normal suspension system. The performance of suspension system was tested by using shock absorber test rig, test rig is a shock simulation machine that generates motion which are applied to the shock absorber to test it for shock absorbing capacity. Figure 3.1 below shows example of shock absorber test rig. This experiment was assist by company specialist in suspension component manufacturing name as Sapura Automotive Industries Sdn Bhd. Sapura Automotive Industries Sdn Bhd supplies suspension system to reputable automotive manufactures nationwide, amongst them Proton, Perodua, Volvo and Daihatsu. Sapura is a leading company expertise in production of absorber, coil spring, stabilizer bar and strut assy.

Figure 3.1: Test rig

3.3.4 Stage Four

In this stage, new method is proposed in order to exhibit semi active characteristic, which is controlling the fluid flow. The fluid flow will be control manually by turning lead screw inside the shaft 10 times with anticlockwise direction. Needle valve will adjust the variation no of hole. The no of hole will determine the volume of fluid damper flow to the damper either to compression or rebound chamber based on stroke applied. When the volume of fluid increases, the stiffness of the spring will increase, hence the objective will be achieved in order to separate between sprung mass and unsprung mass. The principle behind the operation is quite simple. When the piston rod is pressed and moves toward the bottom valve, the pressure in chamber B increases. When vehicle experienced more oscillation the pressure in chamber B will increase continually, in order to balance the force experienced by chamber B the valve will open in order to let the damper fluid flow inside the chamber. When appropriate volume of fluid flow to the chamber, hence it will push the piston more to the chamber A and at the same time adjust the stiffness of the spring. Figure

3.2 below describe the position of the chamber. The advantage of using this method is easy to fabricate and easy to control. However the disadvantage of this method is the amount of fluid flow to the piston chamber is not accurate.

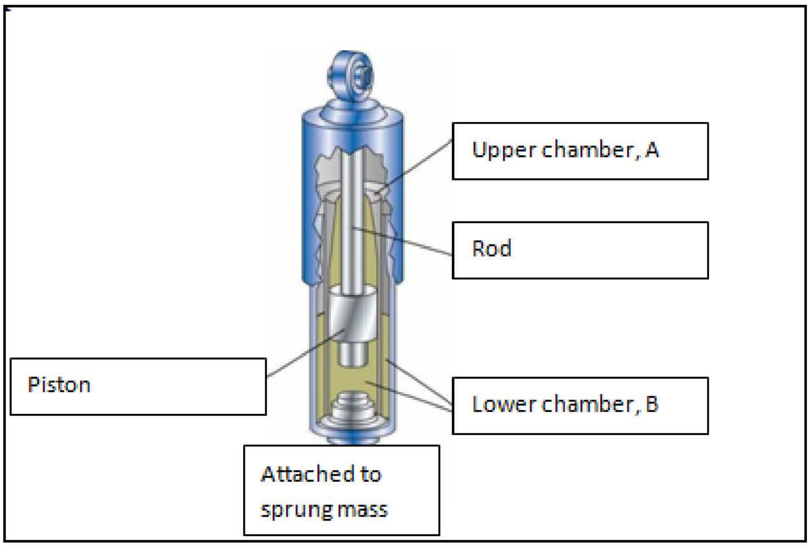


Figure 3.2: Inner side of damper system

3.3.5 Stage Five

Finally, experiments are conducted by implementing developed semi active suspension system by using lead screw as the position control. Lead screw was proposed since it fulfill characteristics that must be considered when dealing with semi active throttle mechanism. There are accurate angle control and lastly high torque. The next characteristic is accurate angle control which in this project there are three valve that control the fluid flow to the damper, the three valve place at different position at the outer surface of the damper. The turning angle of the lead screw will determine the number of hole that will open. The gap between one hole to each other is 8mm, since the lead screw used for this project is M5 with pitch 0.8, user should turn 10times with anticlockwise direction in order to open one valve at a time. Hence, it related with the volume of damper oil flow to the damper. The last characteristic is high torque; high torque is needed since the lead screw needs to pull the needle valve to open the valve. High torque is needed since the barrel is placed in the damper oil.

CHAPTER 4

RESULT AND DISCUSSION

4.1 INTRODUCTION

This chapter shows the collection of the data obtained from simulation, real passive and real semi active result. The data were collected and then processed in response to answer all the problems that have been faced in chapter 1. Sets of data for pressure and speed of the stroke will be compared and analyzed in order to prove the factor that make the system become variable. Besides that in this chapter it will describe the methodology used to answer research question for this project.

4.2 BLEED ORIFICE VALVE ADJUSTMENT

The damper is comprised of a piston assembly that moves inside a fluid filled cylinder. The damper system consists of two modes which are compression and rebound stroke, during compression stroke fluid flow from compression chamber into rebound chamber while during the rebound stroke the piston rod is being retracted from the fluid filled cylinder causing flow from the rebound to the compression chamber. This flow is related to the pressure differences in the pressure chambers. Pressure in the rebound chamber is denoted as P_r and pressure in compression chamber is denoted as P_c. During compression P_c is greater than P_r this pressure difference drives the flow from the compression chamber to the rebound chamber and generates damping forces. For a passive system the fluid allow to flow via two paths which are compression shims and leakage flow around piston cylinder wall. For this prototype, the flow aided by existence of bleed orifice valve which can be controlled .All flow paths are shown in figure 4.1 below.

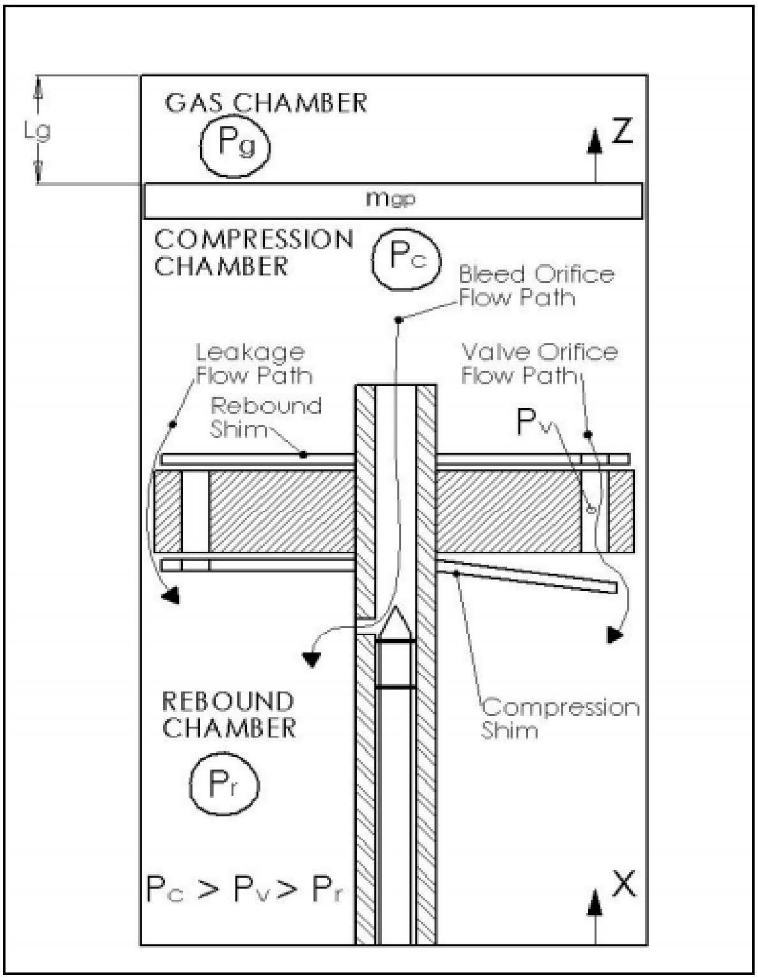


Figure 4.1: Total flow valve

The significant valve in this project is flow the bleed orifice. The bleed orifice flow path begins at the end of the piston rod in the compression chamber as shown below in figure 4.2 and ends out of the side of the piston rod in the rebound chamber as shown below in figure 4.3. The bleed orifice size can be controlled by moving the needle valve inside the piston rod. The needle valve inside the shaft absorber is adjusted in or out using the lead screw inside the absorber shaft. The bleed orifice can be controlled from fully open for less damping to fully close for increasing damping. To fully open the valve all three hole at rebound chamber need to open completely, to fully open all three hole the lead screw need to turn thirty times with anticlockwise direction and vice versa.

Figure 4.2: Bleed orifice beginning

Figure 4.3: Bleed orifice ends

4.3 SIMULATION VS REAL RESULT

Simulation result accomplished by using MATLAB software. MATLAB is powerful software that covers wide range of applications. Simulation using this software applied for passive and semi active system, this is to ensure that the real problem is valid if we compared with simulation using software. While for a real passive result was obtained by testing with Sapura absorber. For a comparison between simulation and actual passive absorber the plot used to characterize performance is the Force vs. displacement plot. FD plot use the same sign convention; positive for compression, negative for rebound. Figure 4.4 below shows graph for passive result, as we can compare from the shape of the graph, both result shows exactly the same shape. However if we compared with total graph produce, it shows differences because in simulation result the speed during stroke is fewer as we compared with the real result. For a real result from Sapura absorber it used their specific speed such as 19.1 rpm, 49.66 rpm, 99.31 rpm, 114.59 rpm, 148.97 rpm, and 198.63 rpm for testing purpose. These speeds represent the rode condition experienced by the car during real driving situations, 19.1rpm represent car absorber speed during flat or normal road condition while 198.63rpm represent car absorber speed during pass through a hole or rough road condition. Figure 4.5 below shows the Sapura testing parameter. Moreover, difference between data in both graph due to the unit used. For simulation result it used U.S unit such as lbs and inch, while for actual result it used SI unit. Different unit will come up with different data. For a passive system, fluid allow to flow only via compression shims and leakage flow around piston cylinder wall. The flow for this system is constant since the two valve used is a fixed design.

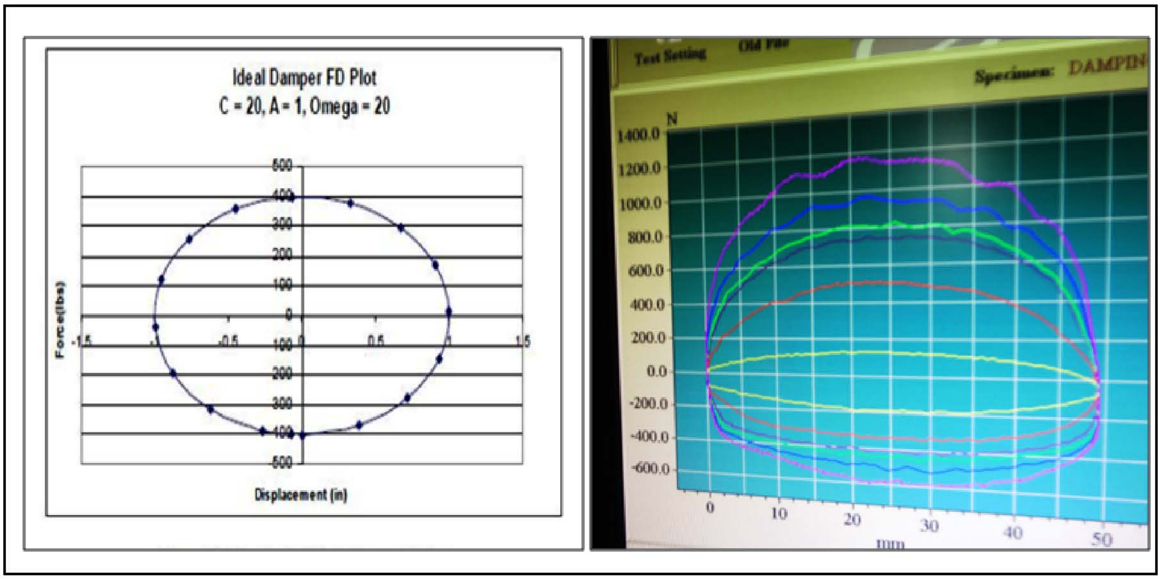


Figure 4.4: Passive simulation and real result

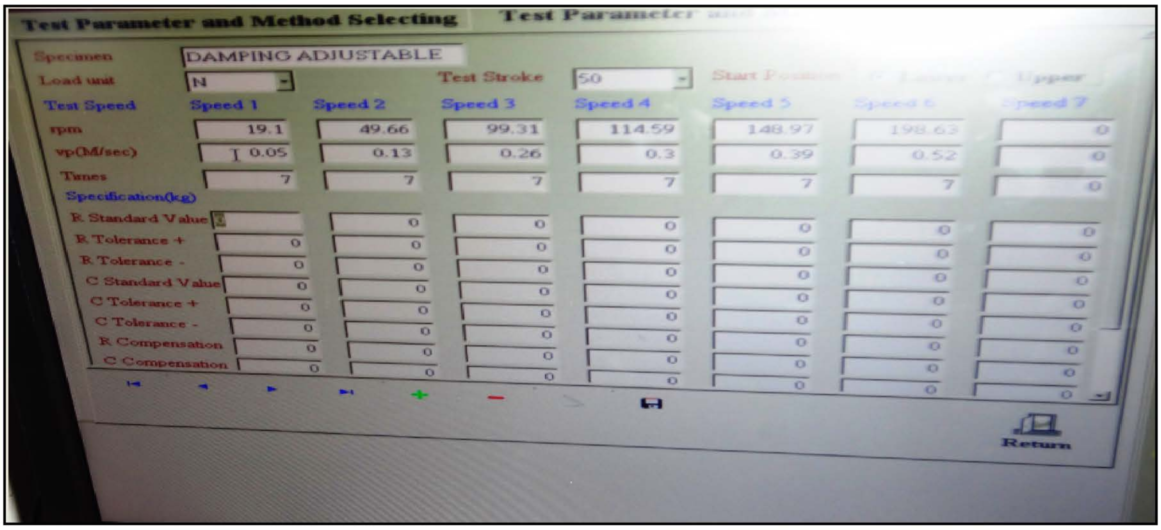


Figure 4.5: Sapura testing parameter

For semi active system which the fluid flow assisted by controlled valve which is bleed orifice valve. Data of force vs. displacement plot are captured when the size of bleed orifice increase slowly. Figure 4.6 below shows when the size of bleed orifice size increase the graph for compression side which is the upper part of the graph underwent reduction, shows the concept used approved, this reduction on the compression part shows the fluid can flow via bleed orifice valve to reduce pressure inside the compression chamber.

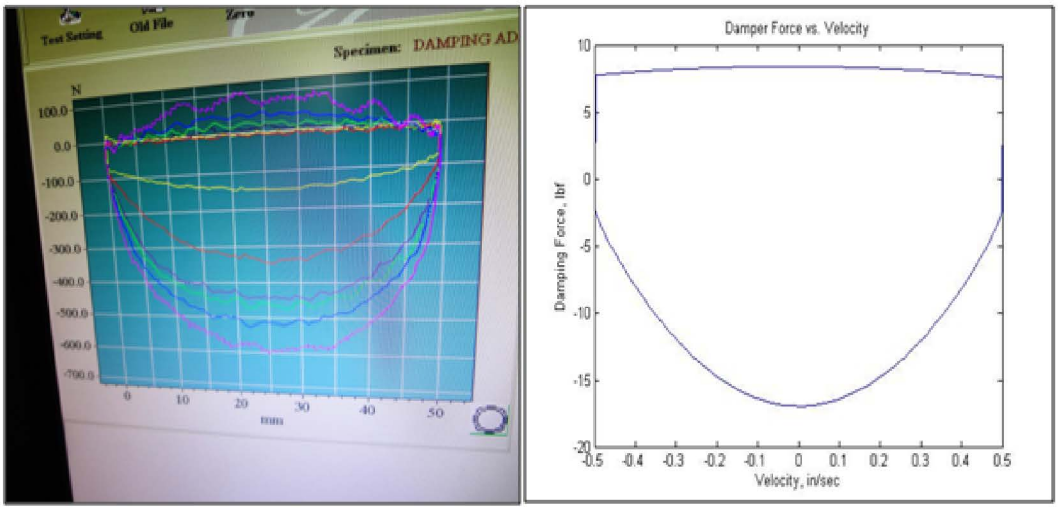


Figure 4.6: Semi active simulation and real result.

4.4 REAL PASSIVE VS SEMI ACTIVE NO HOLE OPEN

Figure 4.7 and 4.8 below shows the graph from experiments that involve comparison between passive system and semi active system when the bleed orifice valve completely closed. Conceptually, the graph for both experiments should show the same result since for semi active system the bleed orifice valve is completely closed, during stroke the fluid only allow to flow only via shim stiffness and leakage flow around piston wall same as passive system. However the data obtain from these experiment shows slightly different from each other. The data for Sapura absorber shows higher force produce during both chambers. The uncertainties result in the both chamber might cause imprecise during fabrication process such as not follow the right dimension as given from Sapura specification or the bur does not remove completely during finishing process. If there is bur remain inside the shaft it might interrupt the fluid flowing process, for example during normal process the fluid will flow via shim stiffness, during compression stroke the shim at the rebound side will deflect as a result of fluid push the shim but at the same time will close the shim at the compression side, this is to make sure the fluid only allow to flow in one direction and preventing flow in opposite direction when the pressure differential is reversed, if there is bur in between the shim, the shim does not close or open completely. This will make the fluid can flow two ways. The other factor is the different material used to make absorber shaft, original shaft from Sapura Automotive is made from S45C mild steel material and undergo hardening and hard chroming process, while for this prototype it used normal S30 stainless steel.

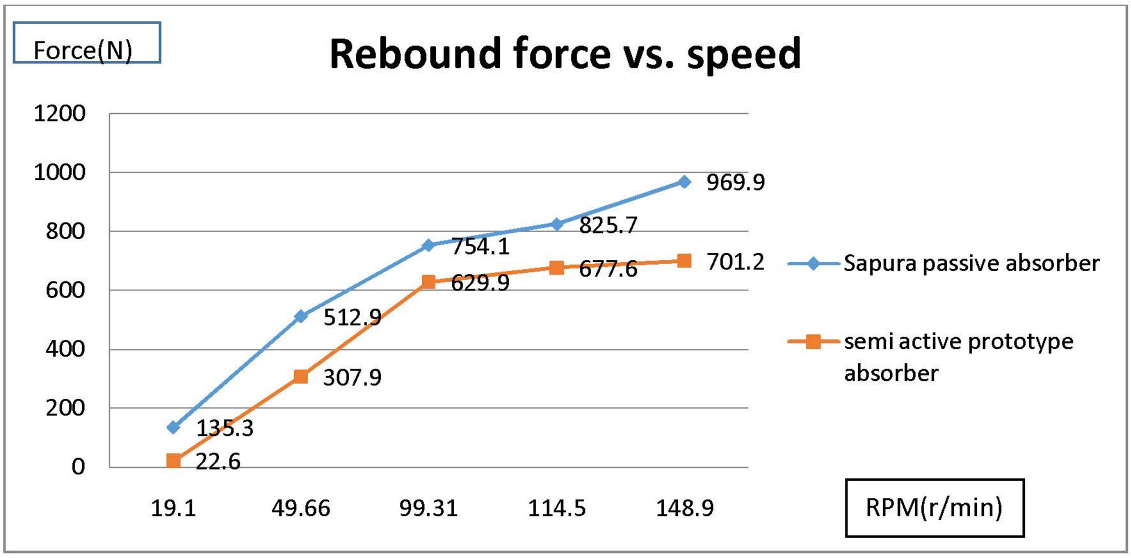


Figure 4.7: Graph for rebound force vs. speed

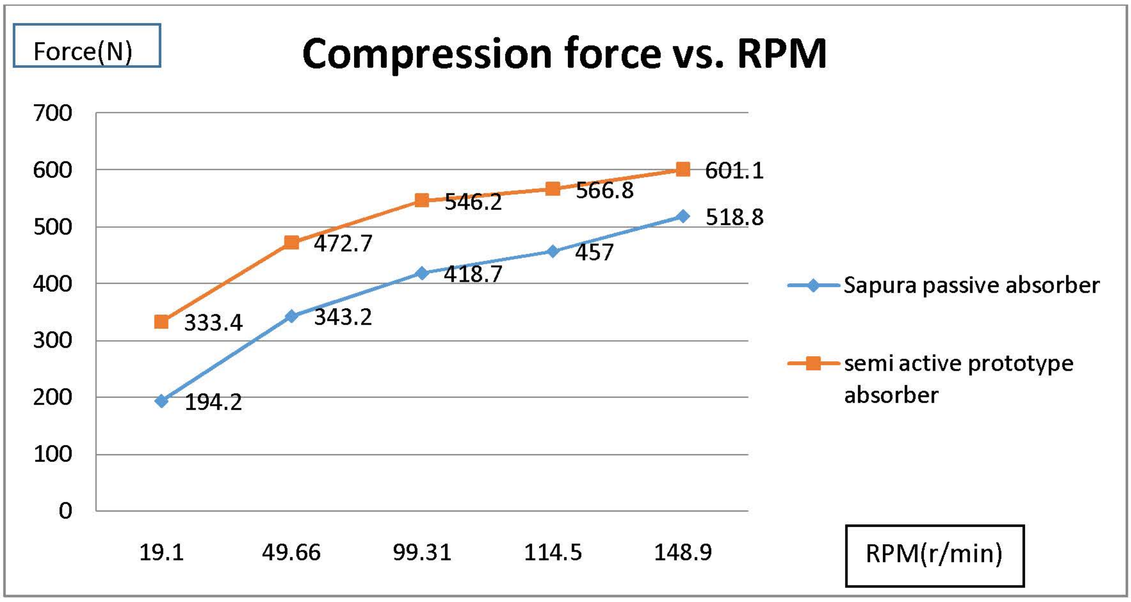


Figure 4.8: Graph for compression force vs. speed

4.5 SEMI ACTIVE RESULT

While in figure 4.9 and 4.10 below shows the result from semi active system. During semi active process the fluid flow was aided by bleed orifice valve, by using bleed orifice valve the opening and closing of the valve can be controlled. During compression stroke the flow path begins at the end of the piston rod in the compression chamber and ends out of the side of the piston rod in the rebound chamber while during rebound stroke the flow begins at the side inlet hole in the piston rod, and exits out the end of the piston rod into the compression chamber. After examination of the compression force vs. RPM, it can be seen that physical operations of the damper fulfill the pressure difference rule. As we can compare between all the compression graph shown in figure 4.9, we can conclude that as the number of hole increase the pressure will decrease this shows that the fluid can flow via bleed orifice valve to reduce pressure inside the compression chamber. However for rebound graph as shown in figure 4.10 it shows uncertainties in the result, it might due to imprecise in fabrication process during drilling three hole for inlet valve. This result shows the fluid cannot return back via three hole provided to return to compression chamber to reduce force. This might due burr remain inside the hole and directly interrupt the fluid flow process.

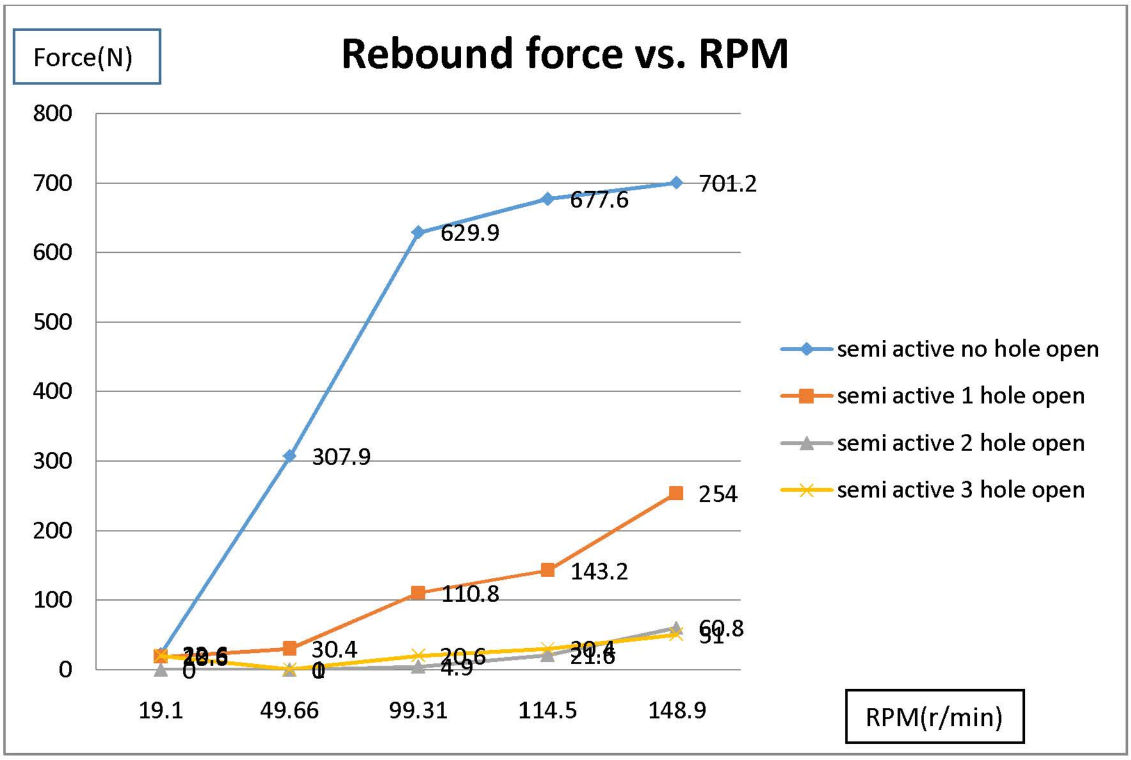


Figure 4.9: Graph for rebound force vs. speed

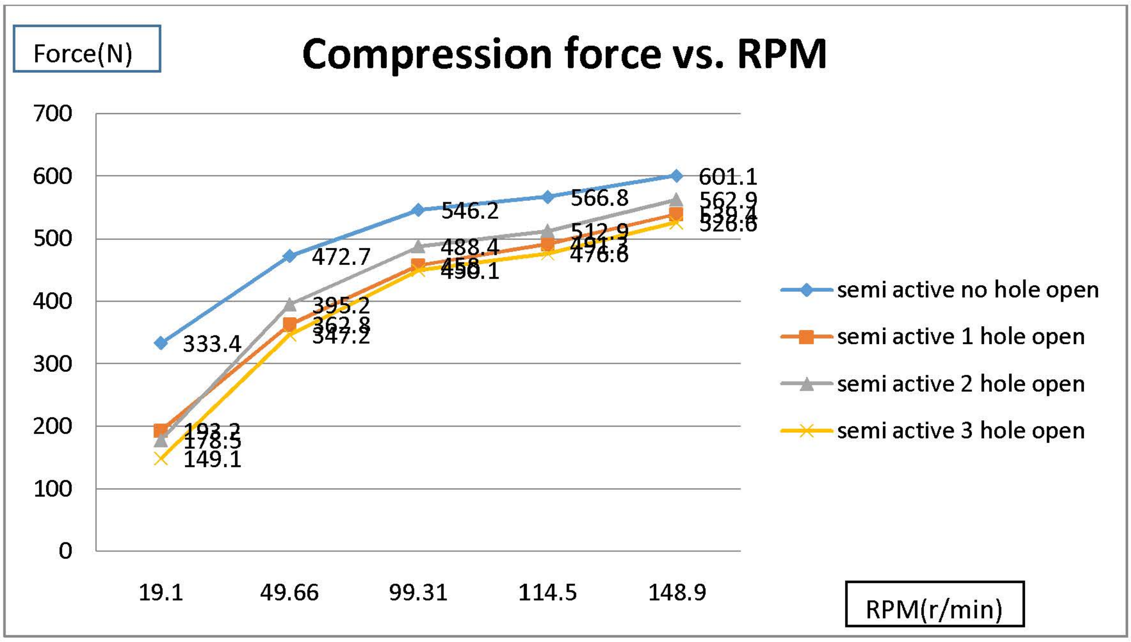


Figure 4.10: Graph for compression force vs. speed

CHAPTER 5

CONCLUSION

5.1 INTRODUCTION

This chapter summarizes the findings, generated conclusions and recommendation on the analysis of the results on modeling, simulation and experimental verification of a semi active absorber system. The first section will summarize all the data and answer the objective of the research. A summary of the major results will be described also in this section. The second part will propose recommendations for further research.

5.2 CONCLUSION AND RECOMMENDATION

This research was conducted in order to answer all four objectives showed in previous chapter. The four objective of this study are: to investigate the passive and semi active suspension system using MATLAB, to determine the factor that changes the suspension system become variable, to design and fabricate semi active suspension system and to distinguish the performance between passive and semi active suspension system.

Simulation for this project use MATLAB software, this simulation was done to ensure that the real situation problem is valid if we compared with simulation using software. For both experiment the graph will shows the characterize performance for Force vs. Displacement plot. Through a comparison between simulation and real FD plot it shows the experiments met its objective. This experiment assumed to be successful when it can produce same type/shape of the FD graph. Both graphs also show the same sign convention, positive for compression and negative for rebound. For further research, there are some recommendation in improving collecting data for simulation and real, equalize the parameter used and unit used. For example during real simulation there are 5 graphs produce so the simulation also should come up with the same no of graph this will make the comparison more accurate. Other than that the unit also needs to synchronize between those two experiments either using SI unit or U.S unit.

Then, the factor that change the system from passive to semi active system was identified, it is by changing the fixed design to control fluid flow into valve system that can be controlled. Bleed orifice valve is a valve that move in or out to control the closing and opening of the hole by moving the lead screw inside the shaft. As the data obtained from test rig machine, it shows the pressure reduce when the number of hole open increase, from the result it shows the fluid can flow via bleed orifice valve.

Besides that, semi active absorber systems have been design and fabricate. During fabrication process there are many advance machine have been used, there are horizontal bend saw, gun drill machine, turning machine, milling machine, die sinking machine and welding machine. These machines have been used to duplicate and make an adjustment in valve controlling system for this prototype. Hence, the pressure difference can be compared between original passive system and prototype semi active system. The difference between two graphs clearly showed in figure 4.7 and 4.8. The data shows uncertainties result between those two absorber, this is because imprecise during fabrication process. In order to improve the system, the entire factor during fabrication process need to considered such as during finishing process. During finishing process remove all burrs in order to make the fluid flow process run smoothly. Other than that, in searching for corrective action, raw material also can be source of error, the material used also need to be considered, to get the accurate data for comparison both shaft should use the same material S45C material, different material have different mechanical properties. S45C material suitable for shaft studs, this material also excellence in weldability and machinability while S304 stainless steel suitable only for general purpose.

From this project, it can be concluded that this semi active system has wide potential in automotive industry. This system comprises the advantage from passive and active system. This system will reduce the cost but at the same time get the functionality. Besides that, bleed orifice valve prove the theory where it allow the fluid to flow to reduce force, when the fluid flow can be controlled the characteristic where a good damper must contain where it can split between the body and the wheel can be achieved.

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APPENDIX

1. Gantt Chart for Final Year Project 1
2. Gantt Chart for Final Year Project 2
3. Gantt Chart for Short Semester
4. Fabrication Block Diagram

FINAL YEAR PROJECT 1															
MOAHAMAD NASRUL BIN MOHD NASIR (FB09021)															
MODELLING, SIMULATION AND EXPERIMENTAL VERIFICACATION OF A SEMI ACTIVE ABSORBER SYSTEM															
TASK NO	**TASK DESCRIPTION**	**W1**	**W2**	**W3**	**W4**	**W5**	**W6**	**W7**	**W8**	**W9**	**W10**	**W11**	**W12**	**W13**	**W14**
1	verify the project title	↔													
1.1	brainstorm, review basic concept	↔	↔												
2	**CHAPTER 1: INTRODUCTION**														
2.1	Project Motivation		↔												
2.2	Project Background		↔												
2.3	Problem Statements			↔											
2.4	Project Objective			↔											
3	Project Scopes														
3.1	Report Organization			↔	↔										
3.2	**CHAPTER 2:LITERATURE REVIEW**				↔	↔									
3.3	History of Shock Absorber					↔	↔								
3.4	Introduction						↔	↔							
4	Basic Type of Shock Absorber														
4.1	Vehicle Model							↔							
4.2	Operating speeds and Strokes								↔	↔					
4.3	Classification of Suspension System									↔	↔				
5	**CHAPTER 3**														
5.1	PSM flow chart											↔	↔		
5.2	Methodology flow chart													↔	↔
5.2	Finalizing report and prepare for presentation														↔

APPENDIX A

FINAL YEAR PROJECT 2

MOHAMAD NASRUL BIN MOHD NASIR (FB09021)

PROJECT TITLE: MODELLING, SIMULATION AND EXPERIMENTAL VERIFICATION OF A SEMI ACTIVE ABSORBER

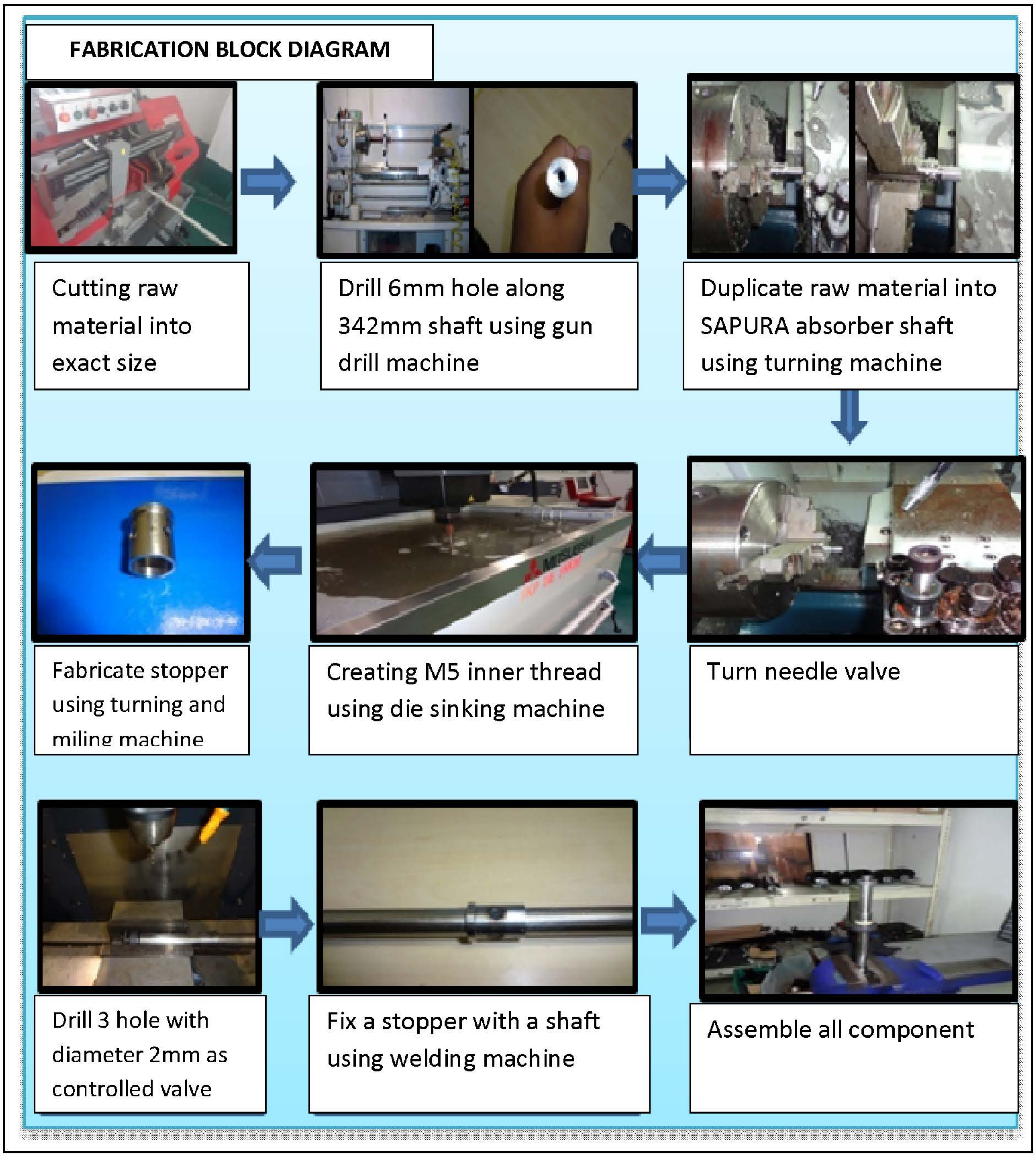
TASK NO	TASK DESCRIPTION	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15	W16	W17
1	Mathematical modelling for absorber.	↔																
2	Use matlab to get absorber curve, use passive parameter.		↔															
3	Confirming Sapure actual data with mathemataical modelling			↔														
4	Use matlab to get absorber curve,use semi active parameter				↔													
5	Fabrication planning					↔	↔											
6	Selecting material, cutting raw material						↔											
7	Gun drill process							↔										
8	Duplicate raw material into originbal absorber							↔										
9	M12 and M8 outer threading								↔									
10	Fabricatiing needle valve									↔								
11	Fabricating stopper										↔							
12	Fluid inlet valve											↔						
13	M5 inner threading(fail, workpiece broken)												↔					
14	Replanning													↔	↔	↔	↔	↔

APPENDIX B

APPENDIX C

FINAL YEAR PROJECT 2(SHORT SEMESTER)									
MOHAMAD NASRUL BIN MOHD NASIR(FB09021)									
PROJECT TITLE:MODELLING,SIMULATION AND EXPERIMENTAL VERIFICATION OF A SEMI ACTIVE ABSORBER									
TASK NO	**TASK DESCRIPTION**	**W1**	**W2**	**W3**	**W4**	**W5**	**W6**	**W7**	**W8**
1	Planning for fabrication process	↔							
2	Choosing best material	↔	↔						
3	Cutting raw material into exact dimension	↔	↔						
4	Duplicate into original absorber		↔	↔					
5	M12 and M8 outer threading		↔	↔					
6	Fabricating needle valve			↔	↔				
7	Fabricate fluid inlet valve			↔	↔				
8	Fabricating stopper				↔	↔			
9	Attach stopper with shaft by using welding machine				↔	↔			
10	M5 inner thread using die sinking machine					↔			
11	Assemble all component					↔			
12	Testing						↔		
13	Comparing real data with simulation data						↔		
14	Prepare for presentation							↔	
15	Completeing thesis							↔	
16	Completing log book								↔
17	video presentation								↔
18	submit all item								↔

APPENDIX D


FABRICATION BLOCK DIAGRAM
Cutting raw material into exact size
Drill 6mm hole along 342mm shaft using gun drill machine
Duplicate raw material into SAPURA absorber shaft using turning machine
Turn needle valve
Creating M5 inner thread using die sinking machine
Fabricate stopper using turning and miling machine
Drill 3 hole with diameter 2mm as controlled valve
Fix a stopper with a shaft using welding machine
Assemble all component

EXAMINER'S APPROVAL DOCUMENT

I certify the thesis entitled "Modelling, Simulation, and Experimental Verification of a Semi Active Absorber" by Mohamad Nasrul bin Mohd Nasir. I have examined the final copy of this thesis and in my opinion it is fully adequate in terms of scope and quality for the award of degree of Bachelor of Mechatronic Engineering. I herewith recommend that it be accepted in fulfilment of the requirement for the degree of Bachelor of Mechatronic Engineering.

SIGNATURE : ....
NAME : DR AHMAD RAZLAN BIN YUSOFF
POSITION : LECTURER
DATE : 19 SEPTEMBER 2013

SUPERVISOR'S DECLARATION

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Bachelor of Mechatronic Engineering.

SIGNATURE : ....
NAME : ASSOC. PROF. DR. WAN AZHAR BIN WAN YUSOFF
POSITION : LECTURER
DATE : 19 SEPTEMBER 2013

STUDENT'S DECLARATION

I hereby declare that the work in this thesis entitled "Modelling, Simulation, and Experimental Verification of a Semi Active Absorber" is my own except for quotations and summaries which have been duly acknowledged. The project has not been accepted for any degree and is not concurrently submitted for award of other degree.

Signature : ....

Name : MOHAMAD NASRUL BIN MOHD NASIR

ID Number : FB09021

Date : 19 SEPTEMBER 2013

Dedicated to my parents

ACKNOWLEDGEMENT

I am grateful and would like to express my sincere gratitude to my supervisor Prof Madya Dr. Wan Azhar bin Wan Yusoff for his germinal ideas, invaluable guidance, continuous encouragement and constant support in making this research possible. He has always impressed me with his outstanding professional conduct, his strong conviction for science, and his belief that a degree program is only a start of a life-long learning experience. I appreciate his consistent support from the first day. I applied to graduate program to these concluding moments. I am truly grateful for his progressive vision about my training in science, his tolerance of my naïve mistakes, and his commitment to my future career. I also would like to express very special thanks to my panel Dr Ahmad Razlan bin Yusoff for his suggestions and co-operation throughout the study. I also sincerely thanks for the time spent proofreading and correcting my many mistakes.

My sincere thanks go to all my lab mates and members of the staff of the Manufacturing Engineering Department, UMP, who helped me in many ways and made my stay at UMP pleasant and unforgettable. Many special thanks go to member for their excellent co-operation, inspirations and supports during this study.

I acknowledge my sincere indebtedness and gratitude to my parents for their love, dream and sacrifice throughout my life. I cannot find the appropriate words that could properly describe my appreciation for their devotion, support and faith in my ability to attain my goals.

ABSTRACT

The vehicle suspension system is responsible for driving comfort and safety as the suspension caries the vehicle body and transmits all forces between the body and the road. The vehicle suspension system consists of wishbones, the spring and the shock absorber to transmit and also filter all forces between the body and road. The spring carries the body mass and isolates the body from road disturbances and thus contributes to drive comfort, while absorber function is to slow down the oscillation experienced by the spring from being transferred into vehicle body. The purpose of his study is to modelling, simulation and experimental verification of a semi active absorber system, for the good absorber it must contain the criteria where it can split between the body and wheel. In order to obtain the characteristic, the fixed design of the suspension system should be change by controlling fluid flow that move from compression and rebound chamber. The experimental result showed that, when increasing the size of valve opening the value of pressure inside chamber also decreases. At the end of the project, the semi active absorber system is developed and can be used to solve the conflict experienced by automotive manufacturer either to choose between passenger satisfaction and cost.

ABSTRAK

Sistem suspensi kenderaan bertanggungjawab memberikan keselesaan dan keselamatan kerana sistem suspensi berfungsi menampung badan kenderaan dan mengalihkan semua tenaga berlebihan di antara badan kenderaan dan tayar kenderaan. Sistem suspensi kenderaan merangkumi tiga bahagian iaitu “wishbones”, spring dan penyerap hentakan, ia bertujuan untuk mengalihkan dan menapis semua tenaga diantara badan kenderaan dan jalanraya. Spring bertujuan untuk membawa berat kenderaan dan mengasingkan badan kenderaan apabila melalui halangan jalan seterusnya menyumbang kepada keselesaan dalam pemanduan, sementara penyerap hentakan berfungsi untuk memperlahankan getaran yang dialami oleh spring sebelum dialirkan kepada badan kenderaan. Tujuan ujikaji ini ialah untuk untuk memodelkan, mensimulasikan dan mengeksperimentkan kesahihan tentang sistem suspensi separuh aktif, bagi sistem hentakan yang baik ia mestilah mempunyai fungsi dimana ia dapat menceraikan di antara bahagian badan kenderaan dengan bahagian tayar. Bagi memperolehi kriteria tersebut , rekaan yang kekal haruslah ditukar menjadi sistem yang boleh dikawal dengan cara mengawal pengaliran keluar masuk cecair di dalam ruang mampatan dan ruang pemulihan. Berdasarkan keputusan yang diperolehi, semakin bertambah saiz injap yang dibuka semakin berkurang tekanan di dalam injap tersebut. Kesimpulannya , sistem suspensi separa aktif ini dicipta dan boleh diaplikasikan untuk menyelesaikan krisis yang dihadapi oleh pengusaha kenderaan sama ada untuk memilih di antara kepuasan pelanggan mahupun kewangan.

TABLE OF CONTENT

LIST OF FIGURES

LIST OF SYMBOLS

m	Wheel masses
k	Tire stiffness coefficients
c	Damping coefficients
q	Road profiles
z	Chassis vertical position
J_x	Chassis moment of inertia around X axis
J_y	Chassis moment of inertia around Y axis
φ	Chassis roll angle in radians
Θ	Chassis pitch angle in radians
F_r	Frictional forces due to rubbing pistons seals with the cylinder walls inside the actuators
F_d	Hydraulic forces provided by actuators they are positive when the actuators under compression
z_b	Sprung mas
z_w	Unsprung mass
F_d	Damper produce force
F_s	Spring produce force
F_{zdyn},	Dynamic tyre load
F_c	Friction of the damper
ΔF_u	Additional force of the active or semi active components
m_b	Body mass
c_w	Tire stiffness
d_b	Damping coefficient
r	Road displacement
F_b	Body weight and the forces resulting from driving maneuvers

$\dot{z}_b$	Body acceleration
$\dot{z}_w$	Tire acceleration
(z_w-z_b)	Suspension deflection
V	Impact speed
m	Mass
g	The gravitational field strength
K	Spring stiffness
C_D	Effective values at the wheels
f_{NH}	Natural heave frequency
V_{SB}	Velocity amplitude
Z_H	Heave displacement amplitude
ω_{NH}	Radian natural frequency
A_x	Longitudinal deceleration
H_G	Mass height
K_w	Suspension stiffness wheel rate
Θ	Angular pitch angle
M_p	Restoring pitch moment
K_p	Pitch angular stiffness
A_x	Longitudinal acceleration
f_{NP}	Natural frequency
ω_{NP}	Natural frequency of the body in pitch
z_{SB}	Displacement of the suspension in bump
k_φ	Suspension roll angle gradient
z_s	Suspension deflection

f_{nr}	Roll natural frequency
$P_{c.}$	Pressure in compression chamber
P_r	Pressure in the rebound chamber

LIST OF ABBREVIATIVES

CATIA	Computer aided three dimensional interactive application
MATLAB	Matrix laboratory
DOF	Degree of freedom