COMFORT PARAMETERS TUNING FOR VEHICLE SUSPENSION PITCH MOTION

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This report is submitted
in fulfillment of the requirement for the degree of
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DECLARATION

I declare that this project report entitled “Comfort Parameters tuning for Vehicle Suspension Pitch Motion” is the result of my own work except as cited in the references.

Signature	:	.....
Name	:	Muhammad Aliff Isyraq Bin Azmi
Date	:	.....

APPROVAL

I hereby declare that I have read this project report 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 : .....

Name of Supervisor : Associate Professor Dr. Mohd Azman bin Abdullah

Date : .....

DEDECATION

To my beloved mother and father

To a respected supervisor

To lecturers

&

To my friends

ABSTRACT

The goal of this project is to analyse the value spring stiffness and damping in order to improve the comfort on the vehicle. Suspension system is the mechanism that apply between the tire and the body of the vehicle. Suspension system also act as mechanism to absorb the undesirable force that exerted on the tire from transmit to the body of the vehicle. Therefore, to reduce the undesirable force from uneven road, the spring stiffness and damping value on the suspension should be tuning in order to improve the comfort for passenger in the vehicle. In tuning process, it should be test on the various spring stiffness and damping value. In order to analyse the performance on each spring stiffness and damping value, it will be run the simulation on three type of vehicle which are Sedan, Hatchback and Sport Utility Vehicle (SUV). In addition, before run the simulation the Four Degree of Freedom (DOF) ride model should create by using Matlab/Simulink based on theoretical equation of motion and need to verify with CarSimEd. The 4 DOF ride model will be simulate on various value of spring stiffness and damping until it produces a result of pitch motion and vertical body acceleration. From the result, it can be analyse the optimal value of spring stiffness and damping that suitable with each of the vehicle in order to improve the comfort on the vehicle.

ABSTRAK

Matlamat projek ini adalah untuk menganalisis nilai kekerasan spring dan damper untuk meningkatkan keselesaan pada kenderaan. Sistem suspensi adalah mekanisme yang dikenakan antara tayar dan badan kenderaan. sistem suspensi juga bertindak sebagai mekanisme untuk menyerap tenaga yang tidak diingini yang dikenakan ke atas tayar dari penghantar kepada badan kenderaan. Oleh itu, untuk mengurangkan daya yang tidak diingini dari jalan yang tidak rata, kekerasan spring dan nilai damper harus di tuning untuk meningkatkan keselesaan untuk penumpang di dalam kenderaan itu. Dalam proses tuning, ia perlu ujian mengenai pelbagai nilai kekerasan spring dan nilai damper. Untuk menganalisis prestasi pada setiap kekerasan spring dan nilai damper, ia akan menjalankan simulasi pada tiga jenis kenderaan yang Sedan, Hatchback dan SUV. Selain itu, sebelum menjalankan simulasi model menaiki 4 DOF perlu mewujudkan dengan menggunakan Matlab / Simulink berdasarkan persamaan teori gerakan dan perlu mengesahkan dengan CarSimEd. Model menaiki 4 DOF akan mensimulasikan tunjukkan nilai kekerasan spring dan damper sehingga ia menghasilkan hasil gerakan pitch dan pecutan badan menegak. Dari keputusan itu, ia boleh menganalisis nilai optimum kekerasan spring dan damper yang sesuai dengan setiap kenderaan untuk meningkatkan keselesaan pada kenderaan.

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LIST OF ABBEREVATIONS AND SYMBOLS

DOF	=	Degree of freedom
SUV	=	Sport Utility Vehicle
Ms	=	mass of body
Mu	=	mass of unsprung
K	=	spring
C	=	damper
kt	=	tyre spring
Zs	=	sprung mass displacement at body center of gravity
Zu	=	unsprung mass displacement at body center of gravity
Zr	=	road displacement
m_b	=	mass of vehicle body
Z_{br}	=	sprung mass displacement of vehicle at rear body
Z_{bf}	=	sprung mass displacement of vehicle at front body
Z_b	=	sprung mass displacement at body center of gravity
l_r	=	distance between rear tire to center of gravity
l_f	=	distance between front tire to center of gravity
c_{sr}	=	rear suspension damping
c_{sf}	=	front suspension damping
k_{sr}	=	rear suspension spring stiffness
k_{sf}	=	front suspension spring stiffness
k_{tr}	=	rear tire spring stiffness
k_{tf}	=	front tire spring stiffness
z_{wr}	=	rear displacement of unsprung mass
z_{wf}	=	front displacement of unsprung mass
z_{rr}	=	rear road input
z_{rf}	=	front road input
I_θ	=	pitch motion of the vehicle
θ	=	pitch inertia

CHAPTER 1

INTRODUCTION

1.1 Background

Suspension system is one of the most important and basic system in a vehicle. The purpose of suspension system is to isolate the vehicle from disturbances that can help driver can keep control of the vehicle and to protect the passenger from feel the shaking when they drive across the road with bump or hole or even on the smooth road. The suspension also helps to support the vehicle weight, improve the stability of vehicles and maintain the correct vehicle ride motion (Oborne, 1978). There are main criteria to improve the comfort parameter the vehicle suspension system which are vibration isolation on the vehicle body, suspension travel between vehicle body with the wheel and road holding between the tire with road surface. Numerous studies have been conducted on the suspension system in order to minimize the vertical motion, as well as pitch and roll movements, as the vehicle passes over an irregular road, performs turning maneuvers, and is accelerated or brakes heavily and to achieve the stability and ride comfort in the vehicle (Cao et al., 2008).

There are three elements that consist in vehicle suspension system which are wishbone, spring and shock absorber. These three elements are to absorb the vibration and transmit the force and torque exerted between the vehicle body and the wheel. There are several forces will affect on the vehicles body which are the vehicle forces or vehicle load, the longitudinal forces for traction and braking force, lateral force and moments of longitudinal forces as shown in **Figure 1.1**. The spring element is important as it carries the body mass and isolates the vehicle from uneven road surface and it also contributes to drive comfort. Moreover, the damper system in the vehicle also contributes to safety as it absorbs

the damping of the body wheel oscillations. The damper system also acts as vibration control for reducing the transfer oscillating movements of the wheel and vehicle body to protect and improve the passenger comfort (Gogaa, 2012).

Pitch and bounce vibration modes are as far as the ride is concerned. Basically, a pitch motion is an upward and downward movement of the front and rear of vehicle body. A pitch motion of vehicle is rotating on y-axis or lateral of the vehicle body through its center of gravity and parallel to the air flow. In order to improve the ride comfort, the damping coefficient and the spring stiffness should be an optimal value. The optimal value of damping coefficient and spring stiffness will minimize the transmissibility of vibration from the rough surface that acting on the vehicles body. Furthermore, the ride natural frequency also will affect the pitch motion of the vehicles in order to reduce the resonant peak of the suspension. The higher the ride natural frequency will minimize the transmissibility of vibration. Ride frequency for front body and rear body are generally not same. The rear body needs higher natural frequency to catch up the front body to reduce the pitch motion (Abdullah et al., 2016).

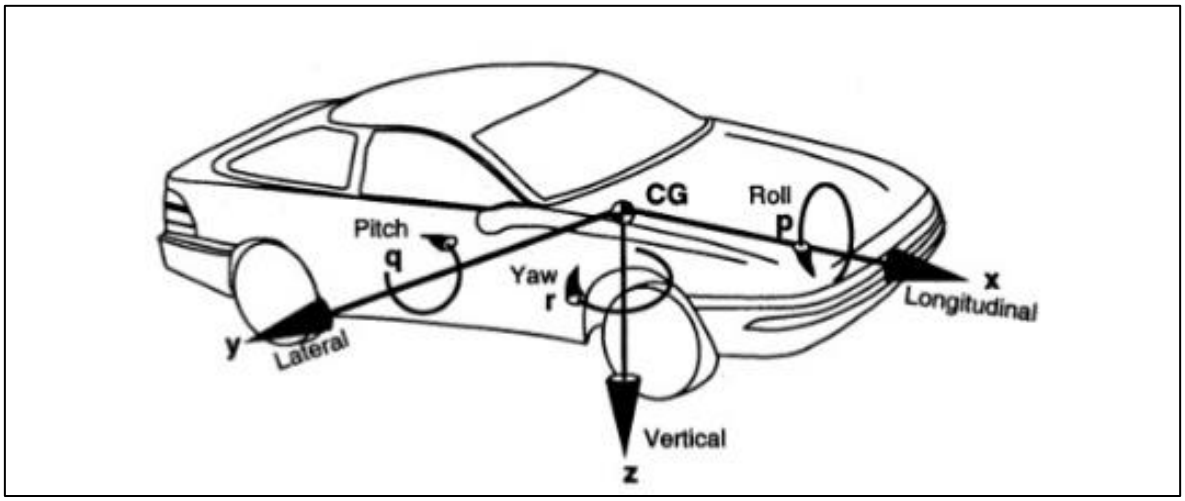

Figure 1.1: Motion of vehicle body

1.2 Problem Statement

In this project, it will be cover on the 4 DOF half car pitch plane ride model that allowed the vehicle body to move in vertical or pitch direction and each wheel is allowed to move in vertical direction. Basically, in the pitch movement of vehicle body, the suspension system will produce a ride comfort rate and natural frequency. In order to improve the ride comfort of the vehicle, it need to reduce the vibration isolation on the suspension. The best vibration isolation will be achieved by keeping the natural frequency as low as possible. The lower the vibration isolation between the vehicle body vertical displacement response and road input, it will form a better performance on the suspension system for the vehicle.

The aim of this project to analyze the comfort parameters for vehicle suspension tuning. This project will be focus on the 4 DOF of half car pitch plane ride model based on the vertical or pitch movement of the vehicles. In order to achieved the ride comfort for the vehicle, it need to find the suitable spring stiffness and the damping coefficient for ride dynamic of the vehicles by using the Matlab Simulink software. From the simulation process, it will produce line graph that need to simulate the different effect of vibration isolation when varied the value of spring stiffness and damping coefficient. The result from Matlab Simulink software need to transfer in Carsim software to analyze the real motion of the passenger vehicle with different effect of real situation. The suspension will be test in the Carsim software with varies input parameter tuning until achieve the ride comfort of the passenger vehicles.

1.3 Objective

There are several objectives included in this research as mentioned below:

a) To identify the most suitable value of spring stiffness and damping coefficient tuning that will ensure optimal ride comfort.
b) To study the effect of spring stiffness and damping coefficient of the vehicle.
c) To simulate a different load condition and road inputs.

1.4 Scope of Project

This research is focused on the analysis of car ride dynamic based on different value of spring stiffness and damping coefficient. This project will be cover a simulation and analysis using Matlab Simulink software. The 4 DOF will be used to study the ride comfort of the vehicle body and will be apply in the Carsim software.

CHAPTER 2

LITERATURE REVIEW

2.1 Background of The Suspension System

According to Bohidar et al., (2015), suspension system is a mechanical system of spring and shock absorber that mounted on the wheel and axle to the chassis of wheeled vehicle. The main functions of the suspension system are for protect chassis from road irregularities, keep wheel camber and wheel direction, react to forces from tyre in longitudinal, lateral and torque motion, carry weight of the vehicle, provide steering stability with better handling, and ensure the passenger's comfort. In the suspension system, there are a few main components with many functions which are steering knuckle, ball joint, control arm, shock absorber, control arm bushing and spring.

The main purpose of shock absorbers is to reduce overall vehicle body movement and to absorb or dissipate energy from the road disturbance without dissipate the vibration energy stored in the spring and dissipate the vibration energy stored in the spring (Poornamohan et al., 2012). When the vehicle through the uneven road, the vehicle body will be moving up and down or side to side to various degrees in response to driving and road condition. Shock absorber also acts as stabilizer to overall vehicle ride. It is because to preventing an excess of vehicle body to roll in any direction during cornering. Other function of suspension is to isolate sprung mass from the unsprung mass vibration. **Figure 2.1** shows the prototype and schematic diagram of the two degree of freedom quarter car model suspension system.

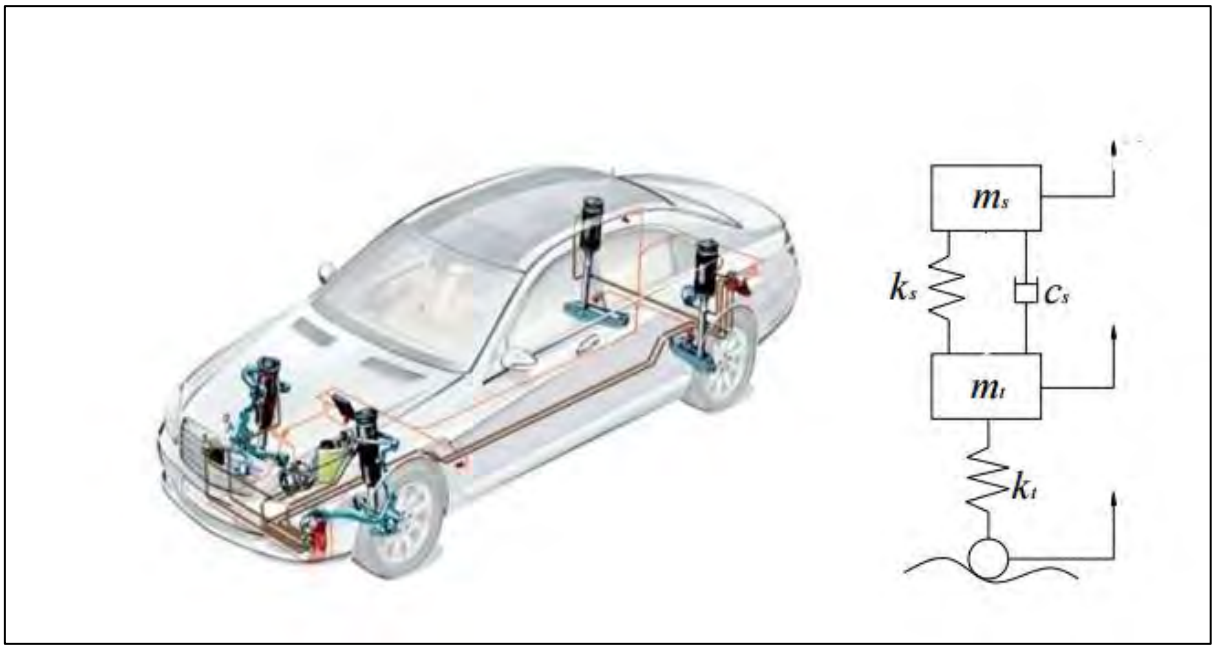

Figure 2.1: Prototype and Quarter Car Model Suspension System.
(Source: Liu et al, (2013))

The suspension is dividing by two catagories which are conventional suspension and advanced suspension. Conventional suspension system indicates the passive suspension system while advanced suspension system refer to active suspension and semi-active suspension system (Harun, 2008).

2.2 Conventional Suspension System

According to Hasan.,(1986), conventional suspension also known as passive suspension system. Most of the passenger vehicle used the passive suspension. A passive suspension system is one in which the qualities of the components which are springs and shock absorbers are fixed. The force versus velocity characteristic of shock absorber or damper usually nonlinear. The function of suspension system are to provide directional stability during cornering, to isolate sprung mass from the unsprung mass vibration and to maneuver and provide damping for the high frequency vibration induced fire excitations (Kumar & Vijayarangan, 2007).