VIBRATION INVESTIGATION OF PASSENGER CAR FRONT SUSPENSION SYSTEM UNDER VARIOUS ROAD CONDITION AND DRIVING MANEUVERS

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SUPERVISOR'S DECLARATION

We hereby declare that we have checked this thesis and in our opinion this project is satisfactory in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering with Automotive Engineering.

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I hereby declare that the work in this thesis is my own except for quotations and summaries which have been duly acknowledged. The thesis has not been accepted for any degree and is not concurrently submitted for award of other degree.

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ABSTRACT

This thesis has the purpose to show the investigation of excitation and vehicle body movements acting on the two front wheel of the vehicle due to the road profile and driving maneuvers based on the experiments. This project endeavor to prove the effect road profile and speed on front suspension and car body movements based on centre of gravity can be used as representative conditions for ride comfort. It is believed that the front suspension is moving faster when the vehicle moves at high speed and due to the vehicle movements it shows that the road surface are irregularity. The procedures constructed on gaining the data on the front suspension linear motion and vehicle's centre of gravity performance in term of movement. Different kind of road surface irregularity has been considered and dissimilar driving maneuvers are identified. The study on the apparatus and instruments contributes in understanding the capabilities of its behavior on going experiments. The test is performed in Universiti Malaysia Pahang (UMP) and using UMP Test Car which has been installed with accelerometers and wire potentiometer sensor on the front suspension, Global Positioning System (GPS) and DEWESOFT software for data acquisition purpose. The analysis was performed using Flexpro 7. Based on the graphs and explanations, comparison between the road conditions due to the driving maneuvers and road variation are made. Thus this study results is comfort ride at all conditions of roads tested except bumpy road and the vehicle roll and yaw angle is high at roundabout road yet the pitch angle are increased at the bumpy road due to driving behavior. Based on the analysis it can be concluded that the front suspension and body of the vehicle are responsive towards the road profile and driving maneuvers. Consequently, this study contribute in identified the ride comfort on the track used for the optimization at other speeds. Lastly, this investigation that been justified in this thesis is only applicable for vehicle passenger.

ABSTRAK

Tesis ini bagi membuktikan kajian perkaitan eksitasi dan pergerakan kenderaan pada dua roda hadapan kenderaan merujuk kepada jenis profil jalan dan juga cara pemanduan berdasarkan eksperimen. Kajian ini bertujuan untuk membuktikan kesan perbezaan profil jalan dan kelajuan kenderaan terhadap sistem suspensi di bahagian hadapan dan pergerakan kenderaan berdasarkan pusat graviti kenderaan boleh dijadikan pengukuran keselesaan memandu. Hal ini diyakini bahawa suspensi hadapan bergerak lebih laju pada saat kenderaan bergerak dengan kelajuan tinggi dan kerana gerakan kenderaan ini menunjukkan bahawa permukaan jalan yang tidak teratur. Penulisan ini menjelaskan prosedur yang dibina bagi memperoleh data pergerakan linear suspensi hadapan kenderaan dan pergerakan kenderaan daripada pusat graviti kenderaan. Kepelbagaian jenis permukaan jalan telah dipertimbangkan dan cara pemanduan yang berlainan dikenalpasti. Walaupun demikian, kajian yang dijalankan pada peralatan dan instrumen memberikan sumbangan dalam memahami kemampuan perilaku pada eksperimen yang dijalankan di Universiti Malaysia Pahang (UMP) dan data yang digunakan untuk analisis diperolehi menggunakan kereta pandu uji UMP yang telah dipasang dengan alat pengesan kelajuan dan juga jarak, ‘Global Positioning System’ (GPS) dan perisian DEWESOFT untuk tujuan pengambilalihan data. Analisis dilakukan dengan menggunakan Flexpro 7. Berdasarkan graf dan penjelasan, perbandingan antara keadaan jalan dengan cara pemanduan dapat dilakukan. Demikian, hasil kajian ini adalah keselesaan pada semua profil jalan yang diuji kecuali jalan berbonggol dan sudut ‘roll’ dan ‘yaw’ kenderaan adalah tinggi di jalan bulatan manakala sudut ‘pitch’ adalah tinggi di berbonggol berdasarkan cara pemanduan. Berdasarkan analisis dapat disimpulkan bahawa suspensi hadapan dan pergerakan kenderaan daripada pusat graviti kenderaan adalah responsif terhadap jenis profil jalan dan juga cara pemanduan. Kajian ini memberikan sumbangan dalam mengenalpasti kemudahan memandu pada jalan yang digunakan untuk pengoptimuman pada kelajuan yang lain. Namun, proses dan data yang telah dinyatakan di dalam penulisan ini hanya boleh dilakukan dengan kenderaan penumpang.

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LIST OF SYMBOLS

CF	centrifugal force in N
CGH	center of gravity height in mm
CR	rate of acceleration/deceleration in N
□□	centrifugal force in percentage of N
R	radius of skid pad in feed mm
W	car weight in kg
WB	wheelbase in mm
WT	lateral weight transfer in kg
T	time to complete one lap in seconds
TW	track width in mm
□	acceleration
□	velocity
a_w	weighted acceleration time history in m/s^2
□, □□, □□	damping constant for constant, sprung and unsprung respectively
□, □□, □□	spring constant for constant, sprung and unsprung respectively
□, □□	length for constant and sprung respectively
□, □□, □□	mass for constant, sprung and unsprung respectively
□□, □□, □□	displacement for road, sprung and unsprung respectively
□̇□, □̇□, □̇□	velocity for road, sprung and unsprung respectively
□̈□, □̈□, □̈□	acceleration for road, sprung and unsprung respectively

LIST OF ABBREVIATIONS

2D	2 Dimension
AC	Alternating Current
CAN	Controller Area Network
CE	Common Era
CG	Center Of Gravity
CPT	Cable Extension Transducer
DC	Direct Current
DFT	Discrete Fourier Transform
FFT	Fast Fourier Transform
FWD	Front Wheel Drive
GPS	Global Positioning System
ISO	International Organization for Standardization
LF	Left Front
MT	Manual Transmission
N&V	Noise and Vibration
PSD	Power Spectral Density
RF	Right Front
RMS	Root Mean Square
SLA	Short Long Arm
SOP	Standard Operating Procedure
UMP	Universiti Malaysia Pahang

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

The purpose of a vehicle is to transport people or cargo from one place to another. Embedded in this purpose in doing so, it shall be as little disturbance as possible of who or what is being carried. For passenger cars, where the cargo is human, the priority of the suspension system is to provide the optimum environment for comfort of the occupants and control by the driver. In addition, the suspension system is required to deliver this performance over a range of load possibilities, from only the driver to a full load of several occupants plus luggage.

Early years of suspension systems back then, the early wagons were known to have used elastic wooden poles to reduce the affects of wheel shock. Leaf springs in one form or another have been used since the Romans suspended a two wheeled vehicle called a Pilentum on elastic wooden poles. After that, new inventor carriage designs included rudimentary leaf suspension systems. All through the history, leaf springs would dominate as the primary suspension design until quite recently (Staniforth, 2006). Leaf springs presented the profit of simplicity in design and relatively economical cost. By merely adding leaves or changing the shape of the spring, it could be made to support varying weights. As a result, major changes primarily tended to revolved around the use of better-quality materials and making improvement in design modifications.

Every vehicle nowadays is equipped with two pair of suspension at the wheels. Suspension is a term which is specified for the system of springs, shock absorbers and linkages that connects a vehicle to its wheels. The suspension system is located between the axles and the vehicle body or frame. For safety purpose, stability, handling and performance of a vehicle depend on many factors. One of the most important aspects of these characteristics is the design of the suspension.

1.2 PROBLEM STATEMENT

Generally, automobile frame and the body can be supported by suspension. Besides that the suspension mechanism is allowing the wheels to “soak up” wrong-doing on the road surface. The consequence is the wheels will tend to stay in contact with the road, and the passengers of the vehicle enjoy a ride that is protected from road shock. The suspension system consists of two basic systems; front suspension and rear suspension. The design of front and rear suspensions of an automotive may be different.

The front suspension need to focus on support the weight of the front end of the vehicle, absorb road shocks and cushion the passengers and load against those shocks, provide steering control and alignment and maintain steering control during severe braking. Notionally, if a road were perfectly flat, with no abnormality, suspensions wouldn't be necessary. Unfortunately, roads are far from flat. Without suspension, a motor vehicle travelling at today’s speeds would not only be uncomfortable, it would be virtually uncontrollable. Suspension vibrations are noticed when vehicle speed changes, as when starting out from a stop, passing, and slowing down or coasting. The perception of ride quality is corrupted by virtually any disturbance experienced by the drivers or passengers. Human sensitivity varies according to the nature of the disturbance. Therefore, a ‘good ride’ not just depends on the overall design of the vehicle, but also the design of the suspension system. Even freshly paved highways have understated imperfections that can interact with the wheels of a car. It's these imperfections that apply forces to the wheels (Harrison, 2004).

Instead of carry the load from engine compartment, different road condition will gives different outcomes for the front suspension system. The front suspension system was designated to perform at certain range of vibration. Yet the drivers and passengers, certain of them not only used the vehicle on the smooth road but then on the various kind of road which sometimes the front suspension does not perform on that kind of road. Thus, the project will investigate the meaning of normal front suspension system performance at various conditions.

1.3 OBJECTIVES

The aim of this project is to investigate the effect of road profile on front suspension system. In addition its objective is also to analyze the effect of front suspension system to car body vibration based on different driving maneuvers.

1.4 WORK SCOPES

The project has to focus on few scopes in order to achieve the objectives:

(i) Literature review on suspension and vibration on the suspension.
(ii) Preparations on the procedures for installation on displacement sensor and pre-testing.
(iii) Run the experiment based on the procedures.
(iv) Analysis the results gained on the front suspension relates to the road conditions and body movement at centre of gravity.
(v) Discuss and conclude the project in a final report.

1.5 HYPOTHESIS

Hypothetically, vibration rises at certain speeds or changes in direct proportion to vehicle speed increment as the road roughness increases. Hence the data obtained may be consistent by taking into considerations of the influenced parameters.

1.6 FLOW CHART

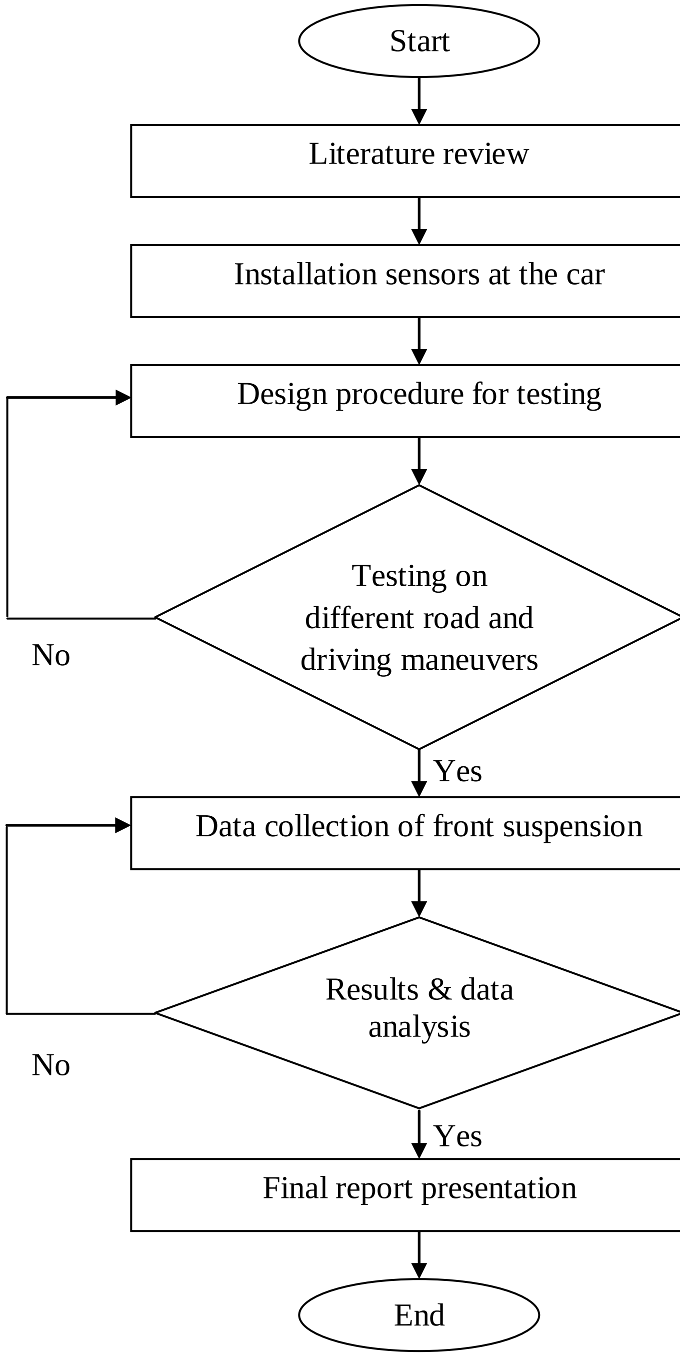

Figure 1.1: Flow Chart

The process of flow chart is explained details in Appendix A.

CHAPTER 2

LITERATURE REVIEW

2.1 SUSPENSION

For a road vehicle, the suspension system isolates the occupants or cargo from severe levels of shock and vibration induced by the road surface. This isolation from road-induced shock and vibration also improves the longevity and durability of the vehicle. Just as importantly, the suspension system enables the wheels to maintain contact with the road, assuring stability and control of the vehicle (Bastow et al, 2004).

The front suspension of a vehicle is designed so the steering knuckle and spindle can pivot on the steering axis to allow steering of the vehicle. The spindle must also rise and fall, relative to the body, to allow the springs and shock absorbers to reduce bump and road shock from the vehicle's ride. The suspension system allows the springs and shock absorbers to absorb the energy of the bump, so drivers and passengers can have smooth ride (Birch, 1999).

While doing these two jobs, the suspension system must not allow loose, uncontrolled movement of the tire and wheel and must keep the alignment of the tire as correct as possible (Birch, 1999). Besides that, front suspension also acts to support the weight of the front end of the vehicle, to provide steering control and wheel alignment and to maintain steering control during severe braking (Crouse and Anglin, 1993). Figure 2.1 shows front suspension diagram.

Figure 2.1: MacPherson strut suspension

Source: http://www.hondanews.com (5 July 2010)

2.1.1 Types of Front Suspensions

Table 2.1: Types of front suspension

Type of Suspension	Descriptions
Solid Beam Axle: The beam setup both of the front wheels are connected to each other by a solid axle.	 Source: http://www.carbibles.com (21 July 2010)
Swing Axle: The axles pivot about a location near the center of the car and allow the wheels to travel up and down through the respective arcs.	 Source: http://www.corvaircorsa.com (21 July 2010)
Trailing Link Suspension: A set of arms located ahead of the wheels to support the unsprung mass.	 Source: http://www.carbibles.com (21 July 2010)
MacPherson Strut: Earle was the one whom patented the idea of locating the lower end of an inclined strut system tangentially with transverse link (or track control arm) and longitudinally by means of the lever arm of the anti-roll bar.	 Source: http://www.carbibles.com (21 July 2010)
Equal Length A-arm: Referred to Double Wishbone suspension as the A shaped control arms resemble a wishbone. The suspension is supported by a triangulated A-arm at the top and bottom knuckle.	 Source: http://www.carbibles.com (21 July 2010)
Unequal Length Double A-arm: Implementing upper and lower A-arms of different length.	 Source: http://www.carbibles.com (21 July 2010)

Source: Bastow et al (2004)

Table 2.2: Types of front suspension advantages and disadvantages

Type of Suspension	Advantages	Disadvantages
Solid Beam Axle	Simplicity in manufacture and assembly. Strength of the beam axle is strong for large loads. Camber control to avoid body roll since both wheels are tied together.	Unsprung mass hinders the road holding capability on rough roads. High mass of the axle and the wheels connected, not much ride isolation between unsprung and sprung mass.
Swing Axle	Simpler than short long arm (SLA) setup. De-coupling the front wheels and not mounting the chassis on a solid beam, there is better ride isolation.	Can create larger cornering forces which could raise the car caused back end lose traction lead to vehicle losing controls.
Trailing Link Suspension	Improvement in ride quality and road handling. Reduced size of the suspension components and reduction in chassis space necessary to house it.	Tend to bend when significant loads are subjected to the trailing links. Control arms very heavy to support the road loads transmitted through the wheels.
MacPherson Strut	Improve in ride quality and road holding that and independent front suspension. Extremely compact and allows smaller chassis dimensions. Suits for front wheel drive (FWD).	Difficult to increase the tire width on the car. Very little camber gain as the wheel moves up In bump.
Equal Length A-arm	Further improvement in ride quality and road holding. Uses solid, rigid control arms to mount the knuckle to the chassis which prevent deflections during cornering.	No negative camber generates as the wheel moves into bump which results the car rolls.
Unequal Length Double A-arm	Gain negative camber keeps the wheel upright against the road surface and allows the tire to generate the maximum possible cornering force and flexible.	Did not feature by vehicles that price and space are more concern than performance.

Source: Bastow et al (2004)