UNDERSTEER PERFORMANCE ANALYSIS FOR FRONT WHEEL DRIVE (FF) SEDAN VEHICLE UNDER STEADY AND RIDE ROAD DRIVING CONDITION

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A report submitted in partial fulfillment of the requirements for the award of the degree of Bachelor of Mechanical Engineering with Automotive

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SUPERVISOR'S DECLARATION

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

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ABSTRACT

Research in the area of vehicle dynamics in the on-road skidding condition is limited. The used methods generally are using simulation that the environmental elements that influence the vehicle dynamics were ignored. The skidding condition is the influences factors in handling the vehicle and user safety in order to achieve the safe and controllable maneuver. The driver input and the responses in the skidding condition have a limitation and range to have a safe maneuver. The purpose of this research is to analyze the yaw stability in the understeer condition. To perform an investigation of understeer performances in the real maneuver, the experiment that considered all the noise from the surrounding that influence the vehicle has been done. The steady state cornering, lane change, and straight line braking experiment was used to determine the relationship between side slip angle and slip angle. Persona 1.6 (MT) equipped with the RV-4 vector sensor, Gyroscopic sensor with DEWEtron Data acquisition system was used as the test car and the apparatus for this experiment. Result obtains from the experiment verified the vehicle stability in the understeer condition being achieve between the theoretical and experimental data.

ABSTRAK

Kajian mengenai dinamika kenderaan dalam situasi gelincir dalam keadaan pemanduan yang sebenar adalah kurang. Kebanyakan dari kajian ini menggunakan simulasi dimana faktor sekeliling yang menpengaruhi dinamika kenderaan telah diabaikan. Keadaan gelincir merupakan faktor yang mempengaruhi tahap kawalan kenderaan dan keselamatan penguna untuk mendapatkan pergerakan kenderaan dalam kawalan dengan selamat. Tujuan kajian ini adalah untuk menganalisis keupayaan kenderaan dalam situasi pergerakan dibawah kawalan stering. Eksperimen mengenai situasi ini telah dijalankan untuk melihat keupayaan kenderaan di dalam keadaan pemanduan sebenar dimana faktor persekitaran telah diambil kira. Pergerakan kenderaan semasa mengambil selekoh yang jitu, penukaran haluan, dan penyahpecutan kenderaan merupakan situasi yang dianalisis didalam exprimen ini telah digunakan untuk mengenal pasti hubungan antara sudut gelincir tayar dan sudut gelincir badan kenderaan. Kereta Proton Person 1.6 (MT) yang dilengkapi dengan pengera vektor dan sudut RV-4, pengera gyro dan sistem pengumpul data DEWEtron telah dijadikan sebagai kereta pandu uji dan alatan dalam menjalankan eksperimen ini. Keputusan dari hasil eksperiment telah digunakan untuk memastikan keseimbangan kenderaan dalan keadaan dibawah kawalan stering dan dibandingkan dengan teori dinamika kenderaan.

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LIST OF SYMBOL

a_y	Lateral Acceleration
b	Distance Front Tyre To Center Of Gravity
c	Distance Rear Tyre To Center Of Gravity
F_y	Lateral Force
F_{yf}	Front Lateral Force
F_{yr}	Rear Lateral Force
g	Gravity Acceleration (9.81m/s^2)
K	Understeer Gradient
L	Wheel Base
m	Mass
R	Cornering Radius
S	Radius Circumference
t	Time
T	Wheel Track
v	Vehicle Speed
V_{char}	Characteristic Velocity
W_f	Weight Front
W_r	Weight Total
W_t	Weight Rear
α	Slip Angle
β	Side Slip
δ	Steer Angle
δ_i	Inner Steer Angle
δ_o	Outer Steer Angle
Θ	absolute vehicle direction angle
C_α	Cornering Stiffness

LIST OF ABBREVIATION

ABS	Anti-Lock Braking System
ADT	Average Daily Traffic
ASR	Anti-Slip Regulation
CG	Center Of Gravity
COG	Course Over Ground
DSC	Vehicle Dynamic Stability Control
EPS	Electronic Stability Program
ESC	Electronic Stability Control
GPS	Global Positioning System
IIHS	Insurance Institute For Highway Safety
NHTSA	National Highway Traffic Safety Administration

CHAPTER 1

INTRODUCTION

1.1 PROJECT BACKGROUND

The analysis of the vehicle performance in skidding condition is important and many methods have been introduced in order to avoid the extreme accident that can cause the serious injuries. Nowadays, systems for active control of vehicle handing are standard equipment in many vehicles, such as anti-lock brake, traction control and yaw control that improve active safety by controlling some key vehicle state during running (Hac,A and Simpson,M.D. 2000). In this research, the relationship between vehicle body slip and tyre slip angle has been determine by using on road experiment.

In order to maintain safe handling characteristics of vehicles, designers strive to maintain consistent, predictable vehicle response to driver steering inputs in the entire range of operation. The purpose of control is to bring the vehicle yaw rate response and the vehicle slip angle into conformance with the desired yaw rate and slip angle. To achieve this goal, vehicle actual response must be known (Haiyan,Z. and Cheng,H. 2008). But acquiring information on the vehicle side slip angle is not an easy task, since there is no physical effect that allows a determination of vehicle lateral movement using a force measurement, as is the case for yaw rate. In this research the yaw rate will be measure by gyroscopic sensor, the steer angle measured by RV-4 vector sensor and the vehicle direction will be determined by using GPS.

In this research the performance of understeer condition is be analyzed in order to guide the driver in vehicle maneuver. The stability of the car and the safety of the driver also the passenger can be ensure with the analysis of the vehicle performance during understeer.

1.2 PROBLEM STATEMENT

Dynamics and performance of vehicles are related to the vehicle maneuver system. The tyre is the only part of contact between the road and the vehicle, they are at the main of vehicle handling and performance. When the vehicle moving, tyres are required to produce the lateral forces that necessary for controlling the vehicle in maintains the traction (T.D. Gillespie 1992). While the tyre maintains the traction, the vehicle trajectory will be different to the steer angle input because of the slip angle. When the vehicle in cornering with varies speed or in the acceleration, deceleration and normal ride mode, there will be a change in the longitudinal axis and the local direction of travel that also known as sideslip angle.

The driver does not have 100% control to the traction and the vehicle maneuver. Under emergency conditions, several maneuvers, or extreme road conditions, the imaginary movement is different to the real movement (Koo,S.L., Tan, H.S., and Tomizuka,M. 2004). The differential of the tyre and longitudinal axis angle is due to the car movement that will cause the unstable maneuver of the vehicle. This problem occur when the traction between the road surface decrease and the moment of vehicle inertia. The traction losses can cause difficulty to the driver to control the vehicle and increase the potential of road accident.

Driver faces the problem of the handling and safety when the vehicle loss the traction between the tyre and the road surface that cause by the existence of the slip angle. The body slips influence the slip angle and the potential to lose the tyre grip that contribute to traction loss. The relation of sideslip angle and the tyre slip angle is the main goal to be determined, in order to achieve the perfect vehicle maneuver and to maintain the car stability.

1.3 OBJECTIVE

To analyze the yaw stability with determine the relationship between slip angle and side slip angle in understeer condition of Front Drive (FF) sedan hatchback vehicle.

1.4 SCOPES

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

i. Literature study on the topics related to the project.

ii. Preparations on the procedures for installation sensor and pre-testing.

iii. Run the experiment based on the procedures.

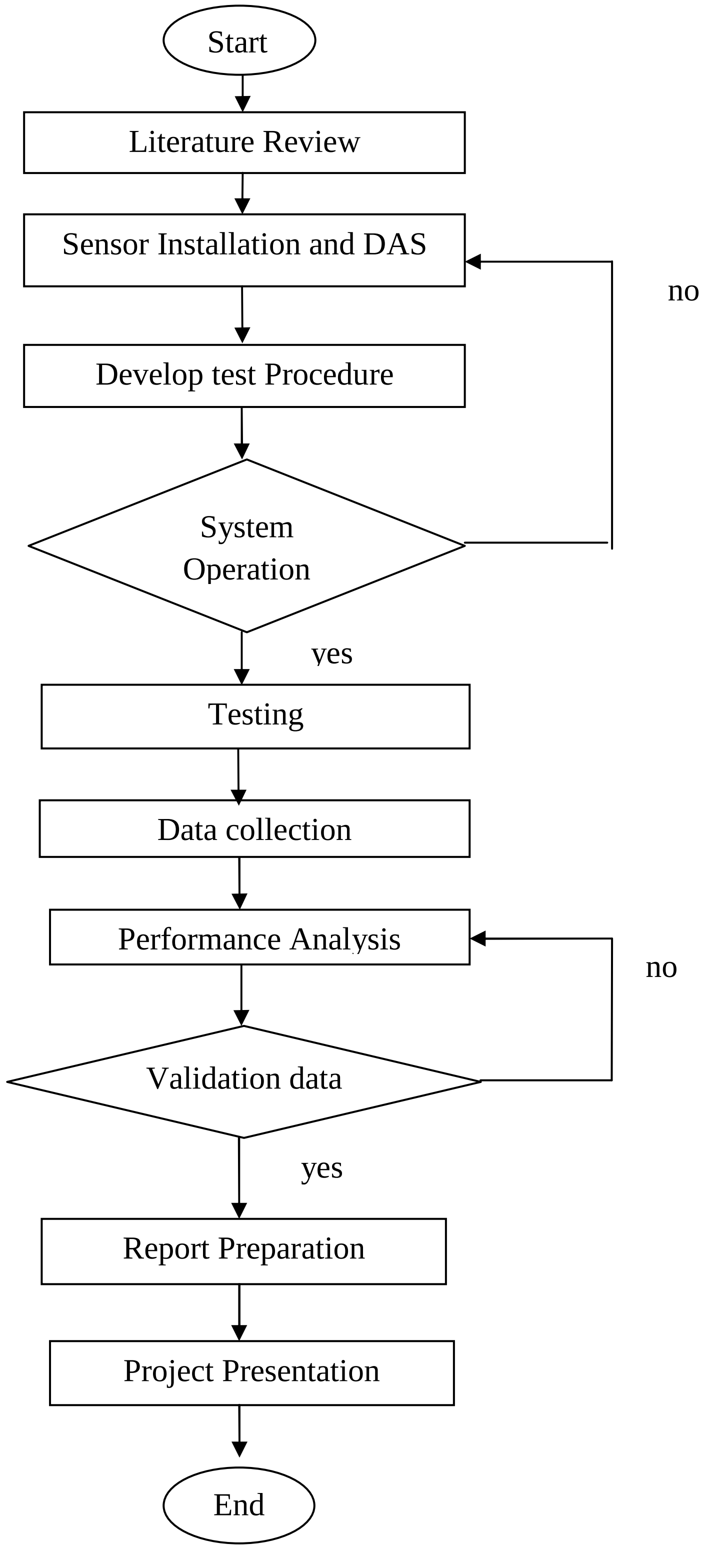
iv. Analysis the results gained on the steer angle and the body.

v. Final report preparation.

1.5 HYPOTHESIS

The steering angle in the understeer condition is influence by the lateral force. The increasing of the side slip angle will reduce the percentage of the vehicle to understeer.

1.5 FLOW CHART



CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

In this chapter the three main topics will be covered, first is the concept of vehicle skid and will focus on understeer, second is the effect of the understeer that influence driving maneuver. The third topics are the factor that leads to the contribution to the vehicle understeer performance. In this chapter also will discuss about the test car specification and the previous research about car understeer performance.

2.2 OVERVIEW OF SKIDDING PROBLEM

2.2.1 Traffic accident

Mustafa M.N has stated that the accident cause can be a combination of either these three basic factors which are road user errors, road environment faults and vehicle defects. In the engineering point of view, these factors below constitute to road and road's environment that usually related to an accident:

Combination of traffic composition

The various types of vehicles that are used on the road are the combination of small, medium and heavy vehicles. Road accident statistic shows that in 2009. Car is the highest vehicle that contributes to the road accident with 68.16% follow by motorcycle 16.16% (Table 2.1). The cause of the no separation for the type of vehicle leads to the road accident.

Table 2.1: Road Accident Statistics (2009)

Type	Casualties	Percentage (%)
Motorcycle	113 962	16.16
Car	480 976	68.16
Heavy Vehicle/Bus	56 104	7.95
Others	54 581	7.73
Total	705 623	100

Source: Jabatan Keselamatan Jalan Raya Malaysia, (2009)

Improper intersection design

Improper design at intersection can cause significant increase of accident. In 2003, accident occurrence at intersection is the second after straight road which constitute about 22% (inclusive of cross, T/Y and staggered junction) (Table 2.2). As an example rear end collision usually cause by improper design of right turn which did not provide enough storage lane for vehicle while wait to turn right. Other related issue to improve design in lack of safe sight distance. From table 2.2 the average percentage road accident that occur at the roundabout are 13.87% the inference that can be made on this percentage is To maintain equilibrium as vehicle speed increases in a turn the increased centrifugal force must be balanced by the steer angles and tire slip angles. If there is greater compliance resulting in higher slip angles--at the front tires than the rear tires, the vehicle is understeer. If there is greater compliance that resulting in higher slip angle at the rear tires than the front tires, the vehicle is oversteer (Fittanto,D.A., and Senalik,A. 2004). The driver false response in either condition on handling the vehicle may lead to the accident.

Table 2.2: Road Accident by Road Type (2003)

Road Type	Fatal	Serious	Total	% ave
Straight	3 690	4 148	7 838	63.10
Roundabout	894	829	1 723	13.87
Bend	23	28	51	0.41
Cross Junction	215	457	672	5.41
T/Y Junction	576	1 424	2 000	16.10
Staggered Junction	36	78	114	0.92
Interchanges	12	11	23	0.19
Total	5 446	6 975	12 421	100

Source: Mustafa,M.N. (2005)

High Traffic Volume

High traffic volume is one of the contributors to traffic accident. It is found that an increase in traffic volume associated with an increase in traffic accident. A study concluded that an accident along sections with the average daily traffic (ADT) of above 30,000 is about 47% higher than ADT less than 30,000. Not enough gaps in between vehicles at intersection and less chance to overtake other motorist are some of the concerns affected from high traffic volumes (Mustafa,M.N. 2005). The increasing of the traffic volume influence the vehicle to decelerates and accelerates base on the traffic volume intensity.

Vehicle Speed

With increase of road network and vehicle's specification, most of new vehicle will drove exceeding the posted speed limit. This may due to the availability and visibility of existing road signage (Mustafa,M.N. 2005). Furthermore, none realistic speed limit may impose to further increase in speeding motorist.

2.2.2 Future Challenge of Road Safety

Ministry of Work Malaysia, MOWs tried to provide a better safety of road in Malaysia alongside with the Government efforts to reduce traffic accident and to achieve its targets. Although studies shown that causes to most of the accident is because of the drivers themselves, MOWs always make it positive effort in order to improve traffic accident by giving further stress on engineering aspect with proactive and reactive action during design, construction and maintenance stage (Mustafa.M.N. 2005).

The major of vehicle that involve in an accident is car and in various type of road. The human factor that leads to an accident is too subjective to be analyzed and the ergonomic factor should be considered if the cases are involving humans.

The vehicle in ride condition will influence the focus of the driver, the ability of controlling the vehicle during skidding condition, and this will influence the percentage of the accident. In this paper the skidding condition properties will be determine the dynamic factor that lead to the road accident.

2.3 SKIDDING TERMINOLOGY

2.3.1 Sprung And Unsprung Mass

The car is a type of vehicle and the vehicle dynamics is part of it. The vehicle will move on a road surface and the dynamics encompasses the interaction of driver, vehicle, load, and the environment. The car is the lumped mass, and under the low velocity the car can be represent as one lumped mass located at its center of gravity (CG) with appropriate mass and inertia properties. For the ride condition the car will be two lumped mass which the body is the sprung mass and the wheel are denoted as unsprung mass (Figure 2.1) (Rill,G. 2009). The inertia of the sprung mass influence the magnitude of the body slip (Bevly, D. M., Gerdes, J. C., Wilson, C. 2002)

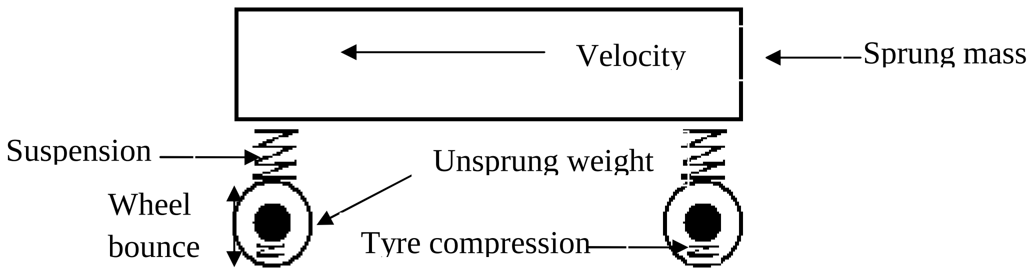


Figure 2.1: Unsprung and Sprung Mass

Source: Rill,G. (2009)

2.3.2 Vehicle Fix Coordinate

The car motions are define with reference to a right-hand orthogonal coordinate system which is the fixed coordinate system (Gillespie,T.D. 1992). The origin of these coordinate is at the CG and travel with the vehicle (Figure 2.2). The car motion are describes by the velocity of forward, lateral, vertical, roll, pitch and yaw with respect to the vehicle fixed coordinate system where the velocities are referred to the earth fixed coordinate.

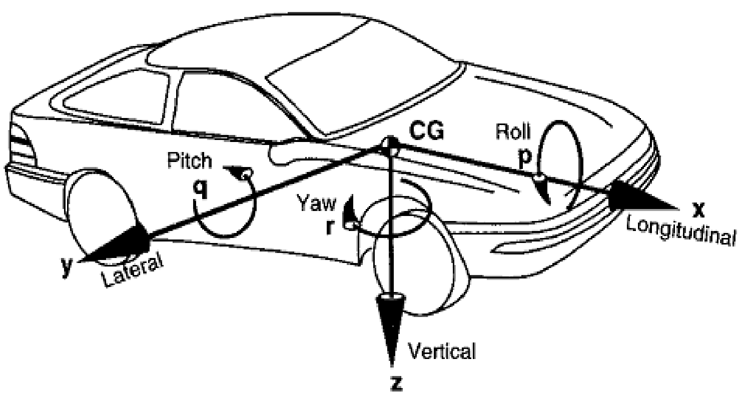


Figure 2.2: Car axis

Source: Gillespie,T.D. (1992)

2.3.3 Vehicle Dynamics Stability Control

Vehicle Dynamic Stability Control (DSC) system can stabilize the vehicle behavior in emergency situations such as spinning, drift out and roll over (Tseng,H.E. 1999). It improves vehicle active safety and comfort greatly. DSC requires measurements of yaw rate and vehicle sideslip angle. The yaw rate can easily be measured by a gyro. Typically, the vehicle sideslip angle is either estimated with an observer integrating the gyro and knowing the vehicle model, by using accelerometers and integrating the lateral and longitudinal acceleration to determine the velocity or some combination of the two (Hahn,J. 2002). These methods have drawbacks due to errors arising from model and sensor uncertainties.

Global Positioning System

The global positioning system (GPS) allows the vehicle sideslip angle to be determined without requiring a model of the system. GPS does have several drawbacks (Ray,L 1995). The sample rate of most GPS receivers is 10 Hz, which is much lower than the typical sample rates of accelerometers and gyros (Bevly,D.M.,Gerdes,J.C.,Wilson,C. 2002). Additionally the GPS measurement contains higher noise than traditional inertial sensors. This paper will show it is possible to utilize the advantages of GPS while working within its limitations to accurately control a vehicle. GPS has already proved effective when used for vehicle navigation and lane keeping as well as estimating cornering stiffness and wheel slip. GPS has also been used to measure yaw rate.

There are two main ways to control the lateral motion of a vehicle. The first is to directly control the steer angle (steer-by-wire); the second is to control the longitudinal force generated at each wheel by differential braking (Zhang,J.Z. and Tian,Z.H. 2009). Steer-by-wire is more widely used for autonomous control of a vehicle because most drivers would feel uncomfortable without a direct mechanical link between the steering wheel and the tires. Differential braking is the method usually employed in vehicle stability control systems. A problem arises, however, when choosing how to split the braking force among the four tires. With GPS it is possible to determine the slip angle