" I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in term of scope and quality for the award of degree of Bachelor Mechanical Engineering (Automotive)"

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Date : 6-5-2008

FRONT WHEEL DRIVE, REAR WHEEL DRIVE, AND FOUR WHEEL DRIVE EFFECT COMPARISON TO VEHICLE DIRECTIONAL STABILITY

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This project report is submitted in partial
fulfillment of the requirements for the award of
the Degree of Bachelor Mechanical Engineering (Automotive)

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" I hereby declare that this thesis is the result of my own research except as cited in the references"

Signature : ……..

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Date : ……..

Special dedication to my family, supervisor, my friends, and all that help me to finish my thesis.

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ABSTRACT

This research was aimed to compare the vehicle model directional stability of Front Wheel Drive (FWD), Rear Wheel Drive (RWD), and Four Wheel Drive (4WD). The model is considered to be directionally stable if, following a disturbance, it returns to a steady – state regime within a finite time. The models were built based on three – degree – of – freedom vehicle motion (bicycle model). Unlike other models done in the past, in this research tractive forces were taken into account. The output responses were lateral acceleration and the vehicle yaw rate responses. The bicycle models produced would be considered having constant forward velocity, 72km/h while aerodynamic effects, chassis or suspension compliance effects, rolling or pitching motions, longitudinal load transfer, and lateral load transfer were been neglected. The comparison to verify the three different models in term of vehicle directional stability was made in computer simulation (MATLAB & Simulink), bearing in mind all the general cornering variable values/parameters. According to the results achieved, it was concluded that RWD having the best vehicle directional stability as it was able to show better handling condition.

ABSTRAK

Penyelidikan ini adalah bertujuan membandingkan kestabilan berarah untuk kenderaan Pacuan Roda Depan (FWD), Pacuan Roda Belakang (RWD), dan Pacuan Empat Roda (4WD). Kenderaan adalah dianggap menjadi stabil secara berarah jika, berikutan satu gangguan, ia kembali ke satu kedudukan kukuh dalam tempoh masa yang paling pendek. Model-model kenderaan yang digunakan adalah dibina berdasarkan model basikal. Model-model lain yang dibuat pada masa lalu adalah berbeza kerana penyelidikan ini mengambil kira daya pergerakan ke hadapan. Jawapan-jawapan pengeluaran adalah pecutan sisi dan kadar rewangan kenderaan. Model-model basikal dihasilkan akan dipertimbangkan maju berterusan ke hadapan dengan halaju yang tetap, 72 km/h, kesan-kesan aerodinamik, casis atau pematuhan penggantungan, kesan-kesan beralun atau memasang, usul-usul pemindahan muatan tayar, dan pemindahan beban sisi telah diabaikan. Perbandingan untuk mengesahkan perbezaan antara tiga model dalam kestabilan berarah kenderaan telah diperbuat dalam penyelakuan komputer (MATLAB & SIMULINK), dengan mengambil kira semua pemboleh ubah yang berkaitan. Menurut hasil-hasil diperolehi, penyelidikan ini boleh membuat kesimpulan bahawa RWD mempunyai kestabilan berarah kereta terbaik kerana ia dapat menunjukkan keadaan pengendalian lebih baik.

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LIST OF SYMBOLS

a_y	=	Lateral acceleration, m/s^2
a_x	=	Forward acceleration, m/s^2
a	=	Distance from vehicle CoG to front axle, m
b	=	Distance from vehicle CoG to front axle, m
$C_{\alpha f}$	=	Cornering stiffness of the front tires, N/rad
$C_{\alpha r}$	=	Cornering stiffness of the rear tires, N/rad
F_{xf}	=	Tractive force at front axle, N
F_{xr}	=	Tractive force at rear axle, N
F_{yf}	=	Lateral force at front axle, N
F_{yr}	=	Lateral force at rear axle, N
I_z	=	Moment of inertia of vehicle about yaw axis, kgm^2
m	=	Mass of the vehicle, kg
α_f	=	Slip angle at front wheel, rad
α_r	=	Slip angle at rear wheel, rad
V_x	=	Forward speed, m/s
V_y	=	Lateral speed, m/s
δ	=	Steer angle at front wheels, deg
r	=	Yaw rate, rad/s
sec	=	Seconds, s

LIST OF NOMENCLATURES

FWD	=	Front Wheel Drive
RWD	=	Rear Wheel Drive
4WD	=	Four Wheel Drive
2WD	=	Two Wheel Drive
MATLAB	=	Matrix Laboratory

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CHAPTER I

INTRODUCTION

1.1 Background Study

In this modern era, automobiles and trucks have played a dominant role in transportation since the onset of their mass production. The primary difference between them is whether the vehicle's power is sent to the rear wheels (rear-wheel drive), the front wheels (front-wheel drive) or both (all-wheel or four-wheel drive). Everywhere on earth, people come into contact with these vehicles, often on a daily basis. Typically, a vehicle is one of the most complex and sophisticated products of the industrial revolution that individuals encounter and which they must interact. Although many people have an intuitive understanding of automobile dynamics, relatively few are able to describe in any quantitative way, just how the physical parameters of the vehicle would influence the vehicle stability and handling characteristics.

In this report, the directional stability during steady - state cornering for Four Wheel Drive vehicle (4WD), Rear Wheel Drive vehicle (RWD), and Front Wheel Drive vehicle (FWD) were been modelled and analyzed in the sense of lateral acceleration and yaw rate for each types of vehicle. The analyzed results were then been compared to determine the best vehicle model in term of directional stability during vehicle handling.

1.2 Problem Statement

The controversy has gone on for decades in deciding the vehicle directional stability for Four Wheel Drive vehicle (4WD), Rear Wheel Drive vehicle (RWD), and Front Wheel Drive vehicle (FWD). The argument on the directional stability often concerns with handling of the vehicle during cornering. Through this research, it is hoped that simulation done can help to provide more detail information to the public in deciding which vehicle suits them best. Moreover the research could act as guidance for further studies, students' references or even assist racers in having a better choice.

1.3 Objectives

- To model Four Wheel Drive vehicle (4WD), Rear Wheel Drive vehicle (RWD), and Front Wheel Drive vehicle (FWD)
- To determine yaw rate and the lateral acceleration for each of the vehicle models
- To find out the behaviour of each drive during cornering
- To expose to the public the parameters that have to be taken in account during cornering

1.4 Scope

The vehicle directional stability analysis was carried out by modelling three types of vehicles (Four Wheel Drive vehicle (4WD), Rear Wheel Drive vehicle (RWD), and Front Wheel Drive vehicle (FWD)). MATLAB & Simulink program was used to evaluate the vehicle models in identifying the behaviours that happened during steady – state cornering. Whole model was built from the basic physical rightfulness and mathematical description of actions, which arised from vehicle motion. The steady – state cornering equations were derived from the application of Newton's Second Law along with the equation describing the geometry in turns. For the purposes of analysis, bicycle model was been applied as it was more convenient and comprehensible.

CHAPTER II

LITERATURE REVIEW

Literature review is the section where previous studies or theories done by other researchers are been described, summarized, and evaluated so as to act as references or theoretical base in the process of undergoing individual research. In this chapter, previous studies are been revealed together with the concept of the three models and information regarding the cornering behaviour in order to determine the vehicle directional stability.

2.1 Handling Characteristics

The cornering behaviour of a motor vehicle is an important performance criterion that concerns with the safety and the comfort of a vehicle. Generally speaking, cornering is often equated with the handling condition. “Handling” on the other hand is a loosely used term meant to imply the responsiveness of a vehicle to driver input, or the ease of control (Gillepsie, 1992).

Frankly speaking, the handling characteristic of a road vehicle usually refers to its response to steering commands and to environmental inputs, such as wind gust and road disturbances, that affect its direction of motion. There are basic issues in vehicle handling: one is the control of the direction of motion of the vehicle; the other is its ability to stabilize its direction of motion against external disturbance.

Generally, when a driver moves the steering wheel and thus changes the angle, δ of the road wheels, two easily sensed effects are produced. One is a change in the lateral acceleration and another is change in the yaw rate. Although the two effects are coupled in a conventionally steered automobile, frequently one is more important to the driver than the other. For example, if the task is to change lanes on a straight freeway when traveling at high speed, the desire is to accelerate laterally without much change in yaw rate. On the other hand, when rounding a right angle corner, one must establish a yaw rate to change the heading angle, and the lateral acceleration is simply a necessary by – product during the maneuver. Thus the driver must use only one control input, the steering angle, to accomplish two quite different types of tasks. Furthermore, the input – output relationship are not constant but vary depending on how fast the vehicle is traveling. It is no wonder that it takes some training and practice to become a good driver.

2.2 Front Wheel Drive (FWD)

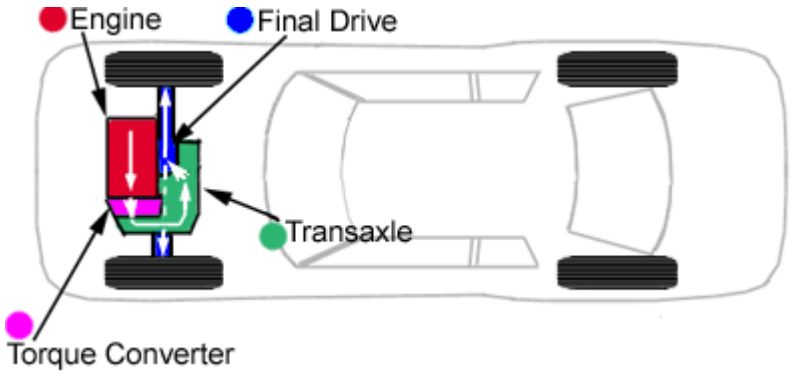

Figure 2.1: Front Wheel Drive (FWD)
(Source: Craigs Automatics, (2007))

In modern passenger cars, front-wheel drive (FWD) is the most common form of engine/transmission layout used, where the front wheels are driven by the engine. Front-wheel drive also means that the front wheels are doing both the driving and the steering for the car. In the year 1924, the first to have successfully implanted the application of the front wheel drive system was Harry Arminius Miller of Menomonie, Wisconsin in the design of Miller 122. Until today, the majority of front-wheel drive vehicles do not have conventional transmissions, drive axles or driveshafts. Instead, power is transmitted from the engine to a transaxle, or combination of transmission and drive axle, in one unit.

Advantages of FWD:

- More interior room for FWD since the powertrain used is a single unit contained in the engine compartment of the vehicle, driveshaft tunnel or rear differential are neglected in this case, increasing the volume available for passengers and cargos
- The production of FWD vehicles is cheaper as fewer components are needed plus engine and drivetrain can be pre-assembled as one unit before assemble into the car
- Lesser weight due to fewer components
- Improved fuel efficiency due to lesser weight
- When the track is straight and when speeding up, FWD car slides less than RWD car
- Better handling than RWD vehicles under slippery conditions like rain, snow and ice

Disadvantages of FWD:

- Front tires take up all work including controlling, speeding, steering and the main part in braking, this directly causes the tires burnt and lost their clutch features
- Immediate pushing of accelerator pedal leads to allocation of car weight, to the front part of the car loading, which causes the following: the back part becomes lighter and it leads to insufficient car turning
- Torque steer occurs as some high power front-wheel drive cars are prone to pull to the left or right under hard acceleration
- Usually during acceleration the weight of a vehicle shifts back, giving more traction to the rear wheels. In FWD case, the weight of the engine takes over the driving wheels limiting the acceleration of the vehicles

Examples:

- Lexus RX 400h
- 2007 Mazda 3 s
- Volvo s80
- Alfa Romeo 147

2.3 Rear Wheel Drive (RWD)

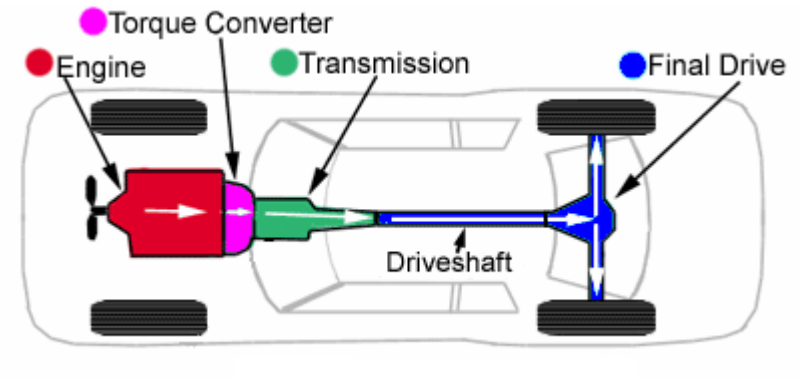

Figure 2.2: Rear Wheel Drive (RWD)

(Source: Craigs Automatics, (2007))

Rear wheel drive, abbreviated RWD, was the first method used to get power from the transmission to the tires. The first mass produced rear wheel drive car was the Curved Dash Olds, in 1901. For rear wheel drives, it can be simplified that the back wheels do the driving while the steering is done by the front wheels. A lot of high performance vehicles still swear by this layout. Unfortunately due to the fact that more materials are required to produce a typical rear wheel drive system, production costs and overall weights are higher, thus the popularity of rear wheel drive vehicles faded out in the economical and small car market when the front wheel drive systems were developed.