STUDY ON THE EFFECT OF DIFFERENT TIRE MODEL ON SPEED CHARACTERISTICS OF A VEHICLE MODEL

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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 "Study On The Effect Of Different Tire Model On Speed Characteristics Of A Vehicle Model" is the result of my own work except as cited in the references

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SUPERVISOR DECLARATION

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 : ……………………………………

Supervisor 1 : En. Faizul Akmar Bin Abdul Kadir

Date : …………………………………….

DEDICATION

To my beloved parents, En. Mohd Nasrin b Sudin and Pn. Halimatun bt Ahmad

ABSTRACT

This report studies the modelling and simulation of the vehicle longitudinal motion system. The steps in modelling and derivation of mathematical equation are discussed in this paper. The complete vehicle longitudinal motion model will be developed in Matlab Simulink R2013 software. It consists of engine model, vehicle dynamics, wheel dynamics, longitudinal slip ratio and tire model. For tire model, two tire models (Pacejka and Calspan) will be developed to be combined into the vehicle model and later go through testings in terms of various aspects, which include acceleration performance (Vx), coefficient friction between front tire and road surface (μ), slip ratio (S) and longitudinal force (Fx), purposely to compute the best tire model (either Pacejka tire model or Calspan tire model) for the study of vehicle longitudinal motion. Also, the braking element is eliminated from this study as the main purpose of the study is to analyse the acceleration performance of vehicle model in longitudinal motion, therefore the braking condition is not necessary. Besides that, the automatic transmission will be used in engine model, based on the shift-map logic diagram of modern vehicle. The input throttle setting is constrained to a value between 0-100%. All modelling that involved in this study are developed in Matlab Simulink software.

ABSTRAK

Laporan ini mengkaji berkenaan pemodelan dan simulasi terhadap sistem pergerakan membujur sesuatu kenderaan. Langkah-langkah untuk proses pemodelan dan perolehan persamaan matematik dibincangkan secara lebih mendalam dalam laporan ini. Seterusnya, model kenderaan dalam pergerakan membujur yang lengkap akan dibina dalam perisian Matlab Simulink R2013. Ia mengandungi model enjin, model dinamik kenderaan, model dinamik roda, nisbah kegelinciran secara membujur, dan juga model tayar. Untuk model tayar. dua model tayar akan dimodelkan untuk digabungkan kedalam model kenderaan dan seterusnya akan melalui ujian-ujian berdasarkan beberapa aspek seperti prestasi pecutan (Vx), pekali geseran diantara tayar depan kenderaan dan permukaan jalan (μ), nisbah gelenceran (S), dan daya membujur (Fx),bertujuan untuk memilih model tayar terbaik (diantara Pacejka dan Calspan) bagi diganapakai dalam kajian terhadap sistem pergerakan membujur sesuatu kenderaan. Elemen brek juga disingkirkan daripada kajian ini atas sebab bercanggah dengan tujuan asal kajian ini, iaitu untuk mengkaji prestasi pecutan sesebuah model kereta ketika bergerak dalam arah membujur.Oleh sebab itu,situasi membrek tidak diperlukan .Selain itu, transmisi automatik akan digunakan dalam model enjin, berdasarkan rajah logik 'shift-map' untuk kenderaan moden. Nilai kemasukan untuk tetapan pendikit akan dihadkan kepada 0-100%. Segala proses permodelan yang terlibat dalam kajian ini dibina menggunakan perisian Matlab Simulink.

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LIST OF SYMBOLS

m	=	Lumped mass, kg
ω	=	Rotation rate of wheels, rpm
R	=	Rolling radius, m
J	=	Polar moment of inertia, kg.m^2
μ	=	Coefficient of friction between wheels and contact surface
L	=	Wheelbase length, m
θ	=	Road gradient, degree
ρ	=	Density of air, Kg/m^3
A	=	Frontal area of the vehicle, m^2
F_x	=	Longitudinal forces acting on a vehicle, N
F_y	=	Lateral forces acting on a vehicle, N
F_z	=	Vertical forces acting on a vehicle, N
V	=	Forward velocity, km/h
F_a	=	Aerodynamic resistance forces, N
F_r	=	Rolling resistance forces, N
F_d	=	Drag forces, N
λ	=	Slip ratio
τ_e	=	Torque delivered by engine to each wheel, Nm
τ_r	=	Reaction torque on each wheel, Nm
$\tau_{d(\omega)}$	=	Viscous friction torque, Nm

C_f = Viscous friction coefficient

C_d = Aerodynamic drag coefficient

C_r = Rolling resistance coefficient

η_g = Current gear ratio

η_f = Final drive ratio

CHAPTER 1

INTRODUCTION

1.1 Background

Every moving vehicle has its own characteristics. It includes weight of vehicle acting to center of gravity, tractive forces, vertical and longitudinal forces, acceleration etc. These characteristics can be seen more clearly by using the Figure 1.1 below:

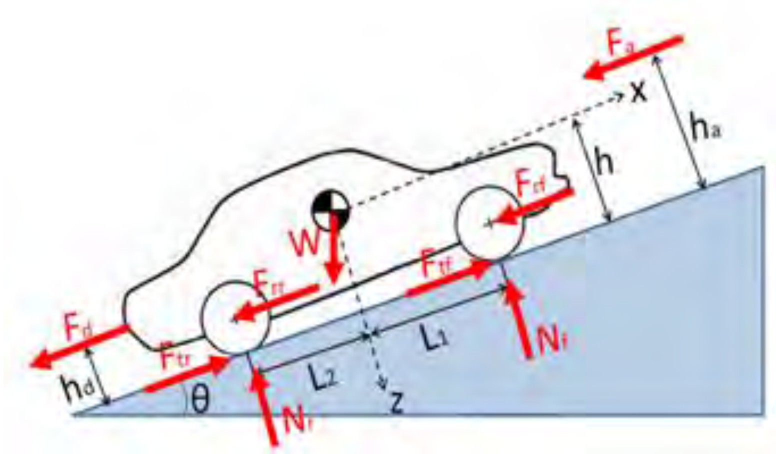

Figure 1.1: Forces Acting On a Vehicle

The simplified version of real system is called the mathematical model. To develop vehicle longitudinal model due to Newton's second law, the vehicle system block must be created first. The system consist of vehicle body dynamics, front tire model traction, front wheel dynamics, powertrain model ,brake system model, real wheel dynamics and rear tire traction model. Throttle and brake settings are chosen as the main inputs, and the outputs are vehicle velocity, and the front/rear wheel velocities. In order to design a controller, a good representative model of the system is needed. A vehicle mathematical model, which is necessary for both acceleration and deceleration, is described in this report. The mathematical model then will be put into equation in block diagram in Matlab Simulink that can be shown in Figure 1.2:

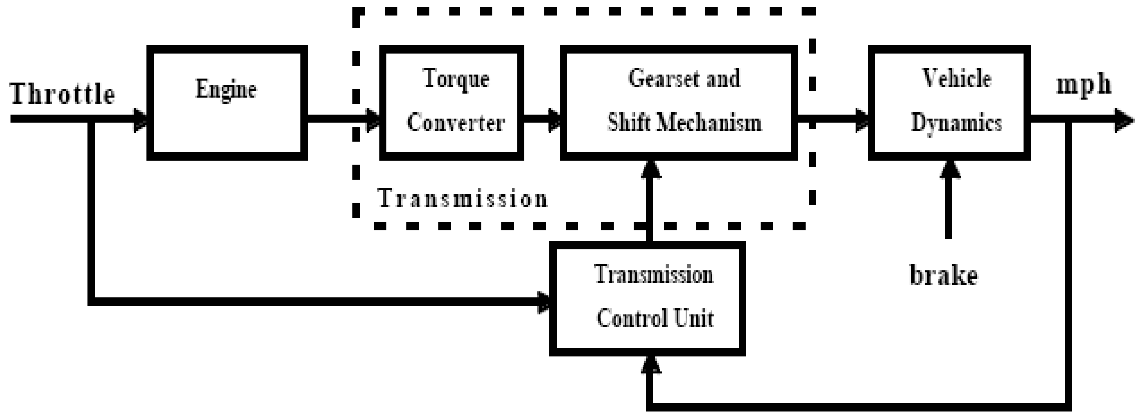

Figure1.2: Example of Block Diagram

The model here retains the elements necessary for dynamics of the system although it relatively simple. The model is intended to calculate the motion of a passenger vehicle when driving in normal conditions, representing real vehicle behaviour in public roads.

Tire important to vehicle control system because it generates the forces that drive and maneuver the vehicle**.** The tire is a system with input and output quantities. The tire is a main component of the wheel-road contact as it ensures three important functions which are bearing the vertical load and absorbing road deformations, producing longitudinal acceleration efforts and contributing to vehicle braking, and producing the required transversal efforts that help the vehicle turning (Kiencke, 2005). The motion of the wheel body with respect to the road covers the six input quantities such as the side slip angle and the fore slip, while the tire with its deflections and natural frequencies produces the six output quantities, such as the cornering force and the normal load. Fundamental differential equations for a rolling and slipping body are derived for serving the tire modeling process in later chapters. Finally, a discussion of different tire models has been given.

Modeling the efforts at the wheel-road contact has been widely regarded nowadays. In this respect, several tire models have been developed with quite different properties, such as Pacejka 'magic', Calspan, Dugoff, Kiencke, and Gim. These tire models will be analyzed and compared further more in later stage of this study.

1.2 Problem Statement

Designing a new or modifying an existing vehicle is a complex, time-consuming process that brings both technical and process challenges. There is an issue of how using software like Matlab Simulink can make the modelling process become easier rather than by test it to real vehicles. Besides that, it is well recognized that tires play an essential role in all aspects of a vehicle behavior. Tires generate the forces that drive and maneuver the vehicle. The knowledge of magnitude, direction and limit of the tire forces are essential and valuable for vehicle control systems. However, the estimation of these variables in all driving conditions and in real-time is a very challenging task. There are few tire models that when it is implemented into computer code, it is not compatible with low speed moving of vehicle, such as Pacejka. There a question arises about how by changing the tire models affect the speed characteristics of the vehicle model itself.

1.3 Objective

The objectives of this project are as follows:

1. To develop vehicle longitudinal model in MATLAB Simulink
2. To apply different tyre model to the vehicle ie: Pacejka vs Calspan
3. To compare the performance of each tyre model proposed by measuring the vehicle speed response towards.

1.4 Scope Of Project

The scopes of this project are:

1. All equation of speed characteristics that related to vehicle dynamics are modelled by using MATLAB Simulink R2013 software.
2. The vehicle longitudinal models used to describe the dynamics in this report are based on two-wheel traction model/half-car model.
3. The analyses of the simulation are measured in kilometre per hour (KPH) unit.

CHAPTER 2

LITERATURE REVIEW

2.1. Introduction

This chapter describes a general overview of this research. Modeling and simulation of vehicle dynamics has become a very important area in vehicle research in recent years. There are numerous controls techniques studied such as linear and adaptive control, genetic fuzzy control, and scheduling gain control PID. However, the aspect of tire model still important to the vehicle dynamics performance.

2.2. Vehicle Longitudinal Model

The distribution of longitudinal forces has a large influence on vehicle handling characteristics such as the driver/vehicle interaction, road holding and yaw stability, in particular during combined traction/braking and cornering near the grip limit of the tires. (Klomp, 2010). Ohstsuka and Vlacic in their study, proposed about a vehicle longitudinal model targeted towards low velocity adaptive cruise control system, which is presented through a review of conventional models. The vehicle model has two inputs in term of engine input and the brake input. The models also described by the composite of the power-train system model, the brake system model and the drive-train model. The resulting response from the proposed model then is examined through numerical simulation (Vlacic, 2002).

2.3. Vehicle Dynamics

Vehicle dynamics is the theory of how tire and aerodynamic forces acting on a vehicle affect the vehicle motion, response, stability, and other characteristics. Vehicle dynamics thereby provides the important aspects necessary to understand the phenomena described above and which are important for a safe driver/vehicle/road interaction. The main focus in the field of vehicle dynamics was on improving the brakes and tires due to the demands of increased vehicle speed (Klomp, 2010).

Occasionally in presenting the dynamic model of a vehicle, the model of the tire has been excluded for simplification, despite being understood as the main realistic source to push the vehicle forward during acceleration (tractive effort) and to hold (or reduce the velocity) the vehicle when applying the brake (braking effort), instead the torque produced at the wheels through the power train is directly considered as a source of pushing the vehicle forward and subsequently the brake torque to reduce the speed of the vehicle. In reality, apart from the effect of the aerodynamic force and the gravitational force (during travelling the vehicle up/down hill) on the longitudinal performance of a vehicle, the forces developed between the tire and the road contact interface have significant impact on the performance of the vehicle. The performance of a vehicle such as motion of accelerating, braking, cornering and ride is a response to forces imposed. The dominant forces acting on a vehicle to control performance are developed by the tire against road. Therefore, it is necessary to develop an understanding of the behaviour of tires, characterized by the forces and moments generated over the various conditions of which the vehicle operate (Shakouri, 2010).

The study of vehicle dynamics can be accomplished by two method, which are empirical method and analytical method. The empirical one is based on understanding derives from trial and error by which one factors influence the vehicle performance, in which way, and under what conditions. However, this method often leads to failure. This is because without mechanic understanding of how changes in vehicle design/properties affect performance, extrapolating past experience to new condition may involve unknown factors which will produce result that defying the prevailing rules of thumb. For this reason, the analytical method is more favourable by engineer. This method firstly attempts to describe the mechanic of interest based on known law of physics and then the analytical models will be established. These models can be represented by algebraic or differential equations that relate forces or motions of interest to control inputs and vehicles or tire properties. These equations then allow one to evaluate the role of each vehicle property in the phenomenon of interest. By doing the models, it provides a means to identify the important factors, the way they operate, and under what conditions. It also provides a predictive capability as well so that the changes necessary to reach performance goal can be identified (Gillespie, 1992).

Konrad Reif (2014) in his study about basic principles of vehicle dynamics, states that a body only can be move or change course by the force action. There are many forces that could act upon a vehicle when it is being driven. Tire aspect should plays an important role as any change of speed or direction may involve forces acting on the tires.

Meanwhile, Olson (2003) proposed about a formulation where the slip is taken to be a dynamic state variable, replacing the absolute rotational rate of tire/wheel. Liu, June (1995) in his study has already developed the equations of motion for quarter car model in that way, but their study was more focusing on control algorithm based on gain-scheduling, rather than dynamic behaviour generally. Therefore, a formulation was created, that focusing more on general dynamic characteristics of the vehicle traction. The formulation could allow the dynamics for entire range of vehicle speeds and also slip values to be captured by a scalar function, in terms of brake/engine torque, slip and friction/slip relationship. The dynamic model presented here are capable of demonstrate the way of vehicle can undergo stable braking or acceleration, depending on engine/brake torque, friction characteristics and the vehicle parameters.

2.4. Vehicle Longitudinal Motion

Vehicle longitudinal motion control objective is to ensuring passenger safety and comfort. It is an important aspect in dynamic collaborative driving such as when multiple vehicles should coordinate to share road efficiently while maintaining safety. For this reason, several works have been sought to create something like an adaptive cruise control that consists in maintaining a specified headway between vehicles. Different control techniques used including linear and adaptive control, genetic fuzzy control, and scheduling gain control involving .There is a need to create a longitudinal control that are based on simple models neglecting important nonlinear aspects of the vehicle such as rolling resistance, aerodynamics effects and road load. The model should accounts for most vehicle nonlinear dynamics including tire-road interaction. A suitable control model is developed for the vehicle longitudinal behaviour. The aspect considered to meet the accuracy requirement here are not only the aerodynamic phenomena, but also tire-road friction. Modelling the tire/road contact is a quite complex issue involving multiple aspects relevant to tire characteristics (e.g. structure, pressure) and to environmental factors (e.g. road load, temperature). Several tire models being considered are Pacejka's model, Gim's model, Dugoff's model, and Kiencke's model (Majdoub, 2012).