SUPERVISOR DECLARATION

"I hereby declare that I have read this thesis 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: ....

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MODELING AND VALIDATING OF
VEHICLE LONGITUDINAL DYNAMIC

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DECLARATION

"I hereby declare that the work in this report is my own except for summaries and quotations which have been duly acknowledged."

Signature: ....

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Especially for

My beloved family

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ABSTRAK

Kajian ini berkaitan dengan simulasi, permodelan dan pengesahan sistem dinamik kenderaan dalam pergerakan kehadapan. Data yang diperolehi daripada kajian ini adalah sesuai untuk membangunkan sistem kenderaan yang lebih komplek seperti kawalan pemanduan adaptif (ACC) dan juga sistem brek anti-kunci (ABS) yang menggunakan pengawalan pecutan dan brek sebagai kawalan. Simulasi ini menggunakan persamaan terbitan matematik untuk menghasilkan model dalam perisian simulasi Matlab. Langkah – langkah dalam permodelan dan penerbitan persamaan matematik juga dibincangkan dalam kajian ini. Ia termasuklah model enjin, dinamik kenderaan, dinamik roda kenderaan, nisbah gelinciran tayar dan juga model tayar Pacejka. Model ini dibangunkan dalam perisian simulasi Matlab dan pengesahan dibuat dengan menggunakan perisian CarSim. Parameter yang digunakan untuk model simulasi ini adalah berdasarkan parameter Proton Iswara Aeroback. Tetapi, model enjin yang digunakan adalah model 75kw enjin berbanding enjin 55kw yang dikeluarkan oleh pengilang asal.Sistem transmisi pula menggunakan sistem transmisi automatic berdasarkan sistem transmisi kenderaan moden.Kami harap kajian ini dapat memberi maklumat untuk membuat simulasi dinamik kenderaan dalam pergerakan kehadapan.

ABSTRACT

This paper studies the simulation, modeling and validation of vehicle longitudinal dynamic system. The data obtained from the studies may be used in developing larger system such as adaptive cruise control (ACC) and antilock brake system (ABS) which used the acceleration and braking as the result to control. The simulation of vehicle longitudinal dynamic use mathematical equation derivation to simulate the model. The step in modeling and derivation of mathematical equation are discussed in this paper. It is consist of engine model, vehicle dynamic, wheel dynamic, longitudinal slip ratio and the pacejka tire model. The modeling is develop in Matlab Simulink software and the validation use the validate software for vehicle which is CarSim software. The parameter use in the modeling is based on Proton Iswara Aeroback parameter but the engine model is used the 75kw engine instead of 55kw original engine by manufacturer. The transmission use the automatic transmission based on the shift-map logic of modern vehicle. We hope that this paper will give information about the simulation of vehicle longitudinal dynamics.

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CHAPTER 1

INTRODUCTION

1.1 OVERVIEW

Modeling and Simulation is a discipline for developing a level of understanding of the interaction of the parts of a system, and of the system as a whole. The level of understanding which may be developed via this discipline is seldom achievable via any other discipline. A simulation generally refers to a computerized version of the model which is run over time to study the implications of the defined interaction (Hung and Ramin1997). Simulations are generally iterative in there development. One develops a model, simulates it, learns from the simulation, revises the model, and continues the iterations until an adequate level of understanding is developed.

Vehicle dynamic is concerned with controllability and stability of automobile, it is important in design of a ground vehicle (Bahouth, G. 2005). Many mathematical model for vehicle were propose and the analysis of the dynamic response of them have been examined in large number of previous investigations. In studying vehicle longitudinal dynamics, three essential components are considered for typical ground vehicle, powertrain dynamics, vehicle body dynamic (two wheel traction model) and wheel dynamics. The incorporation of road tire interaction is also an essential part of vehicle dynamics. Therefore, it is important to construct a mathematical model that include the nonlinear characteristic of the system. So, Pacejka tire model is use in this study.

The proposed model accepts throttle input, braking inputs, and outputs the resulting vehicle longitudinal slip ratio for each tyre. Matlab simulink is chosen as a computer simulation tool used to simulate the vehicle dynamics behavior and performances in this study. The mathematical equations of vehicle model are constructed in the software to create a vehicle model. By inserting the model data, the mathematical equations will be automatically formed internally (Hung and Ramin1997).

The modeling assumption considered in this study is as follow: the vehicle accelerates in full throttle and then sudden brake when it reaches certain time such as 15 second after launch. Then the simulator will find the longitudinal slip ratio for each tire. The ideal slip ratio on braking is 0.2 which appear in most cars equipped with ABS.

This paper is organized as follows: The first section contains introduction and the review of some related works, followed by mathematical derivations of full vehicle longitudinal model with Pacejka tire model in the second section.. The third section presents the results of validation of the full vehicle model with experimental vehicle and the last section contains some conclusions of the work.

1.2 PROBLEM STATEMENT

The longitudinal dynamics used to measure the vehicle speed and each tire longitudinal slip. The variable are very useful in build another system such as Anti-lock Braking System (ABS) and also Adaptive Cruise Control (ACC). To build those system, the vehicle longitudinal dynamics must be derive, simulate and validate first. The simulation must be validate by using the CarSim software. mathematical model of full vehicle model will be developed. The mathematical model then will be derived in Matlab/Simulink software and verified with a validated vehicle dynamic software namely CarSim Software to show the validity of the model. The model is then will be validated with the instrumented experimental vehicle to show the capability of the model.

1.3 OBJECTIVES

ii. To derive the mathematical equation of full vehicle model in longitudinal direction.

iii. To model and simulate the full vehicle model in Matlab Simulink Software.

iv. To validate the full vehicle model with validated vehicle software namely CarSim Software.

1.4.1 SCOPES

i. Derivation mathematical equation of full vehicle longitudinal model.

ii. Modeling and simulate of full vehicle model in Matlab Simulink Software.

iii. Validate with validated vehicle software namely CarSim Software.

iv. Parameter of vehicle is based on Proton Iswara Aeroback.

CHAPTER 2

LITERATURE REVIEW

2.1 LONGITUDINAL DYNAMIC MODEL

Short M. *et al*. in 2004 develop the model of vehicle longitudinal dynamics of a passenger car. The model described provides a suitably detailed description of a host car. Which is controlled by s distributed embedded system in a hardware in the loop real time test facility.This paper consists of vehicle dynamics and powertrain dynamics. Longitudinal tire forces, aerodynamic drag forces, rolling resistance forces and gravitational forces.

Yan and Junmin in 2001 was investigate the adaptive vehicle speed with real-time tire–road friction coefficient estimation method that is independent of vehicle longitudinal motion for ground vehicles with separable control of the front and rear wheels. The tire–road friction coefficient information is of critical importance for vehicle dynamic control systems and intelligent autonomous vehicle applications.

In the paper, the vehicle longitudinal-motion-independent tire–road friction coefficient estimation method consists of three main components: an observer to estimate the internal state of a dynamic LuGre tire model; an adaptive control law with a parameter projection mechanism to track the desired vehicle longitudinal motion in the presence of tire–road friction coefficient uncertainties and actively injected braking excitation signals; and a recursive least square estimator that is independent of the control law, to estimate the tire–road friction coefficient in real time. Simulation results based on a high-fidelity CarSim full-vehicle model show that the system can reliably estimate the tire–road friction coefficient independent of vehicle longitudinal motion.

Khekare in 2009 was investigate a eight degree-of-freedom model that focuses on vertical and longitudinal dynamics developed in Simulink. A rather simple brake system with an ideal antilock system (ABS) was used to avoid wheel lock-up in hard braking scenarios. A Pacejka tire model was employed as well. The nonlinear tire stiffness and the nonlinear shock absorber curves were incorporated in the model using look-up tables. The model was validated in the time domain using the results from a vehicle model in CarSim for similar tests.

The study wasdevelopingwith cooperation with Michelin which invent the new tire which is a non-pneumatic tire (called the TWEEL™). The primary focus area of this thesis is to evaluate the straight line braking performance of a 2007 BMW Mini Cooper with TWEELs™ on randomly irregular roads. Different vertical road profiles were utilized to evaluate their effect on braking. A comparison of results is made between the original equipment (OE) tires and the TWEEL™.

Yao in 2010 investigate about adaptive cruise control (ACC). An Adaptive Cruise Control (ACC) system is a driver assistance system that assists a driver to improve driving safety and driving comfort. The design of ACC controller often involves the design of a switching logic that decides where and when to switch between the two modes in order to ameliorate driving comfort, mitigate the chance of a potential collision with the preceding vehicle while reduce long-distance driving load from the driver.

To develop the ACC system, the vehicle longitudinal dynamics model must develop first. It consists of two major parts, vehicle dynamics and powertrain dynamics. Longitudinal tire forces, aerodynamic drag forces, rolling resistance forces and gravitational forces will be described in the discussion about the vehicle dynamics.

2.2 TIRE MODEL

The primary forces during lateral maneuvering, acceleration, and braking are generated by tires as a function of the driver input. The linear analysis of a tire model commonly considers constant tire side force coefficients at small force output range. The linear tire model doesn't consider longitudinal tire forces due to the complex interactions between lateral and longitudinal tire forces. Thus, linear tire model is suitable for analyzing a stable vehicle behavior under the assumption of small steering and acceleration. In our driving simulator, it is very important to describe the exact behavior of a vehicle in any driving scenario including inclement driving conditions which may require severe steering, braking, acceleration, and other driving related operations. Therefore, in order to simulate the complete vehicle operational range, it is important to properly model tire forces containing the interactions of longitudinal and lateral forces from small levels through saturation. The tire model used in the driving simulator is based on a paper from U.S Department of Transportation (Kadir *et al.* 2008).

The paper presents complete computations of the tire forces by using the parameters available from various tire test results including comprehensive Pacejka model and data. The tire model developed in this paper provides a useful force producing element for a full driver/vehicle model as in our driving simulator. In the following sections, physical and analytical tire model is presented with basic tire variables followed by the identified model equations and resulting plots.