MODELLING AND VALIDATION OF BUS RIDE AND HANDLING MODEL

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BACHELOR OF MECHANICAL ENGINEERING TECHNOLOGY (AUTOMOTIVE TECHNOLOGY) WITH HONOURS

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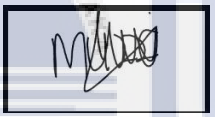
DECLARATION

I declare that this thesis entitled " Modelling And Validation Of Bus Ride And Handling Model" is the result of my own research except as cited in the references. The result has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : 

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APPROVAL

I hereby declare that I have checked this thesis and, in my opinion, this thesis is adequate in terms of scope and quality for the award of the Bachelor of Mechanical Engineering Technology (Automotive Technology) with Honours.

Signature : 

Supervisor Name : *Ir. Ts. Dr. Mohamad Hafiz bin Harun*

Date : 17 JANUARY 2022

DEDICATION

First of all, I would like to thank Allah for giving me strength to complete this study and to see this thesis become reality. I am dedicated this project and research work to my beloved parents, Mohamed Naim bin Abdul Kadir and Noor Hasni binti Abdullah who have always give me support and backup to finish my studies. Not forget also to my siblings, my supervisor Ir. Ts. Dr. Mohamad Hafiz bin Harun and also my friends who help me throughout my study journey. Thank you for all the helping and I always appreciate it and will not forgot the moments about it.

ABSTRACT

As part of the bus ride and handling model development, this project was focused on the modelling and validation of bus ride and handling models. The two-axle bus was utilised to develop the bus ride and handling model. For the bus ride model, the bus ride model equation was derived, which includes three degrees of freedom (DOF) for body motion, which is vertical, pitch, and roll, and four degrees of freedom (DOF) for unsprung mass, which is based on the vertical motion of each tyre. For the bus handling model, the bus handling model equation was derived, which includes three degrees of freedom (DOF) for the vehicle body, which is longitudinal, lateral, and yaw motion, and also another four degrees of freedom (DOF) that corresponds to the spin of each tire. MATLAB/Simulink software was used to simulate the developed bus ride and handling model. The model for the ride model in MALTLAB/Simulink is derived from one that involves the sprung mass, unsprung mass, tires, spring, and damper. The bus parameters are obtained from the bus manufacturer or from TruckSim. The developed ride and handling models are verified using the TruckSim software. For the ride model, the simulation will be simulated on a flat road when the left side of the tyre hits the 10 cm bumps at a speed of 90 km/h. The time for the front left tyre to hit the bumps is 0.4 seconds. For the handling model, two manoeuvring tests will be conducted, namely step steering cornering and single lane change, to investigate the bus handling response while the input of the handling model is steering wheel angle. The speeds that were needed to investigate for the handling model were at speeds of 60 km/h and 90 km/h. The output responses that needed to be discussed for the ride model were pitch angle, roll angle, and vertical acceleration, while for the handling model, the output responses that needed to be discussed were lateral acceleration, yaw rate, and side slip angle. The study findings reveal that the dynamic behaviour of the generated bus ride and handling model substantially resembles the dynamic behaviour of the TruckSim bus ride and handling model. For all the output response for both ride and handling models, the percentage variation in Root Mean Square (RMS) values between the two Simulink and TruckSim models is less than 5%. It gives assurance that the generated model established in this study may be used to develop a bus ride and handling model successfully.

ABSTRAK

Sebagai sebahagian daripada perjalanan bas dan pembangunan model pengendalian, projek ini tertumpu pada pemodelan dan pengesahan perjalanan bas dan model pengendalian. Bas dua gandar itu digunakan untuk membangunkan model perjalanan dan pengendalian bas. Bagi model perjalanan bas, persamaan model perjalanan bas telah diperolehi, yang merangkumi tiga darjah kebebasan (DOF) untuk pergerakan badan, iaitu menegak, padang dan guling, dan empat darjah kebebasan (DOF) untuk jisim tidak bercabang, iaitu berdasarkan gerakan menegak setiap tayar. Untuk model pengendalian bas, persamaan model pengendalian bas telah diperolehi, yang merangkumi tiga darjah kebebasan (DOF) untuk badan kenderaan, iaitu gerakan membujur, sisi dan yaw, dan juga empat darjah kebebasan (DOF) lain yang sepadan. kepada putaran setiap tayar. Perisian MATLAB/Simulink telah digunakan untuk mensimulasikan perjalanan dan model pengendalian bas yang dibangunkan. Model untuk model tunggangan dalam MALTLAB/Simulink diperoleh daripada model yang melibatkan jisim sprung, jisim unsprung, tayar, spring dan peredam. Parameter bas diperoleh daripada pengilang bas atau daripada TruckSim. Model tunggangan dan pengendalian yang dibangunkan disahkan menggunakan perisian TruckSim. Bagi model tunggangan, simulasi akan disimulasikan di atas jalan rata apabila bahagian kiri tayar mencecah bonggol 10 cm pada kelajuan 90 km/j. Masa untuk tayar kiri hadapan terkena bonggol ialah 0.4 saat. Bagi model pengendalian, dua ujian manuver akan dijalankan iaitu selekoh stereng langkah dan pertukaran lorong tunggal bagi menyiasat tindak balas pengendalian bas manakala input model pengendalian adalah sudut stereng. Kelajuan yang diperlukan untuk menyiasat model pengendalian adalah pada kelajuan 60 km/j dan 90 km/j. Tindak balas keluaran yang perlu dibincangkan untuk model tunggangan ialah sudut pic, sudut guling, dan pecutan menegak, manakala bagi model pengendalian, tindak balas keluaran yang perlu dibincangkan ialah pecutan sisi, kadar yaw, dan sudut gelinciran sisi. Penemuan kajian mendedahkan bahawa tingkah laku dinamik bagi model perjalanan dan pengendalian bas yang dijana secara ketara menyerupai tingkah laku dinamik model perjalanan dan pengendalian bas TruckSim. Untuk semua respons keluaran untuk kedua-dua model tunggangan dan pengendalian, variasi peratusan dalam nilai Root Mean Square (RMS) antara dua model Simulink dan TruckSim adalah kurang daripada 5%. Ia memberi jaminan bahawa model yang dijana yang ditubuhkan dalam kajian ini boleh digunakan untuk membangunkan model perjalanan dan pengendalian bas dengan jayanya.

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LIST OF SYMBOLS AND ABBREVIATIONS

R&R	-	Rest and Recreation
MOT	-	Ministry of Transport Malaysia
DOF	-	Degree Of Freedom
MIROS	-	Malaysia Institute of Road Safety Research
K_s	-	Spring
C_s	-	Damper
R&D	-	Research and Development

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background

Accident's statistics are increasing day by day. According to Dewan Bahasa Dan Pustaka, an accident is a disaster that happened unexpectedly. Accidents can cause adverse effects to an individual such as physical injury, property damage and even death. According to the Road Transport Act of 1987, a road accident occurs when harm is caused to a person, property, vehicle, structure, or animal on any public road, including tunnels, side stops (R&R), elevated highway, toll plaza viaducts and many more. Malaysia is one of the countries with the highest rate of traffic accident in the world, according to studies.

Statistics released by the Ministry of Transport Malaysia (MOT) for a period of 10 years from 2009 to 2018 shows that road accident cases in Malaysia showed a significant increase from year to year, it can be seen that the number of accidents in 2009 was 397,330 and road accident cases in 2018 were 548,598. Road accident deaths released from the data of the Ministry of Transport Malaysia also found that more than six thousand people were reported to have died every year from 2009 to 2018.

From the same study released by the Ministry of Transport Malaysia, the statistics of road accidents involving all types of vehicles in 2009 to 2018 are very high and very worrying. Accidents involving all types of vehicles such as motorcycles, cars, vans, buses, lorries, 4-wheel drives, taxis, bicycles and other vehicles show a total of more than 800,000 cases. The most involved cases are of the motor vehicle type which is among the most

numerous vehicles on the road and is followed by motorcycles. Both vehicles show a figure of more than one hundred thousand accident cases every year.

Accident cases involving commercial vehicles such as buses are also seen to be increasingly alarming. Nearly 10,000 cases of road accidents that occur in Malaysia involve buses. Statistics show that in 2012, road accident cases involving bus vehicles were the highest number of cases in 10 years based on records in 2009-2018 which was 10,617. This ratio will increase from year to year if seen from the statistics given.

In the logistics and transportation industries, commercial vehicles, particularly buses, have already become an indispensable way of transporting goods. This is owing to a buses ability to move vast quantities of goods while also having access to a greater range of transportation options. Buses, on the other hand, have low driving and stability analysis due to the vehicle's high gravitational pull. This trait causes the buses to rollover, particularly during fast single lane changes and heavy cornering near highway side streets. Furthermore, the majority of rollover accidents result in injury to the driver. As a consequence, a dynamic study of the buses is needed to determine the reason of the rollover.

The quarter car model, half car model and full car model are the most common types of simplified vehicle models used in a vehicle dynamic analysis. The effects of ride and handling on vehicle model responses are studied independently. The road bump is thought to have provided the input for the ride model. The handling model, on the other hand, assumes that a vehicle is driving on a flat road with cornering and single lane change. The generated vehicle model is then analysed using vehicle dynamic software like TruckSim or an actual vehicle to create a model that accurately represents the real vehicle system. The bus model in this study is developed that used a 7 DOF riding model and 7 DOF handling

model and starts with the formulation equation for the ride and handling model. MATLAB/simulink software is being used to model all of the generated equations. The bus model is validated using the TruckSim software, which includes a ride simulation test and also handling simulation test.

1.2 Problem Statement

Malaysia has been involved in many accidents involving public transport such as buses. As issued by the Ministry of Transport Malaysia which shows that the cases of road accidents involving buses each year are very high to exceed 5000 cases per year. In 2007, a dramatic bus rollover accident that killed 22 people near Bukit Berapit, Bukit Gantang was reported by MalaysiaKini on 13 August 2007. Therefore, a vehicle safety system was developed to prevent accidents against the bus.

This vehicle safety system is developed to provide safety to the bus driver. This is because the road accident involving this bus often happens because of the driver's own disability. In addition, it was also developed to provide safety to the bus itself and the environment and also can save cost.

The vehicle safety system that was develop is difficult to understand the character that occurs in real vehicles because the types of buses used are not the same as each other with other buses. Therefore, the simulation needs to be done by developing an accurate vehicle model in order to give an accurate respond like a real vehicle.

1.3 Research Objective

The main aim of this research is to modelling and validate of a bus ride and handling model. Specifically, the objectives are as follows:

a) To develop bus ride and handling model.

b) To validate bus ride and handling model.

1.4 Scope of Research

The scope of this research is based on the objective above:

a) Develop the 7-DOF bus ride model.

b) Develop the 7-DOF bus handling model.

c) The parameter of the bus model is obtained from the bus manufacturer.

d) Ride maneuvering test is performed in this study to investigate the bus ride responses.

e) Two handling maneuvering tests are performed in this study namely step steer cornering and single land change to investigate the bus handling responses.

f) The verification and validation of the bus model is conducted using the multibody dynamic modelling software known as “TruckSim” and the result from the publish data.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter, research from journal, internet, books and other resources have been used to get information and facts regarding to this research project. The aim of this study is to create a basic knowledge and information from previous knowledge and ideas in order to complete this project.

2.2 Classification of Buses

Buses are big road vehicle that are meant to transport a large number of people as well as driver and, in certain cases, the bus conductor. The word 'Bus" comes from the Latin word "omnibus" which is signifies "for all". The bus full name is 'omnibus vehicle" which mean "vehicle for all". Around the world, there are many buses that can be seen today. Some of the buses that can be seen around the world were transit bus, articulated city bus, coach (long distance bus) and also regional bus.

In Malaysia, buses are categorised into two types that is single storey bus and double storey bus according to Malaysia Institute of Road Safety Research (MIROS). The single – deck bus has a height range of 3 metres to 3.5 metres and has a single deck for passengers. The length of a single – story bus is usually 5 to 12 metres but it can be up to 15 metres as seen in figure 2.1. Low floor and high floor single deck buses are the two varieties of single deck buses. It is crucial to note that the wheelchair ramp at the entrance has been added. For single deck, there are two fundamental qualities that separate low and high floor. Low floor

buses are commonly utilized for public transportation. High floor buses usually for coach travel or long-distance travel. Additionally, extra space beneath the passenger's seat is used for luggage storage.

Double deck buses are classified into two types that is based on their usage that is double deck and high deck. The terms double deck refers to two story transit bus. It has a low floor for easier access and has more headroom on the lower deck as shown in Figure 2.2. Double deck buses can carry a passenger up to 100 at one time. Lower deck passengers may stand whereas the upper deck passenger must sit properly due to the space constrains and a wheelchair bay is available. The terms high deck refers to a double decker bus that is used for long distance journey. The majority of the passengers' seats are at the upper deck.

Figure 2.1 Single Deck Bus

Figure 2.2 Double Deck Bus

2.3 Vehicle Model

In general, vehicle model is an importance factor in the development of the of the vehicle control system. Many automotive researchers used various types of vehicles. The first is quarter car model. Quarter car model is rarely used by automotive researchers. The following model is the half car model. The half car model is less used by automotive researchers because of the behavior of the half car model is too limited. Lastly, many automotive researchers used full car model. Full car model represented as 14 degree of freedom (DOF) vehicle model. By using 14 degree of freedom (DOF) of vehicle model, researchers can do experiment, modelling, validation and also verification such as according to the title (Ghike & Shim, 2006) which is 14 Degree-Of– freedom vehicle model for roll dynamic study, (Setiawan et al., 2009) which is simulation and validation of 14 DOF full vehicle model based on modeling and validation of 14 DOF full vehicle model.

2.3.1 Quarter Car Model

A 2 Degree of Freedom (DOF) of suspension system with quarter car model is shown in figure 2.3. It represent the vehicle's suspension system at any of four wheels, and the degrees of freedom are axle displacement and vehicle body displacement at the specific wheels (Mahala et al., 2004). This model is made up of three parts: a spring,K_s, a damper, C_s, and an active force actuator. In a passive suspension, the active force,F_a, is said to be zero. The sprung mass, m_b, and unsprung mass, m_u, represent the mass of the vehicle body equivalent to the quarter car and the axle and tire equivalent mass, respectively. The vertical stiffness of the tire is represented by the spring, k_t.

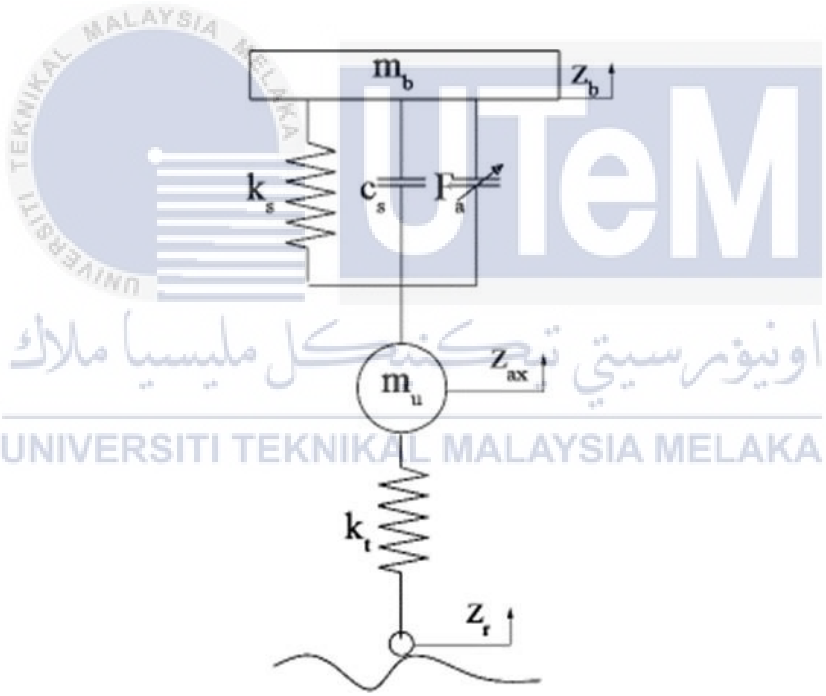

Figure 2.3 Quarter Car Model (Mahala et al., 2004)

2.3.2 Half Car Model

4 Degree of Freedom (DOF) or Half Car Model is the vehicle model that can be used to study the dynamic interaction between the vehicle and the road roughness profile and thus the vibration generated by road traffic. It is possible to model any type of road vehicle by