UNIVERSITI TEKNIKAL MALAYSIA MELAKA

MODELLING AND VALIDATION OF RIDE MODEL FOR UTILITY TRUCK

This report submitted in accordance with requirement of the UniversitiTeknikal Malaysia Melaka (UTeM) for the Bachelor's Degree in Mechanical Engineering Technology (Automotive Technology) (Hons.)

by

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ABSTRACT

This paper presents the modeling and validation of 7-degree of freedom (DOF) full vehicle model to study ride performance of utility truck. To improve utility truck suspension system that can reduce roll over effect and improve ride comfort, passive utility truck ride model was constructed. The simulation model was developed in Maltlab Simulink software. Several assumption related to 7-degree of freedom modeling were made and stated in this paper. The model was validated using vehicle dynamics simulation software known as Carsim. The validation was done by comparing the simulation result. Next, PID controller was applied to the system to see the improvement response between passive and PID controller and the simulation result consist of pitch angle, roll angle and vertical acceleration are analyzed.

ABSTRAK

Kertas ini membentangkan pemodelan dan pengesahan model penuh kenderaan 7 darjah kebebasan (DOF) untuk mengkaji prestasi trak utiliti. Untuk meningkatkan sistem penggantungan trak utiliti yang dapat mengurangkan pengurangan kesan dan meningkatkan keselesaan perjalanan, model perjalanan trak utiliti pasif telah dibina. Model simulasi dibangunkan dalam perisian Maltlab Simulink. Beberapa asumsi yang berkaitan dengan 7 darjah pemodelan kebebasan telah dibuat dan dinyatakan dalam tesis ini.Model tersebut telah disahkan menggunakan perisian simulasi dinamik kenderaan yang dikenali sebagai Carsim. Pengesahan dilakukan dengan membandingkan hasil simulasi. Seterusnya, pengawal PID digunakan untuk sistem untuk melihat tindak balas peningkatan antara pengawal pasif dan PID dan hasil simulasi terdiri daripada sudut pitch, sudut roll dan pecutan menegak dianalisis.

DEDICATIONS

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LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURES

DOF	-	Degree of Freedom
m_s	-	Sprung mass
m_u	-	Unsprung mass
K	-	Stiffness
L	-	Wheelbase
$\ddot{\theta}$	-	Pitch angular acceleration
$\ddot{\emptyset}$	-	Roll axis angular acceleration
I_{xx}	-	Longitudinal axis moment inertia
I_{yy}	-	Lateral axis moment inertia
F_d	-	Force Damper
$\ddot{Z}_s$	-	Vertical acceleration at sprung mass
$\ddot{Z}_u$	-	Vertical acceleration at unsprung mass
F_s	-	Vertical force at each suspension
F_t	-	Vertical force at each tire
Cs	-	Damping Coeffiecient

Zs	-	Vertical Acceleration
zsdd	-	Vertical Acceleration
pdd	-	Pitch Angle
rdd	-	Roll Angle

CHAPTER 1

INTRODUCTION

1.0 Introduction

This research studies on vehicle suspension system through the vehicle dynamics model. The mathematical derivation will be performed to produce 7 Degree Of Freedom ride truck utility vehicle. The 7DOF equations will be modeled in Matlab Simulink software in order to simulate the ride behavior of this vehicle. The 7DOF ride model then will be validated using the Carsim Software. Appropriate controller will be proposed in this research in order to improve the vehicle suspension system. Three criteria of vehicle suspension performance will be improved in terms of body roll, pitch and vertical acceleration. (M.Hafiz.et.al.2016)

1.1 Problem Statement

Utility truck has become one of the most popular transport mechanisms. The problem statement from this research is, since the utility truck is essential to increase their speed on the road, the vehicle's dynamic performance is negatively affected. The suspension system of the vehicle has to be modified in order to compensate for the weakened dynamic behavior. However, improvement possibilities by means of passive suspension technology will eventually reach a limit. To avoid any damage and to ensure the safety of vehicle, suspension system must be improved. Semi-active suspension system is the alternative method to improve the vehicle suspension system. (M.Hafiz.et.al.2016)

1.2 Objective

The objectives of this study are:

1. To develop the utility truck ride vehicle model.
2. To validate the utility truck vehicle model.
3. To improve the utility truck suspension system by using the appropriate controller.

1.3 Scope

The scopes of this project are:

1. Development of utility truck ride vehicle model using Matlab Simulink software.
2. Validate utility truck ride vehicle model by using Carsim software.
3. Improve the vehicle ride comfort using a semi-active suspension system.

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

This section discusses about literature of this research. The consideration is about general definition of vehicle suspension, types of suspension model and control strategies for semi-active suspension. Suspension system has been categorised as a part of chassis, which consist of all of the main system located under the car's body. Basically, vehicle suspension system has spring and dampers which combined together. The roll trade-off of suspension systems has been a long standing challenge for vehicle dynamics performance. When ride performance improved, it almost invariably leads the increasing of vehicle roll overs. Roll overs occurred when overturning moment of the vehicle caused by lateral acceleration and displacement of Centre of Gravity (COG), exceed the restoring forces that supplied by tires. The COG must accelerate outwards and a static balance is no longer possible to respond. The vehicle is tending to involve in a roll accident caused by the less stable.

There are many type of suspension system which categorized as passive, semi-active and active suspension system. The passive suspensions components have capability only dissipate the energy. Passive suspension has the conflict in difficulties of ride comfort and handling. Because of that, these passive suspensions are achieving the border of improvement. In order to overcome these problems, active suspension system has been considered in this research. Active suspension system usually utilised hydraulic actuation to supply power. This leads to the great power intake and superior level of complexity design. To control body and wheel motion, it required a high bandwidth. A semi-active roll control system is considered in this study where it provides the vehicle with switchable roll stiffness. In case of small lateral forces on the vehicle, the low roll stiffness setting would be implemented. This will improve the ride performance of the vehicle. The vehicle will switch to the higher roll stiffness configuration when greater lateral forces are presented. The vertical bounce stiffness is unaffected under all conditions by changing the roll stiffness of the vehicle. Hence, the ride is just modified in reaction to roll-plane roughness. This system could stay practically implemented with least power consumption.

2.1 Vehicle Suspension System

In automotive systems, ride comfort is one of the parameters to measure the level of suspension.The ride cosiness determines the ability of vehicles to provide passenger comfort. One of the interests of riding comfort is significantly applied to agricultural tractors. It is due to the vibration of the vehicle components and the road disturbance being delivered very high to the passenger compared to other cars (Horton and Crolla, 1984). As the basis of human body posture, comfortable limits required by the driver of the tractor agriculture are similar to drivers of passenger vehicles.Both require comfort, especially during long distances and long working hours. All these situations will affect the effectiveness, awareness, and most importantly the safety of the driver.

Vibration sources which influenced the ride comfort have been classified into two category; road and on-board sources (Jamei, 2002). First, the on-board sources generated from the rotational parts like wheels, driveline and engine. In the frequency range of 25 to 20,000 Hz, it will cause the aural vibration which also known as noise (Gillespie, 1992). These frequencies are low and high frequency based on the threshold of human hearing limits.The road's sources are the second of the vehicle's vibration sources, which indicate road hardness and maneuvering enthusiasts.Usually the frequency range of these frequencies is 0-25 Hz where the range is the natural sensitivity to the individual body. Hence, the greatest significant feature disturbing vehicle ride comfort is road excitation sources.

Stable and secure vehicle can be realized by handling attributes to ensure constant contact among the tires and road profile. A RLF "Radlastfaktor" factor is defined for calculating vehicle handling (Mitschke, 1984). To perform calculation, vertical dynamic tire force will be added by reviewing vertical standard tire forces. The RLF factor is equivalent toward the rate of the tire force that changes the rate of static tire forces. The higher the value of the RLF factor is the more instability in the tire contact. The efficiency of vehicles handling performance can be determined by using RLF factor. This factor was used to assess the handling capacity of a tractor suspension system (Hope, 2006).

2.2 Classification Vehicle Suspension Systems

The suspension system can be categorized as passive, semi-active and active suspension system which is based on exterior power input to the system and/or its controller bandwidth (Appleyard and Wellstead, 1995). The passive suspension system occurred at the motion defined completely through the path profile which is contains of a non-controlled spring and shock-absorbing damper for example presented in Figure 2.1. While the semi-active suspension for instance shows at Figure 2.2 has similar features as well as the damper has the ability to change the damping rate. For active suspension, the passive mechanisms keep on improved through actuators which can furnish extra force to the system.

2.2.1 Passive Suspension System

Recently, most of the vehicles used passive suspension system to regulate the behaviour motion of a vehicle's vertical movement, pitch and roll. The term passive shows all the suspension components certainly not allowed supplying force towards suspension system. Next, the passive suspension system as shown in Figure 2.1 regulates the movement of the body and wheel with narrowing together the corresponding speeds with the constant rate that provides the essential ride characteristics. It is implemented by consuming a damping element located in between the body and the wheels of the vehicle, for instance hydraulic shock absorber. The characteristics of the conventional shock absorber form the trade-off between reducing the body vertical acceleration and keeping good tire-road interaction force.

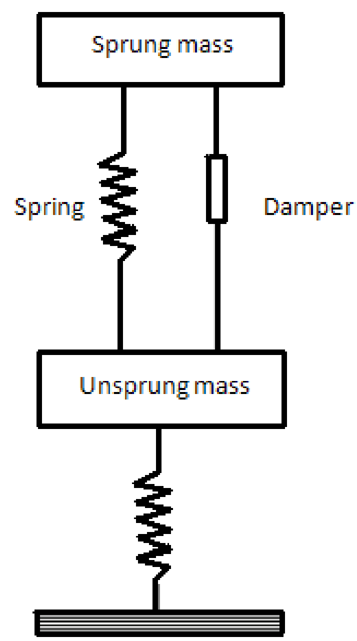

Figure 2.1: Passive suspension