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: ………………………..

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MODELING, SIMULATION AND CONTROL OF ANTILOCK BRAKING SYSTEM USING MULTIBODY VEHICLE

WAN ELLENA NADIA BT WAN KAMAL

This report was submitted in accordance with partial requirements for honor of Bachelor of Mechanical Engineering (Automotive)

Faculty of Mechanical Engineering

UniversitiTeknikal Malaysia Melaka (UTeM)

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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 knowledge."

Signature: ……………………………..

Author: ……………………………..

Date: ……………………………..

Dedicated to beloved father and mother

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ABSTRAK

Anti- kunci system brek mengesan perubahan drastic dalam kelajuan roda. Apabila kelajuan merosot dikesan, system brek anti-kunci akan mengurangkan tekanan hidraulik yang dibekalkan kepada system brek sehingga rosa bermula untuk mempercepatkan lagi. Apabila pecutan mengesan tekanan sekali lagi meningkat sehingga suatu amaun yang luar biasa gencatan di kesan. Kertas kerja ini membentangkan penggubalan model kawalan slip untuk tujuan melaksanakan penjejakan slip slip sasaran. Rekabentuk satu pengawal system brek anti-kunci, yang secara automatic mengurangkan jarak brek dengan menyesuaikan tork brek sebagai tindak balas kepada slip roda, membangunkan untuk pelbagai model kenderaan tubuh. Kebanyakan pengawal anti-kunci system brek yang di bangunkan adalah bertujuan untuk mengekalkan slip roda pada nilai yang dikehendaki. Ini memerlukan ukuran yang tepat slip roda. Jadi, kita perlu mengawal tork brek slip membujur optimum untuk mengelakkan roda dari penguncian.

ABSTRACT

Anti-lock braking system detects drastic changes in the speed of wheels. When a sharp deceleration is detected the anti-lock braking system will reduce the hydraulic pressure supplied to the braking system until the wheel begins to accelerate again. When the acceleration is detected the pressure is again increased until an unusual amount of deceleration is detected. This paper presents the formulation of a slip control model for purposes of performing slip tracking of target slip. The design of an anti-lock braking system controller, that automatically minimizes the braking distance by adjusting the braking torque in response to the wheel slip, is develop for multi body vehicle model. Most of the anti-lock braking system controllers developed were aim to maintain the wheel slip at a desired value. This requires accurate measurement of the wheel slip. So, we need to control the brake torque to the optimum longitudinal slip to avoid wheel from locking.

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SYMBOLS	DESCRIPTION
B	Distance between vehicle centre of mass and front axle
C	Distance between vehicle centre of mass and rear axle
H	Height of vehicle
L	Wheel base
S	Wheel slip
C_r	Rolling resistance coefficient
C_d	Aerodynamic drag coefficient
F_a	Aerodynamic resistance forces
F_r	Rolling resistance forces
F_{zf}	Front normal forces
K_{bf}	Front wheel pressure/ torque conversion constant
K_{br}	Rear wheel pressure/ torque conversion constant
K_{cf}	Front simple pressure gain
K_{cr}	Rear simple pressure gain
R_f	Front rolling radius
R_r	Rear rolling radius
$T_{\max}$	Maximum available engine torque

α_f	Front wheel velocity
α_r	Rear wheel velocity
λ_f	Front wheel slip ratio
λ_r	Rear wheel slip ratio
η_f	Final drive ratio
η_g	Current gear ratio
ρ_{bf}	Pressure applied to the front brake disk
ρ_{br}	Pressure applied to the rear brake disk
τ_{bs}	Brake torque
τ_{bf}	Torque applied to front wheel
τ_{br}	Torque applied to rear wheel
τ_{ef}	Torque delivered by the engine to front wheel
τ_{er}	Torque delivered by the engine to rear wheel
τ_{rf}	Reaction torque on front wheel
τ_{rr}	Reaction torque on rear wheel
μ_{bf}	Front input brake setting
μ_e	Energy transfer coefficient
μ_t	Input throttle setting

CHAPTER 1

INTRODUCTION

1.0 BACKGROUND

The basic design of a braking system has been around and in use in other applications for many years. The theory behind anti-lock braking system is simple. A skidding wheel, where the tire contact patch is sliding relative to the road has less traction than a non-skidding wheel. This problem brought about the invention of the anti-lock braking system.

The anti-lock braking system is a four-wheel system that prevents wheel lock up by automatically modulating the brake pressure during an emergency stop. By preventing the wheels from locking, it enables the driver to maintain steering control and to stop in the shortest possible distance under most conditions. During normal braking, the anti-lock braking system and non-anti-lock braking system brake pedal feel will be the same. During anti-lock braking system operation, a pulsation can be felt in the brake pedal, accompanied by a fall and the rise in brake pedal height and a clicking sound.

Anti-lock braking system or the ABS control unit helps to maintain control and directional stability of an automobile in case of extreme braking circumstances. This is achieved by controlling the rotational speed of every wheel by metering the brake line pressure at the time of extreme braking. The system works on most types of road surfaces and decreases the risk of an accident and severity of an impact.

Not only does anti-lock braking system provide non-skid functionality but it also supports electronic stability control, brake assist and traction control. Recently, additional sensors have been added to the system, gyroscopic sensors and steering wheel angle sensors. Both synchronize to match the direction of the car with the direction of the steering wheel. The wheel angle sensor also helps the anti-lock braking system control the outer wheels to have a more positive braking effect when compared to the inner wheels on the curve.

The anti-lock braking system assembly is made up of a central electronic unit, four solenoid valves and two or more electric hydraulic pumps. The function of the electric hydraulic pump is to supply brake fluid pressure to the braking system by forcing hydraulic pressure to a reservoir located in the accumulator. The four solenoid pressure valves control brake fluid pressure for each individual wheel. During an anti-lock braking operation event, one or more of the solenoid valves dump brake line pressure to a particular wheel allowing it to start turning.

1.1 PROBLEM STATEMENT

The problem with the traditional braking system is that the force exerted by the brakes on the wheel cannot exceed the force of friction between the wheel and the road. If the braking force exceeds the force of friction from the road the vehicle will begin to slide. This problem brought about the invention of the anti-lock braking system (ABS).

The ABS detects drastic changes in the speed of the wheels. But the control of an ABS is a difficult problem due to its strongly nonlinear and uncertain characteristics. Most of the ABS controllers developed were aim to maintain the wheel slip at a desired value. This requires accurate measurement of the wheel slip. So, we need to control the brake torque to the optimum longitudinal slip to avoid wheel from locking.

1.2 OBJECTIVES

Objectives of this project are:

- To develop multi body vehicle model using MATLAB and CARSIM software.
- To develop hydraulic brake model and study the torque tracking performance.
- To evaluate the performance of anti-lock braking system (ABS) controller through simulation.

1.3 SCOPES

Scopes for this project are:

- To control brake torque.
- To get the optimum longitudinal slip which 0.2 seconds to avoid wheel from locking.
- Apply MATLAB and CARSIM to validate the system.

CHAPTER 2

LITERATURE REVIEW

2.0 INTRODUCTION

The purpose of this chapter is to give the reader the necessary background information as to understand the research background of this study. The first part of this chapter introduces the fundamental idea involved in the design and development of a vehicle longitudinal model. The second part of this chapter gives information on previous researchers about the current technology relating to anti-lock braking system. In the second part also, there will be stated most of controller that are used in antilock braking system and their results from using the controller in their model. From there, we can see which one is the most popular controller that has been used in the previous researcher.

2.1 VEHICLE LONGITUDINAL MODEL

For a simulation of vehicle dynamic performance, the gross vehicle dynamics and wheel dynamics must both be considered (Michael Short *et al.,* 2004). These can both be captured by simplified lumped mass models and may consist of single-wheel versions, two-wheel versions or full four-wheel models for cornering as well as acceleration and braking analysis.

In order to simulate the dynamics of a passenger vehicle whilst driving down motorway, the lateral forces acting upon the vehicle may be, in general, neglected. This is because the motorway systems in many countries worldwide have been designed to be as straight as possible and the forces involved during steering to change lanes have a relatively small effect and act for only small periods of time, when compared to the much larger longitudinal forces involved when cruising at high speed.

This is in stark comparison to, for example a race car simulation where the acceleration, braking and cornering dynamics are much more coupled and essential to produce a realistic model. For this reason, a full four-wheel model is considered unnecessary for the purposed of the simulation. Passenger vehicles of the type under simulation are generally built to be as stable as possible with center of gravity as close to the center of the car as possible. However, the effects of longitudinal load transfer are still present.

2.2 ANTI-LOCK BRAKING SYSTEM CONTROLLER

2.2.1 Self-Learning Fuzzy Sliding-Mode Control

The self-learning fuzzy sliding-mode control for anti-lock braking system will modulate the brake torque for optimum braking (Lin *et al.,* 2003). The self-learning fuzzy sliding-mode control system is comprised of a fuzzy controller and a robust controller. The fuzzy controller is designed to mimic an ideal controller and the robust controller is designed to compensate for the approximation error between the ideal controller and the fuzzy controller. The tuning algorithm of the controller is derived in a Lyapunov sense; thus, the stability of the system can be guaranteed. Also, the derivation of the proposed self-learning fuzzy sliding-mode control anti-lock braking system does not need to use a vehicle-braking model.

2.2.2 Gain-Scheduling Scheme

Yong and Jing (1995) proposed a gain-scheduling scheme for optimum target slip tracking of an anti-lock braking system. The study is based on the fact that for certain road surface condition, the tires force characterization. The optimal slip at which the braking force achieves its maximum is not, in contrast to what most slip regulator design is based upon, a constant. Gain-scheduling scheme regulates the slip to different levels depending on the instant vehicle forward speed along the braking process. The control algorithm, coupled with a feedback linearization compensation outer loop, is applied to a quarter-car anti-lock braking system model. Simulations are performed using MATLAB. It is shown that the gain-scheduling slip regulator improves the vehicle braking performance are compared to constant slip regulator.

2.2.3 Sliding Mode Control

A nonlinear observer-based design for control of vehicle traction that is important in providing safety and obtaining desired longitudinal vehicle motion (CemUnsal and Pushkin, 1999). First, a robust sliding mode controller is designed to maintain the wheel slip at any given value. Simulation shows that longitudinal traction controller is capable of controlling the vehicle with parameter deviations and disturbances. The direct state feedback is then replaced with nonlinear observers to estimate the vehicle velocity from the output of the system. The nonlinear model of the system is shown locally observable. The effects and drawbacks of the extended Kalman filters and sliding observers are shown in simulations. The sliding observer is found promising while the extended Kalman filter is unsatisfactory due to unpredictable changes in the road conditions.

2.2.4 Gain-Scheduling and Iterative Feedback Tuning of PI Controllers

Radac and Precup (2008) suggest PI controllers for longitudinal slip control in the framework of a laboratory anti-lock braking system. The new design methods make use of gain-scheduling and Iterative Feedback Tuning. Iterative Feedback Tuning is a technique used for iterative tuning and optimization of conventional controllers. It starts with the design of a stabilizing controller for the plant which needed even if the plant has an unknown model. They prove to be relatively simple and transparent thus ensuring low cost automation solutions. The digital implementation of the controllers is done for the laboratory anti-lock braking system. The real time experimental results included and associated with the original design methods validate the theoretical approaches. They highlight the low cost which is a major advantage with respect to other similar control solutions.

2.2.5 Sliding Mode Control with Gray Predictor

Regarding the fact that the system parameters highly depend on the road conditions and vary over a wide range, the performance of anti-lock braking system may not always be satisfactory (Kayacan *et al.*, 2009). The motivation behind this investigation is to propose a sliding mode control coupled with a gray predictor to track the target value of the wheel slip. Although the target wheel slip is considered to be a constant corresponding to the maximum value of the road adhesion coefficient in numerous studies, it is taken to be also a velocity dependent variable in this chapter. In other words, as the velocity of the vehicle changes, the optimum value of the wheel slip will also alter.

The gray predictor is employed to anticipate the future outputs of the system using current data available. It estimates the forthcoming value of both the wheel slip and the reference wheel slip; in addition, the sliding mode control takes the necessary action to maintain the wheel slip at the desired value. The main advantage of gray prediction is that it requires only limited data to develop the gray model compared with the conventional controllers which need samples of reasonable size and good distribution of the data to develop an appropriate model.

Gray predictors adapt their parameters to new conditions as new outputs become available. Hence, gray controllers are more robust with respect to noise, lack of modeling information, and other disturbances when compared with the conventional controllers. Consequently, the gray predictor is an excellent candidate to be incorporated in real time control systems. The combination of gray predictors with conventional sliding mode control is therefore likely to result in an increase in the performance specifications as such a controller would anticipate the upcoming values of the wheel slip, all the while ensuring robustness to varying dynamic conditions.