MODELING AND SIMULATION OF A NONLINEAR ACTIVE SUSPENSION SYSTEM USING A CONTROLLER

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DEDICATIONS

To Family

RAMLI BIN HASHIM

SALMAH BTE CHE ROS

MOHD AIZAT

MOHAMAD NABIL

NUR ATIQAH

MOHAMAD ARIFF

Thank you for everything. Love you all.

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ABSTRACT

This proposal presents a mathematical model and control law of a nonlinear active suspension system. The goal of active suspension system is to control the vehicle's body even though with the occurrence of driver's and road perturbation. The perturbation tends to degrade the performance of active suspension systems which introduce harshness to the ride quality and reducing off-road mobility. Since the characteristics of spring, damping force and the road model are mostly nonlinear, the suspension system is thorny to control. The objective of designing the active suspension system's controller is to control the suspension forces to suit the road and driving conditions. The controller will improve the performance of the nonlinear active suspension system.

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ABSTRAK

Proposal ini mengenenengahkan model matematik dan undang-undang kawalan bagi sistem gantungan aktif. Tujuan sistem gantungan aktif adalah untuk mengawal badan kenderaan walaupun dengan kehadiran gangguan daripada pemandu dan keadaan jalan. Gangguan ini telah menyebabkan kemerosotan prestasi sistem gantungan aktif di mana ia menjadikan kualiti tunggangan tidak lancar. Sistem gantungan sukar untuk dikawal disebabkan oleh ciri-ciri spring, daya dan model jalan yang kebanyakannya adalah bersifat tidak linear. Tujuan merekabentuk pengawal sistem gantungan aktif adalah untuk mengawal daya gantungan supaya bersesuaian dengan keadaan jalan dan pemanduan. Pengawal sistem gantungan aktif akan memperbaiki prestasi ketidaklinearan sistem gantungan aktif ini.

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LIST OF ABBREVIATIONS

DOF	Degree of Freedom
PID	Proportional-Integral-Derivative

LIST OF SYMBOLS

A	-	N x N system matrix for the Active Suspension System
B	-	N x 1 input matrix for the Active Suspension System
C	-	1 x N ouput matrix for the Active Suspension System
D	-	N x 1 input matrix for the Active Suspension System
L	-	Lagrangian function
T	-	Kinetic energy
U	-	Potential energy
m	-	mass of the particle(kg)
m_b, m_s	-	mass of the car body (kg)
m_w, m_u	-	mass of the wheel (kg)
v	-	velocity of the particle
k	-	stiffness of spring (N/m)
k_b, k_s	-	stiffness of the car body (N/m)
k_w, k_t	-	stiffness of the car tire (N/m)
c, c_b, c_p,	-	damping force of damper (Ns/m)
x_b, z_s	-	vertical displacement of the car body (m)
x_w, z_c	-	vertical displacement of the car wheel (m)
w, z_r	-	irregular excitation from the road surface (m)
l	-	length (m)
l_A	-	distance from A to O(m)
l_B	-	distance from B to O (m)

l_c	-	length of the control arm (m)
α	-	angle betweenOA
θ_0	-	angular displacement of the control arm at a static equilibrium point
f_s	-	control input (N)

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CHAPTER I

INTRODUCTION

1.0 Introduction

Automotive suspension systems have been developed from time to time since the beginning of car industrial with a simple passive mechanism to the present with a very high level of sophistication. Suspension system is an automobile technology that controls the vertical wheels movement via an onboard system rather than the movement being determined entirely by the surface on which the car is driving. Suspension system is the mechanism that physically separates the vehicles body from the wheels of the vehicle. Suspension systems serve a dual purpose which is contributing to the vehicle's handling and braking for good safety and driving satisfaction, and keeping vehicle passengers comfortable and reasonably well isolated from road perturbation, bumps and vibrations. Generally, these objectives are at odds, so the regulation of suspensions involves finding the right compromise.

It is very important for the suspension to keep the wheel in contact with the road surface as much as possible, because all the forces acting on the vehicle do so through the contact patches of the tires. The suspension also protects the vehicle itself and any goods from damage under disturbance condition.

The suspension would not be necessary if a road were perfectly flat which is with no irregularities but roads are far from flat. Even freshly paved highways have slight imperfections that can interact with the wheels of a car. It's these imperfections that apply forces to the wheels. According to Newton's laws of motion, all forces have magnitude and direction. A bump in the road causes the wheel to move up and down perpendicular to the road surface. The magnitude, of course, depends on whether the wheel is striking a giant bump or a tiny speck. Either way, the car wheel experiences a vertical acceleration as it passes over an imperfection (Harris).

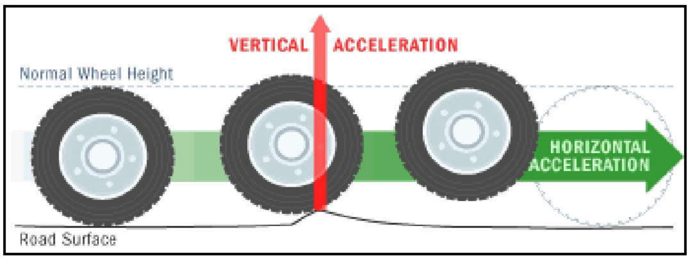

Figure 1.1 The vertical and horizontal acceleration of the wheel (Harris)

All of wheel's vertical energy is transferred to the frame without an intervening structure, which moves in the same direction as shown in Figure 1.1. In that situation, the wheels can lose contact with the road completely. The wheels can slam back into the road surface under the downward force of gravity and there will be a system that will absorb the energy of the vertically accelerated wheel which allowing the frame and car body to ride undisturbed while the wheels follow bumps in the road.

The study of the forces on a moving car is called vehicle dynamics. Some of these concepts are needed to be understood in order to appreciate why a suspension is necessary in the first place. The dynamics of a moving car are considered from two perspectives:

i. Ride – a car's ability to smooth out a bumpy road
ii. Handling – a car's ability to safely accelerate, brake and corner

Appleyard and Wellstead (1995) have proposed several performance characteristics to be considered in order to achieve a good suspension system. These characteristics deal with the regulation of body movement, the regulation of suspension movement and the force distribution. The regulation of body movement describe that ideally the suspension should isolate the body from road disturbances and inertial disturbances associated with cornering (causing body roll) and braking or acceleration (causing body pitch). The regulation of suspension movement explains the excessive vertical wheels travel will result in non-optimum attitude of the tire relative to the road. The result will be poor handling and adhesion.

The force distribution is to maintain good handling characteristics which mean that the optimum tire-to-road contact must be maintained on all of four wheels. These characteristics are at times contradictory and are not met in a conventional suspension system in all conditions.

1.1 Problem Statement

As a suspension system mostly is nonlinear due to drivers and road perturbation, it gives an uncomfortable ride. The disturbances will cause the suspension system's performances degrade which introduce harshness to the ride quality and reducing off-road mobility. The main goal of this research is to control the nonlinearity of the vehicle's suspension while traveling over rough roads.

1.2 Objective of the Research

The objectives of this research are:

i) To study the principle of active suspension system.
ii) To formulate a mathematical model of a nonlinear active suspension system.
iii) To perform a simulation of mathematical model of a nonlinear active suspension system using Matlab-Simulink platform.

1.3 Scope of the Research

The limitations of this research are:

i) Derivation of the mathematical equation of active suspension system.
ii) Simulation study conducted in Matlab-Simulink software.

1.4 Significance of the Research

The significance of the study is as follows:

i) To show that the active suspension system works well and making it possible to solve mathematically.

ii) The problem can be extended to a new problem involving more number of inputs with the addition of suspension system over rougher road condition.

1.5 Organization of the Research

There are seven chapters in this dissertation.

Chapter I will review about the introduction, problem statement, objective, scope and significance of the research.

In Chapter II, the literatures review of the passive suspension system and active suspension system and also Lagrangian method and linear state space model will be presented. This chapter will discuss the Lagrangian method in modeling the passive and active suspension system and the linear state space model in solving the nonlinear active suspension system based on previous work presented by Lin and Kanellakopoulos (1995).

In Chapter III, the model of active suspension system will be introduced. The development of mathematical model for the suspension systems will be done.

In Chapter IV, the problem will be solved using Matlab-Simulink simulation methodology. The method will be discussed and flow chart of the method will be given.

Chapter V will present the simulation result for active suspension system obtained from Matlab-Simulink in graphical.

Chapter VI will present the analysis of the simulation result for active suspension system.

Finally, Chapter VII concludes the research work that had been done together with some suggestions for future research.

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