

FUZZY CONTROL ON VEHICLE ACTIVE SUSPENSION SYSTEM

MUHAMAD NAZMI BIN AHMAD NAZARI

**BACHELOR OF ENGINEERING
UNIVERSITI MALAYSIA PAHANG
2010**

UNIVERSITI MALAYSIA PAHANG

BORANG PENGESAHAN STATUS TESIS

JUDUL: **FUZZY CONTROL ON VEHICLE ACTIVE SUSPENSION SYSTEM**

SESI PENGAJIAN: **2010/2011**

Saya, **MUHAMAD NAZMI BIN AHMAD NAZARI (880412-02-5633)**
(HURUF BESAR)

mengaku membenarkan tesis (Sarjana Muda / ~~Sarjana~~ / ~~Doktor Falsafah~~)* ini disimpan di perpustakaan dengan syarat-syarat kegunaan seperti berikut:

1. Tesis ini adalah hakmilik Universiti Malaysia Pahang (UMP).
2. Perpustakaan dibenarkan membuat salinan untuk tujuan pengajian sahaja.
3. Perpustakaan dibenarkan membuat salinan tesis ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. **Sila tandakan (√)

SULIT

(Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia seperti yang termaktub di dalam AKTA RAHSIA RASMI 1972)

TERHAD

(Mengandungi maklumat TERHAD yang telah ditentukan oleh organisasi / badan di mana penyelidikan dijalankan)

TIDAK TERHAD

Disahkan oleh:

(TANDATANGAN PENULIS)

(TANDATANGAN PENYELIA)

Alamat Tetap:

**3242,-C, Jalan Pn Maimunah,
2 ¼ Jalan Datuk Kumbar,
05300 Alor Star,
Kedah**

MUHAMMAD HATIFI BIN HJ MANSOR
(Nama Penyelia)

Tarikh: **6 DISEMBER 2010**

Tarikh: **6 DISEMBER 2010**

CATATAN: * Potong yang tidak berkenaan.

** Jika tesis ini SULIT atau TERHAD, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan dengan menyatakan sekali tempoh tesis ini perlu dikelaskan sebagai SULIT atau TERHAD.

◆ Tesis dimaksudkan sebagai tesis bagi Ijazah Doktor Falsafah dan Sarjana secara Penyelidikan, atau disertasi bagi pengajian secara kerja kursus dan penyelidikan, atau Laporan Projek Sarjana Muda (PSM)

UNIVERSITI MALAYSIA PAHANG
FACULTY OF MECHANICAL ENGINEERING

We certify that the project entitled “*Fuzzy Control on Vehicle Active Suspension System*” is written by *Muhamad Nazmi Bin Ahmad Nazari*. We have examined the final copy of this project and in our opinion; it is fully adequate in terms of scope and quality for the award of the degree of Bachelor of Engineering. We herewith recommend that it be accepted in partial fulfillment of the requirements for the degree of Bachelor of Mechanical Engineering

Dr Gigih Priyandoko

Examiner

Signature

FUZZY CONTROL ON VEHICLE ACTIVE SUSPENSION SYSTEM

MUHAMAD NAZMI BIN AHMAD NAZARI

Thesis submitted in fulfillment of the requirements
for the award of the degree of
Bachelor of Mechanical Engineering

Faculty of Mechanical Engineering
UNIVERSITI MALAYSIA PAHANG

DECEMBER 2010

SUPERVISOR'S DECLARATION

I hereby declare that I have checked this project and in my opinion, this project is adequate in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering

Signature

Name of Supervisor: Muhammad Hatifi Bin Haji Mansor

Position: Lecturer

Date: 6 December 2010

STUDENT'S DECLARATION

I hereby declare that the work in this project is my own except for quotations and summaries which have been duly acknowledged. The project has not been accepted for any degree and is not concurrently submitted for award of other degree.

Signature

Name: Muhamad Nazmi Bin Ahmad Nazari

ID Number: MA07089

Date: 6 December 2010

TABLE OF CONTENTS

		Page
SUPERVISOR’S DECLARATION		ii
STUDENT’S DECLARATION		iii
DEDICATION		iv
ACKNOWLEDGEMENTS		v
ABSTRACT		vi
ABSTRAK		vii
TABLE OF CONTENTS		viii
LIST OF TABLES		xi
LIST OF FIGURES		xii
LIST OF SYMBOLS		xiv
LIST OF ABBREVIATIONS		xv
CHAPTER 1 INTRODUCTION		
1.1	Introduction	1
1.2	Problem Statement	2
1.3	Objectives of the Research	2
1.4	Scopes	3
1.5	Organization of the project	3
CHAPTER 2 LITERATURE REVIEW		
2.1	Introduction	5
2.2	Car Suspension	5
	2.2.1 Passive Suspension System	6
	2.2.2 Semi Active Suspension System	8
	2.2.3 Active Suspension System	9
2.3	Dynamic Model	11
	2.3.1 Quarter Car Model	11
	2.3.2 Half Car Model	12
	2.3.3 Full Car Model	13

2.4	Fundamental of Vibration	15
2.5	Vibration Control	18
2.6	Proportional-Integral-Derivative (PID) Controller	19
	2.6.1 Design of PID Control Systems	20
2.7	Tuning the PID Controller	21
	2.7.1 Manual Tuning	22
	2.7.2 Ziegler–Nichols Method	22
2.8	Fuzzy Logic Controller	24
	2.8.1 Fuzzification	25
	2.8.2 Defuzzification	26
	2.8.3 Membership Functions in Fuzzy Logic	27
2.9	Conclusion	28

CHAPTER 3 METHODOLOGY

3.1	Introduction	29
3.2	Research of Methodology	29
3.3	Dynamic Model	30
3.4	Mathematical Modeling	31
	3.4.1 Equation of Motion	32
	3.4.2 Transfer Function Equation	32
3.5	Test Data	34
3.6	Actuator	35
3.7	Simulation	35
	3.7.1 Blocks	35
	3.7.2 Passive System	37
	3.7.3 Active System	38
	3.7.4 PID Controller with Fuzzy Logic Controller (Fuzzy-PID)	39
	3.7.5 Fuzzy Logic Control Model	40
3.8	Conclusion	42

CHAPTER 4 RESULTS AND DISCUSSION

4.1	Introduction	43
4.2	Passive System for Suspension System	43

4.3	Effect of Proportional-Integral-Derivative gain on the system	45
4.4	Comparative Study	47
4.4.1	P, PI and PID controller	48
4.4.2	PID Scheme with Fuzzy Logic Control	51
4.5	Input Signal	50
4.6	Conclusion	50

CHAPTER 5 CONCLUSION AND RECOMMENDATION

5.1	Conclusion	51
5.2	Recommendation	52
	REFERENCES	53
	APPENDICES	55
A		55
B		56

LIST OF TABLES

Table No.	Title	Page
2.1	Action Modes of PID Controller	21
2.2	Formulas in the Ziegler-Nichols closed loop method.	23
3.1	Property of the Laplace Transform	32
3.2	The assumed values for suspension system	34
3.3	Blocks	36
3.4	The rule for Mamdani type (Rule 4)	41
4.1	The parameter of K_p , K_i and K_d for PID controller	46
6.1	The rule for Mamdani type (Rule 1)	56
6.2	The rule for Mamdani type (Rule 3)	56
6.4	The rule for Mamdani type (Rule 4)	56

LIST OF FIGURES

Figure No.	Title	Page
2.1	Car suspension systems	6
2.2	Passive suspension systems	7
2.3	Semi active suspension system	9
2.4	Active suspension system	10
2.5	Quarter car model	12
2.6	Half car model	13
2.7	A full-car model	15
2.8	Simple types of vibration system	16
2.9	PID controller	20
2.10	The block diagram of a fuzzy controller	25
2.11	Membership Functions in Fuzzy Logic	28
3.1	Flow chart of the research methodology	30
3.2	Quarter car model of passive suspension systems	31
3.3	Block diagram of the passive suspension system model	38
3.4	Block diagram of the active suspension system model	39
3.5	Fuzzy Logic Controller	39
3.6	PID and Fuzzy-PID in active system block diagram	40
3.7	The membership function	41
4.1	Plot of displacement with time for passive system	44
4.2	Plot of error with time for passive system	44
4.3	Plot of displacement with effect of P, PI and PID controller and actuator on active system	46
4.4	Plot of error with effect of P, PI and PID controller and	47

	actuator on active system	
4.5	The comparative study of FLC-PID and PID scheme	49
4.6	Plot of error with effect fuzzy-PID controller and actuator on active system	49

LIST OF SYMBOLS

ω	Circular Natural Frequency
m_1	Sprung Mass
m_2	Unsprung Mass
c_1	Sprung Mass Damping Coefficient
k_1	Suspension Spring Constant
k_2	Tire Spring Rate
Δ	Determinant
\ddot{x}	Acceleration
\dot{x}	Velocity
x	Displacement
f_n	Natural Frequency
t	Time
F	Force
w	Road Profile
K_p	Proportional Gain
K_i	Derivative Gain
K_d	Integral Gain
g	Acceleration Due To Gravity
l	Distances Of The Suspension Locations
θ	Rotary Angle Of The Vehicle Body At The Centre Of Gravity.

LIST OF ABBREVIATIONS

PID	Proportional-Integral-Derivative
FLC	Fuzzy Logic Control
DOF	Degree Of Freedom
PI	Proportional- Integral
P	Proportional
C-o-A	Center-Of-Area
C-o-M	Center-Of-Maximum
M-o-M	Mean-Of-Maximum
trimf	Triangular Membership Function
trapmf	Trapezoidal Membership Function
gaussmf	Gaussian Membership Function
gbellmf	Generalized Bell Membership Function
EOM	Equations Of Motion
CST	Control System Toolbox
VS	Very Small
S	Small
M	Medium
L	Large
VL	Very Large