

**MODELING, SIMULATING, AND ANALYZING QUARTER CAR PASSIVE
AND ACTIVE SUSPENSION USING MATLAB SIMULINK AND V-REP
SIMULATOR**

By

Mochammad Rizky Diprasetya S
11111034

BACHELOR'S DEGREE
in

MECHANICAL ENGINEERING – MECHATRONICS CONCENTRATION
FACULTY OF ENGINEERING AND INFORMATION TECHNOLOGY

SWISS GERMAN UNIVERSITY


SWISS GERMAN UNIVERSITY
EduTown BSD City
Tangerang 15339
Indonesia

August 2015

Revision after the Thesis Defense on 13th August 2015

STATEMENT BY THE AUTHOR

I hereby declare that this submission is my own work and to the best of my knowledge, it contains no material previously published or written by another person, nor material which to a substantial extent has been accepted for the award of any other degree or diploma at any educational institution, except where due acknowledgement is made in the thesis.

Mochammad Rizky Diprasetya S

Student

Date

Revision after the Thesis Defense on 13th August 2015

Approved by:

Kirina Boediardjo, ST, M.Sc

Thesis Advisor

Date

Yunita Umniyati, PhD

Thesis Co-Advisor

Date

Dr. Ir. Gembong Baskoro, M.Sc

Dean

Date

Mochammad Rizky Diprasetya S

ABSTRACT

MODELING, SIMULATING, AND ANALYZING QUARTER CAR PASSIVE AND ACTIVE SUSPENSION USING MATLAB SIMULINK AND V-REP SIMULATOR

By

Mochammad Rizky Diprasetya S
Kirina Boediardjo, ST, M.Sc, Advisor
Yunita Umniyati, PhD, Co-Advisor

SWISS GERMAN UNIVERSITY

This thesis work's purposes are to develop a mathematical model for quarter car passive and active suspension, to simulate its behavior, and analyze the difference of both suspension. The active suspension use PID controller to control the displacement of the car in vertical direction caused by different road profile. The displacement has to be small, these condition are achieved by manipulating the force actuator inside the suspension. The force actuator manipulated according to the output of controller system. V-REP simulator is used to visualize the physical simulation. The physical model of suspension developed in V-REP. The result from V-REP compared with the result from MATLAB Simulink.

Keywords: Quarter Car Suspension, MATLAB, Simulink, V-REP Simulator, Full Car Suspension, PID, LQR.



SWISS GERMAN UNIVERSITY

DEDICATION

I dedicate this works for my parents, my friends, and myself.



ACKNOWLEDGEMENTS

I thank All for His constant blessing and supports during this thesis development.

I would like to thank to my parents for their patience in these past four years.

I would like to thank Kirina Boediardjo, ST, M.Sc for her support throughout the development of the thesis, time, and her guidance in building the system model schematic during development of this thesis.

I would like to thank to Yunita Umniyati, PhD for her inputs, advice, and support for this thesis.

Last but not least I thank all of my beloved friends who have supported me from the very beginning until the very end of this thesis development.



SWISS GERMAN UNIVERSITY

TABLE OF CONTENTS

	Page
STATEMENT BY THE AUTHOR	2
ABSTRACT.....	3
DEDICATION	5
ACKNOWLEDGEMENTS	6
TABLE OF CONTENTS	7
LIST OF FIGURES	10
LIST OF TABLES	13
CHAPTER 1 - INTRODUCTION.....	14
1.1 Background	14
1.2 Thesis Purpose	16
1.3 Objective	16
1.4 Hypothesis.....	16
1.5 Thesis Scope	17
1.6 Thesis Limitations.....	17
1.6 Thesis Organization	17
CHAPTER 2 - LITERATURE REVIEW	19
2.1 Theoretical Perspectives	19
2.1.1 Suspension System.....	19
2.1.2 Spring in Suspension System.....	21
2.1.3 Damper in Suspension System.....	22
2.1.4 Force Actuator in Suspension System.....	23
2.1.5 Hydraulic Actuator.....	23
2.1.6 Electromagnetic Actuator.....	24
2.1.7 PID Control.....	25
2.1.8 Linear Quadratic Regulation (LQR)	27
2.1.9 MATLAB Simulink	28
2.1.10 V-REP Simulator.....	29
2.1 Previous Studies.....	31
2.1.1 Modeling, Simulating, and Analyzing an Overhead Crane Using MATLAB Simulink and V-REP Simulator [5].....	31
CHAPTER 3 – RESEARCH METHODS	33

3.1 Simulation Model Methodology	33
3.2 Mathematical Model	34
3.2.1 Mathematical Model of Quarter Car Passive Suspension.....	35
3.2.2 Mathematical Model of Quarter Car Active Suspension	38
3.2.3 Mathematical Model of Full Car Passive Suspension	41
3.2.4 Mathematical Model of Full Car Active Suspension.....	45
3.3 Control Design	50
3.3.1 Proposed PID Control Design.....	51
3.3.2 Linear Quadratic Regulator.....	52
3.4 Mechanical Part	53
3.4.1 Model Parameter.....	58
3.4.2 Road Disturbance Environment.....	59
CHAPTER 4 – RESULTS AND DISCUSSIONS	62
4.1 System Model Result	62
4.1.1 Quarter Car Suspension System.....	63
4.1.1.1 Passive Suspension System Response Analysis	65
4.1.1.1.1 Impulse Input	65
4.1.1.1.2 Step Input.....	68
4.1.2 Full Car Suspension System	71
4.1.2.1 Passive Suspension System Response Analysis	76
4.1.2.1.1 Impulse Input	77
4.1.2.1.2 Step Input.....	78
4.3 Control Analysis.....	79
4.3.1 PID Controller for Quarter Car Suspension.....	79
4.3.2 PID Controller for Full Car Suspension.....	81
4.3.3 LQR Controller for Quarter Car Suspension	83
4.3.4 LQR Controller for Full Car Suspension	83
4.4 Quarter Car Passive and Active Suspension Comparison.....	83
4.4.1 Comparison with PID Controller for Step Input.....	83
4.4.2 Comparison with PID Controller for Impulse Input	86
4.4.3 Comparison with LQR Controller	88
4.5 Full Car Passive and Active Suspension Comparison for Rear Right Suspension	90
4.5.1 Comparison with PID Controller for Step Input.....	91
4.5.2 Comparison with PID Controller for Impulse Input	92
4.6 Full Car Suspension Simulink Model and Full Car Suspension V-REP Comparison	92

4.7 Comparison V-REP and MATLAB Simulink Rear Right Suspension of Car Result with Impulse Input	95
4.8 Comparison V-REP and MATLAB Simulink V-REP Front Right Suspension of Car Result with Step Input.....	103
CHAPTER 5 – CONCLUSIONS AND RECCOMENDATIONS	110
5.1 Conclusions.....	110
5.2 Recommendations.....	111
GLOSSARY	112
REFERENCES	113
APPENDICES	114
APPENDIX A - MATLAB CODE FOR LQR CONTROLLER OF QUARTER CAR SUSPENSION	115
APPENDIX B - MATLAB CODE FOR LQR CONTROLLER OF FULL CAR SUSPENSION	117
APPENDIX C – STATE SPACE MATRIX OF FULL CAR PASSIVE SUSPENSION	120
APPENDIX D – STATE SPACE MATRIX OF FULL CAR ACTIVE SUSPENSION	123
CURRICULUM VITAE	124



SWISS GERMAN UNIVERSITY