

# RUBBER FLIPPER UNLOADING SYSTEM

A dissertation submitted to the  
Department of Electrical Engineering, University of Moratuwa  
in partial fulfillment of the requirement for the  
degree of Master of Science

by



University of Moratuwa, Sri Lanka.

ABESINGHE ARACHCHIGE DUMINDA

[www.lib.mrt.ac.lk](http://www.lib.mrt.ac.lk)

KUMARASINGHE

Supervised by: Dr. A.M. Harsha S. Abeykoon

Department of Electrical Engineering  
University of Moratuwa, Sri Lanka

March 2011

University of Moratuwa



96795

96795



96795

621.3 "11"

621.3(043)

## DECLARATION

The work submitted in this dissertation is the result of my own investigation, except where otherwise stated.

It has not already been accepted for any degree, and is also not being concurrently submitted for any other degree.

### *UOM Verified Signature*

A. A. D. Kumarasinghe

08/03/2011



University of Moratuwa, Sri Lanka.  
Electronic Theses & Dissertations  
[www.lib.mrt.ac.lk](http://www.lib.mrt.ac.lk)

I endorse the declaration by the candidate.

### *UOM Verified Signature*

Dr. A. M. Harsha S. Abeykoon

# CONTENTS

Declaration	i
Abstract	v
Acknowledgement	vi
List of Figures	vii
List of Tables	ix
<b>01. Introduction</b>	<b>1</b>
1.1 Introduction	1
1.2 Scope and objectives of the project	4
1.2.1 Scope of the project	4
1.2.2. Objectives	4
<b>02. Background</b>	<b>5</b>
2.1 Existing process	5
2.2 Rubberizing of plastic flippers	5
2.3 Human interaction	8
2.3.1 Loading the plastic flipper	8
2.3.2 Unloading the plastic flipper	9
<b>03. Literature review</b>	<b>11</b>
3.1 Automation of production system	11
3.1.1 Production rate	12
3.2 Rubber injection molding machine	13
3.3 Robot arm kinematics	14
3.3.1 Direct kinematics	14
3.3.2 Inverse kinematics	15
3.4 Coordinate frame representation of robot arm	16
3.4.1 Mapping between translated frame	16
3.5 Dynamics analysis of unloading system	19
3.6 Vacuum technology	21

3.6.1	Definition of vacuum	21
3.6.2	Vacuum generator	22
<b>04.</b>	<b>Methodology</b>	<b>24</b>
4.1	Concept and coordinate frame of robot arm	24
4.1.1	Robot arm coordinate frame	25
4.1.2	Robot arm kinematics model	26
4.2	Designing and fabricating unloading system gripper	27
4.2.1	Designing gripper	27
4.2.2	Selecting vacuum pad	28
4.2.2.1	Holding force and break-away force calculation	29
4.2.3	Selecting vacuum generator	31
4.2.3.1	General features of vacuum generator	33
4.2.4	Fabricating gripper arm	34
4.3	Designing of vertical motion	36
4.3.1	Vertical movement method	36
4.3.1.1	Rack method with gear box	36
4.3.1.2	Stepper motor	36
4.3.1.3	Linear pneumatic cylinder	37
4.3.2	Selecting vertical moment actuator	38
4.3.1.1	Key features of selected cylinder	38
4.3.1.2	High functionality	39
4.3.1.3	Calculation of impact velocity	41
4.3.3	Fabricating and combining with gripper	42
4.4	Designing of horizontal movement	43
4.4.1	Selecting horizontal movement actuator	43
4.4.2	End position controlling method	49
4.4.3	Fabricating and combining gripper and horizontal movement actuator	51
4.5	Designing of main structure	52
4.5.1	Main structure fabrication	52



4.5.2	Main structure mounting method	53
4.5.3	Fabricating and assembling main structure	54
4.6	Pneumatic diagram	55
4.7	Controller description and program	56
4.7.1	Programmable logic controller unit	57
4.8	Robot arm interface with rubber molding machine	58
4.8.1	Injection mold machine operating sequence	59
<b>05.</b>	<b>Result and discussion</b>	<b>60</b>
5.1	Dynamic characteristic of twin rod drive system	60
5.2	Dynamic characteristic of roadless linear drive system	62
5.3	Cycle time analysis after implementing unloading system	64
<b>06.</b>	<b>Conclusion</b>	<b>66</b>
6.1	Comparison of production data before and after implementing robot arm	66
6.1.1	Comparison of average daily production	66
6.1.2	Comparison of daily production	67
6.2	Further development of the system	68
<b>Reference</b>		<b>69</b>
<b>Appendix A</b>		<b>71</b>
<b>Appendix B</b>		<b>73</b>



University of Moratuwa, Sri Lanka.  
 Electronic Theses & Dissertations  
[www.lib.mrt.ac.lk](http://www.lib.mrt.ac.lk)

## Abstract

Brandix hangers (Pvt) Ltd is one of factory in Brandix group which is a large scale hanger manufacturing factory in Sri Lanka. The main production of the factory is hangers. The current production is 4 million hangers per month. However the monthly demand is around 5.5 Million hangers per month. The key concern for this research is to increase the production of the hanger manufacturing at Brandix Hangers (Pvt) Ltd to cater the current market demand.

However the purchasing of new advanced machine was very expensive and at the same time increasing the number of labour was also not a good option. Therefore by using the existing machines and labour the production had to be increased.

The rubber lever machine was selected as the best option to increase the production rate by replacing the human interaction with any other effective method. The main concern was given to minimize wasting time and decrease the cycle time. To improve the production, human interaction should be replaced or should need to be speed up. However speed up of the human has a maximum limit and it is impossible to increase more than that. So by replacing the human activity with any other method, the cycle time can be minimized. Therefore automate some function of human process was identified as one of the best solution to decrease the cycle time and hence cater the market demand.

Rubber lever machine loading and unloading processes were done by human. If the automation is introduced for the loading process, the image processing technology has to be used because the placement of the flipper levers is very important factor to follow the next steps. However the image processing equipment was very expensive and could not bear it within the available budget. The other option was to automate the unloading process. Since the placement was not a very important factor for the unloading process (this was the end of the process and only the removal of the complete product was done) not needed image processing technology. On the other hand the longest time was taken for loading. Since the loading process cannot be automated to minimize the loading time the manual input should have to be increased. For that the unloading operator was transferred to the loading process. Hence the loading time becomes half.



## Acknowledgement

This research project would not be possible without the generous support, help and advice of my academic supervisor, Dr. Harsha Abeykoon, Department of Electrical Engineering, University of Moratuwa. He has deep understanding for the details and superb analytical skill, these have been key in the success of the project. I am also grateful to Dr. Palitha Dasanayaka, Department of Mechanical Engineering, University of Moratuwa, for his precious advices, support and guidance to complete my research successfully.

My gratitude extends to Prof. Lanka Udawatta, Prof. Sisil Kumarawadu, Dr. Nalin Wickramarachchi, Department of Electrical Engineering, University of Moratuwa, for serving as my committee members. Their valuable advices and the suggestions were very worth to make my research in the correct path.

I would like to take this opportunity to extend my deepest gratitude to Mr. K.P. Thayakaran (Chief Operating Officer), Brandix Hangers (Pvt) Ltd for giving me the opportunity and providing the funds and resources to carry out this project. My warmest gratitude goes to Mr. Rajitha Wellagiriya (Factory Manager), Brandix Hangers (Pvt) Ltd for his great help in many ways to complete this project. All the shift engineers who lend a hand to me in this regards are highly appreciated.

All the technicians such as welder, lathe man, machine fitters and work shop supervisor are extremely appreciated for their assistance to fabricate the robot arm and sharing their ability to successfully complete this project within short period.

Finally I dedicate this research to my parents, sisters and my wife who have always encouraged me to go after my dreams and for their constant moral support.

## List of Figures

Figure	Page
2.1 Schematic diagram of plastic flipper rubberizing operation	5
2.2 Manual loading process of plastic flipper	8
2.3 Manual unloading process of plastic flipper	9
3.1 Rubber injection molding machine	13
3.2 Translation of frames [17]	16
3.3 Two-link Cartesian manipulator [22]	19
3.4 Vacuum cup with suction generator	21
3.5 Vacuum cup with suction generator in food industry [5]	22
3.6 Vacuum $p_u$ as a function of operating pressure $P_1$ [6]	22
3.7 Suction rate $q_{ns}$ as a function of operating pressure $p_1$ [6]	23
4.1 3 - DOF Cartesian arm configuration and its workspace [14]	25
4.2 Flipper arrangement of the mold	27
4.3 Puncher side of the mold with rubber injection molding machine	27
4.4 Vacuum pad touching area of plastic flipper	28
4.5 Suction cup diagram	29
4.6 Suction cup	29
4.7 Suction force variation with vacuum [6]	30
4.8 Vacuum generator cross section [9]	31
4.9 Vacuum generator	32
4.10 Placement of mold plate	34
4.11 Gripper model using "Pro Engineering" software	35
4.12 Final view of the completed gripper arm	35
4.13 Motor with gear box	36
4.14 Stepper motor	36
4.15 Vertical motion cylinder	37
4.16 Horizontal motion cylinder	37
4.17 Guide twin rod actuator	38
4.18 Lifting load of twin cylinder	39



4.19	Cylinder moving direction	39
4.20	Load under lateral load	40
4.21	3D model of twin cylinder and gripper before fabricating	42
4.22	Complete view of gripper with guide cylinder	42
4.23	Selected rodless drive (DGC – 25 – 500 – KF – YSR – A)	43
4.24	Adjustable end position of shock absorber	44
4.25	Force and torque applying diagram	45
4.26	Operating range of cushioning	46
4.27	Horizontal mounting position	47
4.28	Central lubrication system of rod less cylinder [10]	48
4.29	Selected shock absorber	49
4.30	Rodless linear drive mounting with main structure	51
4.31	3D model of the robot arm main structure	52
4.32	Complete view of main structure	52
4.33	3D model of mounting brackets	53
4.34	Robot arm mounting position of the injection molding machine (Tie bar)	53
4.35	3D model of complete robot arm before fabricating	54
4.36	Photograph of completed robot arm	54
4.37	Main pneumatic diagram of robot arm	55
4.38	Sensor arrangement of the system	56
4.39	Pneumatic circuit diagram with valve solenoid	56
4.40	Programmable logic controller	57
4.41	Front elevation of robot arm after fixing rubber injection molding machine	58
4.42	End elevation of robot arm after fixing rubber injection molding machine	58
5.1	Speed diagram with load	61
5.2	Acceleration diagram of cylinder	61
5.3	Speed diagram with load	63
5.4	Acceleration diagram of rodless cylinder	63
6.2	Daily production before and after implementing robot arm	66
6.1	Average daily production before and after implementing robot arm	67

## List of Tables

Table	Page
2.1 Cycle time analysis of manual rubberizing process	6
4.1 Selected suction cup specification	30
4.2 Performance data of selected vacuum generator	33
4.3 Speed characteristic of selected cylinder	40
4.4 Physical specification of rodless linear drive	44
4.5 Permissible forces and torques	45
4.6 Specification of shock absorber	50
4.7 Specification force of shock absorber	50
4.8 Energies energy of shock absorber [J]	50
4.9 Memory location and device for develops the program	57
5.1 Simulation results of selected cylinder	60
5.2 Simulation results	62
5.3 Cycle time analysis of rubberizing process after fixing arm	64
5.4 Cycle time comparison of manual process and automated process	65
A.1 Average daily production detail	71
A.2 Average daily production detail	72