

DEVELOPMENT OF LOW PRESSURE WATER HYDRAULIC SYSTEM

NUR FATHIAH BT MOHD NOR

A project report submitted in partial fulfilment of the requirements for the award of
Degree of Bachelor Mechanical Engineering (Thermal-Fluid)

Faculty of Mechanical Engineering
Universiti Teknikal Malaysia Melaka

APRIL 2010

“I/We* hereby declared that I/We* have read this thesis and in my/our* opinion this thesis is sufficient in terms of scope and quality for the award of Degree of Bachelor Mechanical Engineering (Thermal-Fluids)”

Signature :

Supervisor :

Date :

“I hereby declared that this is my own work except the ideas and summaries which I have clarified their sources”

Signature :

Author : NUR FATHIAH BT MOHD NOR

Date :

Special dedication to my family, supervisor, my friends and all that help me to finish my thesis.

ACKNOWLEDGEMENT

Alhamdulillah, I am most grateful and thankful to ALLAH the Almighty for His blessing, authorization and kindness that has allowed me to conduct and complete this project.

My most appreciation and grateful is to my project supervisor, Mr. Faizil Bin Wasbari for his recommendations, assistance, advice, encouragement and patience during this progress of this report.

I would also like to thank all those who had contributed directly and indirectly, to make this project successful especially to Mr. Ikhmal Hisham Bin Ibrahim@Ibrahim, the technicians of Hydraulics and Pneumatic Laboratory for his help and opinion during this final year project.

Moreover, thanks to my friends and coursemate who are always willing to help me when I needed, especially Mohd Faiz Abdol Aziz and Mohd Fahmi Abd Majid. My appreciation goes to both of you for the helps and guidance given.

I would also like to thank my family who were always there for me. Their support and encouragement brings my confidence up in undergoing this project.

ABSTRAK

Tesis ini menerangkan kajian tentang pembangunan sistem hidraulik air tekanan rendah. Kajian ini tertumpu kepada pembinaan unit kuasa hidraulik, mereka system hidraulik air, memasang sistem pengujian dan unit kuasa hidraulik dan menjalankan ujian-ujian tertentu kepada sistem hidraulik air tersebut. Kajian ini juga tertumpu kepada prestasi hydraulic air apabila tekanan rendah diaplikasikan terhadap sistem tersebut. Selain itu, kajian ini juga tertumpu kepada penggunaan “*Programmable Logic Controller (OMRON)*” sebagai sistem kawalan untuk sistem hidraulik air tekanan rendah. Penggunaan sistem hidraulik air ini telah digunakan dalam sektor industri sejak beberapa tahun dahulu, tetapi kemudian telah digantikan kepada minyak sebagai penggerak sistem disebabkan oleh masalah-masalah yang dihadapi dengan menggunakan air sebagai penggerak sistem. Kajian ini dijalankan untuk mengetahui had sistem hidraulik air dan penyelesaian untuk mengatasi masalah yang berlaku. Sistem pengujian telah direka bentuk dan simulasi telah dilakukan dengan menggunakan “*Programmable Logic Controller (OMRON)*” yang digunakan dalam sektor industri masa kini. Melalui simulasi, ia dapat mengurangkan masa pemasangan dan membantu dalam pemasangan sistem pengujian dengan betul. Beberapa ujian telah dijalankan dengan bantuan system pengujian tersebut. Ujian yang sama telah dilakukan terhadap sistem pneumatic dan sistem hidraulik untuk perbandingan terhadap sistem hidraulik air tekanan rendah. Prestasi ujian yang diuji adalah seperti tekanan lolos, kebocoran dalaman, kelajuan lejang dan daya keluaran. Keputusan telah dicatat dan dianalisis untuk menentukan kebolehan sistem hidraulik air tekanan rendah dan membuat perbandingan diantara sistem pneumatik dan sistem hidraulik. Sebagai keputusan, sistem hidraulik air tekanan rendah adalah praktikal. Akan tetapi, beberapa pembaikan diperlukan supaya sistem tersebut lebih bersesuaian dan efisien.

ABSTRACT

This thesis presents a study on development of low pressure water hydraulic system. This study mainly focuses on building a hydraulic power unit, design of control system, fabricate water hydraulic power unit and system and run testing procedures on the testing system. The purpose of this study is to test the performance of water hydraulic when low pressure is applied. Besides that other purpose of this study is to use *Programmable Logic Controller (OMRON)* as the control system for this low pressure water hydraulic system. Water hydraulic system is commonly used in industries years ago, but then water hydraulic is replaced with oil as pressure medium because of disadvantages of using water as pressure medium. This study is done to explore the limitations of using water hydraulic system and the solution to solve the occurred problems. A testing system was designed and simulated by using *Programmable Logic Controller (OMRON)* which is widely used in industries nowadays. From the simulation, the motion of cylinder is shown. This simulation can help reduces time in designing and assembling the testing system correctly. Several tests were done with the aid of the testing system for low pressure water hydraulic system. The same tests were also done on pneumatic system and hydraulic system for comparison in terms of performance. The performance of system was tested in terms of breakaway pressure, internal leakages, speed of stroke and output force. The results were recorded and analysed to verify the ability of low pressure water hydraulic system and to make comparison between pneumatic system and hydraulic system. As a result, low pressure water hydraulic system is applicable. However, improvements are needed to make sure the system is more suitable and efficient.

TABLE OF CONTENT

CHAPTER	TITLE	PAGE
	ACKNOWLEDGEMENT	iv
	ABSTRACT	v
	ABSTRAK	vi
	TABLE OF CONTENTS	vii
	LIST OF TABLES	xv
	LIST OF FIGURES	xviii
	LIST OF ABBREVIATIONS	xvii
CHAPTER 1	INTRODUCTION	
	1.1 Background	1
	1.2 Objective	2
	1.3 Scope	2
	1.4 Problem Statement	3

CHAPTER	TITLE	PAGE
CHAPTER 2	LITERATURE REVIEW	
2.1	Introduction on Fluid Power System	5
	2.1.1 Basic Components on Fluid Power System	5
	2.1.1.1 Power Unit	6
	2.1.1.2 Control	6
	2.1.1.3 Output	7
	2.1.1.4 Formula	7
2.2	Low Pressure Theory	9
	2.2.1 Introduction to Water Hydraulic System	10
	2.2.2 Pumps	12
	2.2.3 Water Quality	13
2.4	Introduction on Programmable Logic Controller (PLC)	14
	2.4.1 How PLC Works	15
	2.4.2 Ladder Diagram	16
	2.4.3 Basic PLC Instructions	17
	2.4.4 Benefits of PLC control system	19
2.5	Water Hydraulics – A Novel Design Spool Type Valves for Enhanced Dynamic Performance	20
2.6	Fault Diagnosis of Water Hydraulic Actuators under Some Simulated Faults	21
2.7	A Study of Hydraulic Seal Integrity	23
2.7	Characteristics of Hydrostatic Bearing/ Seal Parts for Water Hydraulic Pumps And Motors	25

CHAPTER	TITLE	PAGE
	2.8 High Speed On/Off Position Control Of a Low Pressure Water Hydraulic Cylinder Drive	26
CHAPTER 3	METHODOLOGY	
3.1	Methodology	28
3.1.1	Literature Review	29
3.1.2	Design Water Hydraulic Power Unit	29
3.1.3	Design PLC Control System	29
3.1.4	Simulate and Validate PLC Control System	30
3.1.5	Fabricate Water Hydraulic Power Unit and System	30
3.1.6	Testing of System	30
	3.1.6.1 Testing for Leakage In Components	30
	3.1.6.2 Testing for Breakaway Pressure	31
	3.1.6.3 Testing for Cylinder Speed	31
	3.1.6.4 Testing for Output Force	31
3.1.7	Result	32
3.1.8	Analysis	32
3.1.9	Report Writing	32

CHAPTER	TITLE	PAGE
CHAPTER 4	PROPOSAL	
4.1	Introduction	35
4.2	Schematic Diagram	36
4.3	Design of Chassis and Component Location	37
4.3.1	Full Assemble	37
4.3.2	Top View	38
4.3.3	Side View	39
4.4	Ladder Diagram	40
4.4.1	Ladder Diagram 1	40
4.4.2	Ladder Diagram 2	41
4.5	Operation of PLC Circuit	42
4.5.1	Flow Chart for Ladder Diagram 1	42
4.5.2	Flow Chart for Ladder Diagram 2	43
4.6	Validation	44
4.6.1	Single Stroke Motion	44
4.6.1.1	1 st Stage – Initial Position	44
4.6.1.2	2 nd Stage – Extending Position	45
4.6.1.3	3 rd Stage – Retracting Position	45
4.6.2	Continuous Motion	46
4.5.2.1	1 st Stage – Initial Position	46
4.5.2.2	2 nd Stage – Extending Position	47

CHAPTER	TITLE	PAGE
	4.6.2.3 3 rd Stage – Retracting Position	48
	4.6.2.4 4 th Stage – Cycle Cont.	49
CHAPTER 5	DEVELOPMENT OF WATER HYDRAULIC SYSTEM	
5.1	Power Supply Unit	50
5.1.1	Pump	51
5.1.2	Reservoir	52
5.2	Control System	54
5.2.1	Water Hydraulic Control System	54
5.2.1.1	Pressure Relief Valve	54
5.2.1.2	Directional Control Valve	55
5.2.2	PLC Control System	55
5.3	Actuator	56
5.5.1	Cylinder	56
CHAPTER 6	RESULT	
6.1	Hydraulic System	57
6.1.1	Breakaway Pressure of Cylinder	58
6.1.2	Internal Leakage of Cylinder	58
6.1.3	Stroke Time	59
6.1.4	Pressure Drop during Cylinder Movement	60

CHAPTER	TITLE	PAGE
6.2	Pneumatic System	60
6.2.1	Breakaway Pressure of Cylinder	60
6.2.2	Internal Leakage of Cylinder	61
6.2.3	Stroke Time	62
6.2.4	Pressure Drop during Cylinder Movement	63
6.3	Water Hydraulic System	63
6.3.1	Breakaway Pressure of Cylinder	63
6.3.2	Internal Leakage of Cylinder	64
6.3.3	Stroke Time	65
6.3.4	Pressure Drop during Cylinder Movement	66
CHAPTER 7	ANALYSIS	
7.1	Cylinder Speed	67
7.1.1	Hydraulic System	68
7.1.2	Pneumatic System	69
7.1.3	Water Hydraulic System	71
7.1.4	Comparison between Hydraulic System, Pneumatic System and Water Hydraulic System in terms Of Cylinder Speed	72
7.1.4.1	Cylinder Speed for Extension Process	72
7.1.4.2	Cylinder Speed for Retraction Process	74

CHAPTER	TITLE	PAGE
7.2	Output Force	75
7.2.1	Hydraulic System	76
7.2.2	Pneumatic System	77
7.2.3	Water Hydraulic System	78
7.2.4	Comparison between Hydraulic System, Pneumatic System and Water Hydraulic System in terms Of Output Force	78
7.1.4.1	Output Force for Extension Process	78
7.1.4.2	Output Force for Retraction Process	80
CHAPTER 8	DISCUSSION	
8.1	Breakaway Pressure	82
8.2	Overall Speed and Output Force of Cylinder	83
8.3	Internal Leakage of Cylinder	84
8.4	Leakage of Control Valve	84
8.5	Contamination	85
8.6	Effect of Friction	87
8.7	Application of System	87

CHAPTER	TITLE	PAGE
CHAPTER 9	CONCLUSION AND RECOMMENDATION	
9.1	Conclusion	88
9.2	Recommendation	90
	9.2.1 Possible Recommendation for Improvements	90
	REFERENCES	92
	BIBLIOGRAPHY	94
	APPENDICES	95

LIST OF TABLES

NO	TITLE	PAGE
5.1	Technical Data for Spray Pump	51
6.1	Visual Result of Internal Leakage	58
6.2	Stroke Time for Test Pressure of 2 Bars	59
6.3	Stroke Time for Test Pressure of 4 Bars	59
6.4	Stroke Time for Test Pressure of 6 Bars	59
6.5	Stroke Time for Test Pressure of 8 Bars	59
6.6	Pressure Reading	60
6.7	Breakaway Pressure during Extension	61
6.8	Breakaway Pressure during Retraction	61
6.9	Visual Result of Internal Leakage	61
6.10	Stroke Time for Test Pressure of 2 Bars	62
6.11	Stroke Time for Test Pressure of 4 Bars	62
6.12	Stroke Time for Test Pressure of 6 Bars	62
6.13	Stroke Time for Test Pressure of 8 Bars	62
6.14	Pressure Reading	63

NO	TITLE	PAGE
6.15	Breakaway Pressure during Extension	64
6.16	Breakaway Pressure during Retraction	64
6.17	Visual Result of Internal Leakage	64
6.18	Stroke Time for Test Pressure of 2 Bars	65
6.19	Stroke Time for Test Pressure of 4 Bars	65
6.20	Stroke Time for Test Pressure of 6 Bars	65
6.21	Stroke Time for Test Pressure of 8 Bars	65
6.22	Pressure Reading	66
7.1	Cylinder Speed for Test Pressure of 2 Bars	68
7.2	Cylinder Speed for Test Pressure of 4 Bars	68
7.3	Cylinder Speed for Test Pressure of 6 Bars	68
7.4	Cylinder Speed for Test Pressure of 8 Bars	69
7.5	Summary of Cylinder Speed	69
7.6	Cylinder Speed for Test Pressure of 2 Bars	69
7.7	Cylinder Speed for Test Pressure of 4 Bars	70
7.8	Cylinder Speed for Test Pressure of 6 Bars	70
7.9	Cylinder Speed for Test Pressure of 8 Bars	70
7.10	Summary of Cylinder Speed	70
7.11	Cylinder Speed for Test Pressure of 2 Bars	71
7.12	Cylinder Speed for Test Pressure of 4 Bars	71
7.13	Cylinder Speed for Test Pressure of 6 Bars	71
7.14	Cylinder Speed for Test Pressure of 8 Bars	71
7.15	Summary of Cylinder Speed	72

NO	TITLE	PAGE
7.16	Cylinder Speed for Extension Process	72
7.17	Cylinder Speed for Retraction Process	74
7.18	Dimension of Cylinder	76
7.19	Output Force	76
7.20	Dimension of Cylinder	77
7.21	Output Force	77
7.22	Output Force	78
7.23	Output Force for Extension Process	79
7.24	Output Force for Retraction Process	80

LIST OF FIGURES

NO	TITLE	PAGE
2.1	Simple Hydraulic Jack Concept (Source: http://upload.wikimedia.org/wikipedia)	8
2.2	PLC Basic Structure (Source: Vernon,J (2007))	14
2.3	Relay Concept (Source: http://yourplctrainer.com (2008))	16
2.4	Contact Instruction (Source: http://yourplctrainer.com , (2008))	17
2.5	Normally Closed Contact (Source: http://yourplctrainer.com , (2008))	17
2.6	Output (Source: http://yourplctrainer.com , (2008))	18
2.7	Timer (Source: http://yourplctrainer.com , (2008))	18
2.8	Counter (Source: http://yourplctrainer.com , (2008))	18

NO	TITLE	PAGE
3.1	Flow Chart of Methodology	33
4.1	Schematic Diagram	36
4.2	Full Assemble View of Chassis	37
4.3	Top View of Chassis	38
4.4	Side View of Chassis	39
4.5	Ladder Diagram 1 (Single Stroke Motion)	40
4.6	Ladder Diagram 2 (Continuous Reciprocating Motion)	41
4.7	Flow Chart for Ladder Diagram 1	42
4.8	Flow Chart for Ladder Diagram 2	43
4.9	1 st Stage – Initial Position	44
4.10	2 nd Stage – Extending Position	45
4.11	3 rd Stage – Retracting Position	45
4.12	1 st Stage – Initial Position	46
4.13	2 nd Stage – Extending Position	47
4.14	3 rd Stage – Fully Extend	48
4.15	4 th Stage – Retracting Position	49
5.1	Power Spray Pump	51
5.2	Hose Connector Pump	52
5.3	Stainless Steel Reservoir	53
5.4	PVC Connector and Hose Connector	53
5.5	Polyurethane Tube 10 mm x 6.5 mm	54
5.6	Pressure Relief Valve with Pressure Gauge	55

NO	TITLE	PAGE
5.7	5/2 Way Double Solenoid DCV	55
5.8	PLC main board and ON and OFF switch button	56
5.9	Stainless Steel Pneumatic Cylinder	56
7.1	Cylinder Speed Versus Test Pressure	73
7.2	Cylinder Speed Versus Test Pressure	74
7.3	Output Force Versus Test Pressure	79
7.4	Output Force Versus Test Pressure	80
8.1	Leakage at Control Valve	85
8.2	Condition of water before testing	86
8.3	Condition of water after testing	86

LIST OF ABBREVIATIONS

PLC	=	Programmable Logic Controller
F	=	Force, N
A	=	Area, m ²
P	=	Pressure, Bar
Q	=	Flow rate, m ² /s
v	=	Velocity, m/s
P	=	Power, J/s
N	=	Angular Speed, rad/s
T	=	Torque, Nm
η	=	efficiency
CFD	=	Computational Fluid Dynamics
L	=	Length
t	=	Time

CHAPTER 1

INTRODUCTION

1.3 Background

Fluid power is a technology that uses pressurized fluids for transmission of power. Fluid power is called hydraulics when the fluid is liquid and pneumatics when the fluid is a gas. The first fluid that is used in fluid power applications was water. However water was overtaken by oil hydraulics due to the cause of deficiencies shown by water as pressurized medium. Due to the growing concern of environmental issues has led to the interest of using water hydraulics again. Because water is non toxic, environmental friendly, and readily available is the main factors that many industries are turning to water hydraulic system.

Usually hydraulic system is design for high pressure, but because of water can only work with low pressure, therefore a study is carried out to develop a system for low pressure water hydraulic. In this study, the pressure that will be loaded on to the system for testing is below 10 bars. The control system that will be used in controlling the actuator is by using PLC control system where it is more suitable to used compare to electrical control system.

1.2 Objective

The objectives of this study are:

- i. To learn and understand the concept of low pressure water hydraulic system
- ii. To re-design the existing low pressure water hydraulic system using PLC control system
- iii. To fabricate the new water hydraulic system
- iv. To conduct an experiment to test the system
- v. To compare between water hydraulic system, pneumatic system and hydraulic system in terms of cylinder speed and output force of cylinder

1.3 Scope

The scopes of the project are:

- i. Re-design the existing system by using PLC control system and new pump
- ii. Validate the system control
- iii. Fabricate the new design of low pressure water hydraulic system
- iv. Test the system control design of low pressure water hydraulic system
- v. Uses RO water as operating medium
- vi. Uses pneumatic cylinder as actuator system
- vii. Compare water hydraulic system with pneumatic system and hydraulic system