POSITION CONTROL OF ELECTRO-HYDRAULIC SYSTEM USING PID-MRAC APPROACH

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A report submitted
in fulfilment of the requirements for the degree of
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DECLARATION

I declare that this report entitled “Position Control of Electro-hydraulic System Using PID-MRAC Approach” is the result of my own work except as cited in references.

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Signature	:	....
Name	:	....
Date	:	....

APPROVAL

I hereby declare that I have read this project report and in my opinion this report is sufficient in term of scope and quality for the award of the degree of Bachelor of Mechanical Engineering.

Signature	:	…………………………
Supervisor’s Name	:	…………………………
Date	:	…………………………

DEDICATION

I dedicate this thesis to the Almightiest which is Allah, my creator, my strong pillar, which is one of my sources of inspiration and the one that give me strength when I thinking of giving up. Big thanks to my beloved family and my final year's project supervisor Sir Zairulazha Bin Zainal. I also dedicate this project to my fellow friends who has lend their hand to help me to complete the studies and give reinforcement when I'm in need all the way and whose encouragement has ensure me to give all I have no matters what it takes to finish the things that I have started.

ABSTRACT

Electro-hydraulic system is a type of feedback-controlled parameter regulates a hydraulic actuator, whether linear or rotary. The input, e.g. displacement or load, is commanded and the actual parameter is measured. An error signal is generating and apply to a servo-valve controller. The waveform produced can be any form of wave either static or dynamic, one shot or cyclic. It is very flexible and can be applied commanded complex pre-programmed load or displacement parameters. The range of loads can be applied is wide and the displacement precise. The purpose of this study is to design a PID controller with MRAC approach to improve the performance of the system. A model is obtained from a journal and all the parameters has been identified. The parameters are then will be derived to get the system transfer function.

ABSTRAK

Sistem elektro-hidraulik adalah sejenis parameter yang dikendalikan maklum balas mengawal penggerak hidraulik, sama ada secara linear atau berputar. Input, seperti pergerakan atau beban, dikawal dan parameter sebenar diukur. Isyarat ralat dijana dan dihantar kepada sistem servo-valve. Bentuk gelombang yang terhasil boleh menjadi apa jua bentuk gelombang sama ada statik atau dinamik, satu pukulan atau kitaran. Ia sangat fleksibel dan boleh digunakan untuk mengarahkan beban kompleks pra-program atau parameter pergerakan. Beban yang boleh digunakan adalah luas dan ketepatan pergerakan. Tujuan kajian ini dijalankan adalah untuk mereka bentuk pengawal PID bersama pendekatan MRAC untuk meningkatkan prestasi sesebuah sistem. Model diambil dari jurnal dan semua parameter akan dikenal pasti. Parameter-parameter itu kemudiannya akan diderivasi untuk mendapatkan fungsi pemindahan sistem itu.

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LIST OF ABBREVIATIONS, SYMBOLS, SPECIALIZED NOMENCLATURE

PID	-	Proportional Integral Derivative
MRAC	-	Model References Adaptive Control
LVDT	-	Linear Variable Differential Transformer
ω_γ	-	Natural frequency of servo valve
ζ_γ	-	Damping ratio of servo valve
Q_ν	-	Related flow rate of servo valve
C_t	-	Total leakage coefficient
K	-	Torque motor grain of servo valve
P_s	-	Supply pressure
B	-	Bulk module of oil
ρ	-	Mass density of oil
M_e	-	Equivalent mass of both the load and the piston
d_{rod}	-	Diameter of load
d_{piston}	-	Diameter of piston
X_p	-	Max stroke of cylinder
L	-	Length of pipeline and hoses from pump of cylinder
F_{fc}	-	Cylinder coulomb friction force

LIST OF SYMBOL

c	=	Damping coefficient
ξ	=	Damping ratio
F_e	=	Excitation force
F_t	=	Force transmitted
i	=	$\sqrt{-1}$
m	=	Mass
k	=	Spring stiffness
ω	=	Operating frequency
ω_n	=	Natural frequency
T_f	=	Transmissibility
x	=	Displacement
$\dot{x}$	=	First derivatives of x
$\ddot{x}$	=	Second derivatives of x
Kp	=	Proportional Gain
Kd	=	Derivative Gain
Ki	=	Integral Gain

CHAPTER 1

INTRODUCTION

1.1 Background

The investigation for the looking of electro-hydraulic system with stable highlights, for example, elite level, quality guaranteed, environmentally-friendly and easy for maintenances has flooded explores to consider and grow facilitate on the capacity and abilities of electro-hydraulic system framework.

Electro-hydraulic system are generally utilized in industry and mechanical applications. The nonlinearities of an electro-hydraulic system including liquid nonlinearity, uneven mechanical attributes, and so on, cause the control execution changing with the moving course and the situation of the piston while utilizing a linear controller. The vulnerabilities of the pressure driven framework including load, erosion, and so on, will also influence the control execution. These two perspectives influence a conventional straight controller to be constrained to completely misuse the dynamic ability of the hydraulic system framework.

Electro-hydraulic system framework has become logically mainstream in different types of engineering equipment and by using it worthwhile and diverse applications, for example, flying machines, producing machines, fatigue testing, pressure driven excavator, sheet metal forming process and car applications built up so the actuator system will be more surely understood and important these days. However, the electro-hydraulic system is known as a convoluted framework which experiences vulnerabilities, nonlinearities and disturbances. These bothers may prompt degradation of control execution in trajectory tracking of the electro-hydraulic system.

Different kinds of criticism controller extending from direct to nonlinear compose are generally executed and distributed among the scholarly community and scientists for direction following control of electro-hydraulic system. The expanding quantities of works managing electro-hydraulic system over the previous decades included a linear control, intelligent control and nonlinear control methodologies, for example, Neural Network (NN), Self-tuning Fuzzy-PID, Model Reference Adaptive Control (MRAC), Generalize Predictive Control (GPC) and Sliding Mode Control (SMC).

Therefore, a feedback control methodology is dependably needed in outlining a great functioning trajectory tracking and positioning of electro-hydraulic system.

1.2 Problem Statement

The electro-hydraulic system is an electrically operated valve that control how hydraulic fluid transferred to an actuator. Servo valve operates by transforming the analog or digital signal into a movement in hydraulic cylinder. This system combined two control modes of electrical and mechanical. However, the dynamic properties of electro-hydraulic system is highly nonlinear and cause this system difficult to control. Non-linear system also may cause the system to be non-smooth and discontinuous due to directional change of valve opening, friction and valve overlap (Hong et al., 2004). Mathematical model of a system will use to model and simulate the system (Dechrit, 2009). Modelling and simulation is to optimize the dynamic performance by controlling the speed and displacement of the actuator.

This project will study on the characteristic of dynamic system execution of an electro-hydraulic system by using modelling and simulating in MATLAB and Simulink. The transfer function of the system will be developed for modelling and simulating in MATLAB and Simulink. Electro-hydraulic system will move with various speeds of piston motion. Displacement sensor was mounted to the hydraulic piston for measuring piston motion. The electro-hydraulic system will be run by a Simulink. This research also applied closed loop control during conducting experiments.

1.3 Objectives

The objectives for pursuing the current research topic are:

1. To develop mathematical models of a hydraulic servo system.
2. To model and simulates a hydraulic servo system for studying dynamic characteristics of the system.
3. To design an electro-hydraulic controller with PID-MRAC.
4. Testing the controller system by using PID-MRAC and drive the system to pursue perfectly the desired direction.

1.4 Scope

The scope of this project is:

1. Make a journal research on electro-hydraulic system on how to derive the equation and obtain complete parameters.
2. Deriving the equation and analyse all the parameters needed to the system.
3. Apply the final equation in Simulink apps and record the result.
4. Create the controller system by using PID-MRAC approach.

1.5 General Methodology

All the action that need to apply to achieve the objectives are listed below:

1. Literature Review

   Journals, articles, magazine and all the materials regarding to this project will be researched.

2. Simulation

   Simulation that will be used is Simulink apps to test the equation and PID-MRAC apps to test the controller system.

3. Analysis and Results

   Analysis will be calculated on how the product reacts to the control system whether it pursue the desire direction or not.

4. Report

   A report based on this project will be conducted at the end of this research.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The electro-hydraulic system is an electrically operated valve that controls the hydraulic fluid, which is ported to an actuator system. A valve is a device in the hydraulic system, which controls the flow of the hydraulic fluid. The electro-hydraulic system has the abilities to apply very large forces and torques, thus, it was being applied widely in heavy industry. Besides that, it also has high stiffness and fast response for heavy industry. Some applications of electro-hydraulic system in heavy industrial are in automotive, construction machinery, lifting and conveying devices (Markle et al., 1998). However, electro electro-hydraulic system is typically a non-linear system. It causes the system difficult to control due to problems with high non-linearity and motion friction (Shao et al, 2009).

Non-linear system is a system, which is the output, is inversely proportional to its input for certain system such as dynamics of aircraft (nonlinear dependences on speed, angles, altitudes), helicopters, satellites, and that is most systems in aerospace engineering. Therefore, for some applications these systems are quite complicated system for perfect control. A non-linear phenomenon may cause non-smooth and discontinuous nonlinearities due to directional change of valve opening, friction and valve overlap (Yao et al., 1998). Thus, there are many previous researchers had studied the dynamic characteristic of an electro-hydraulic system to develop a controller for this system. The designed controller must work properly with dealing the non-linear phenomenon and dynamic of the hydraulic servo system parameters (Nitin, 2009).

2.2 Introduction to Electro-Hydraulic System

Basic servomechanism as shown in Figure 2.1 is an electro-hydraulic system which a criticism-controlled parameter directs a pressure hydraulic actuator, either straight of revolving. A parameter, e.g. removal or load, is applied and the real parameter estimated and a blunder flag created and connected to a servo-valve controller. The instructed waveform can be any wave shape, static or dynamic, one shot or cyclic. It is entirely adaptable means suitable to any system and can connected to complex pre-modified load or uprooting parameters. Various free channels can be connected and related. The scope of load can be connected is wide and the exactly located.

Typically, an electro-hydraulic system consists of various components:

1. A hydraulic power supply providing a motive source (e.g. electric motor), a hydraulic pump (often 3000 psi) an oil sump, oil cooler and accumulator, relief valves.
2. Manifolds, hard piping, flexible hoses and fitting,
3. Hydraulic manual or servo-valves,
4. Load or displacement measuring equipment (optional for high performance and automated control)
5. Feedback-control electronics, including PID controls (optional).

Advantages of electro-hydraulic are obviously known. Higher density power, easy to control the motion, higher reliability and strength, possibility to implement customized solutions, good resistance to vibrations and able to absorb impulsive loads and management of simple thermal exchange. Every one of these factors has made hydraulic systems capable to withstand for the power actuation in highly variation fields from aeronautics to earth handling, from bigger industrial applications such as steel mills to civil applications such as lifting bridges, dams and so on.

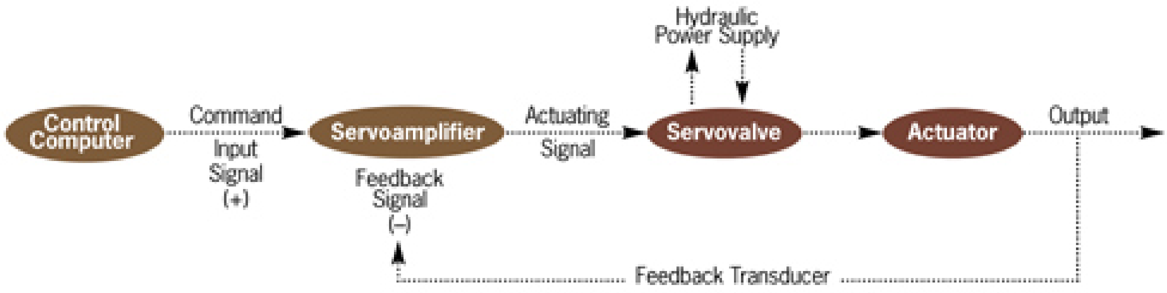

Figure 2.1 : Basic servomechanism (Karl Erik, 2008).

An electro-hydraulic system control contains of six major components showed in the picture above, which is control hardware such as a computer, microchip or system guidance which make an order input signal, a servo-intensifier which gives a low power electrical, activating signal which is the contrast between the order input signal, and the feedback signal created by the input transducer. The valve system reacts with this low electrical signal power and controls the flow of hydraulic fluid into the actuation, for example, a cylinder and chamber which positions of the devices are being controlled; and a power supply, for the most part an electric engine and siphon, which gives the flow of hydraulic fluid to deal with high pressure. The feedback transducer estimates the yield position of the actuator and changes over this estimation into a corresponding sign which is sent back to the servo-enhancer.

2.3 Design the PID controller

PID controller is one of the major control techniques. Its initial usage was in most gadgets, trailed by vacuum and strong state simple gadgets, previously touching base at the present computerized usage of chip. It contains a basic control structure which was comprehended by system administrators and which they found moderately simple to adjust. Since many controller systems utilizing PID control have demonstrated agreeable, despite everything it has an extensive variety of uses in mechanical control. As per study for a process control system led in 1989, more than 80 of the control circles are the PID type. The PID control has been used for exploration theme for some years. Since a lot of process plants are controlled by PID controllers has comparative elements, it has been discovered conceivable to set tasteful controller parameters from less plant data than an entire scientific model. These systems came about as a result of the desire to alter parameters of the controller in situ with the minimum of effort. Furthermore, in light of the fact that of the conceivable trouble and poor cost advantage of acquiring scientific models.

2.3.1 The PID Actions

Hydraulic servo system is a control system as shown in Figure 2.2, which made of by combining two modes of control of hydraulic and electric respectively. Movement of load and hydraulic transmission in the hydraulic servo system are being control by detecting the digital signal, transmitting the signal, and processing the signal by using electric and electronic components (Cheng et al., 2011). The servo systems can calculate their own output and force the output for the system to obey a command signal to the desired position and direction. The effect on incidence when the actual result under a given set of assumptions is varying from the expected result in control device and the load can be minimized as well as external disturbances in this system. For the block diagram of the hydraulic crane system. As shown in Figure 2.3.

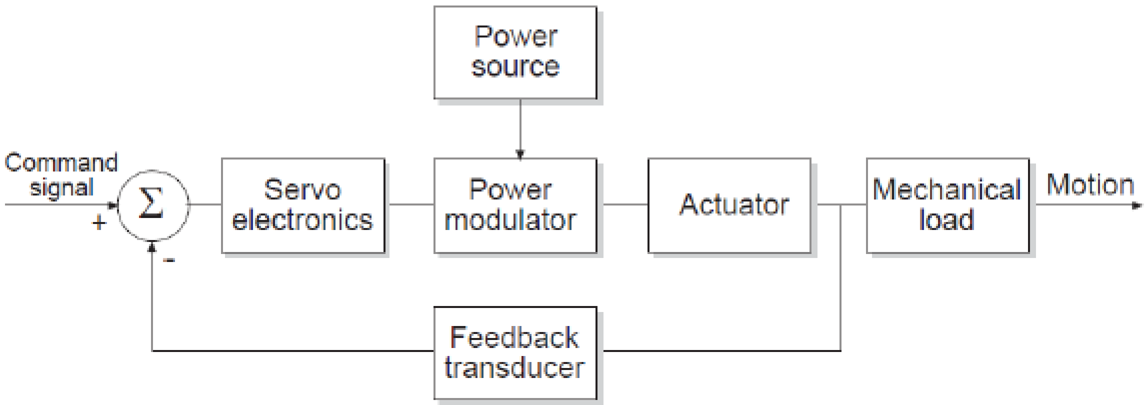

Figure 2.2: Basic servo mechanism (Karl Erik, 2008).