PARAMETER ESTIMATION OF ELECTRO-HYDRAULIC ACTUATOR SYSTEM

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2021

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A report submitted
in partial fulfillment of the requirements for the degree of
Bachelor of Electrical Engineering with Honours

Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2021

DECLARATION

I declare that this thesis entitled "PARAMETER ESTIMATION OF ELECTRO-HYDRAULIC ACTUATOR SYSTEM is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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APPROVAL

I hereby declare that I have checked this report entitled "title of the project" and in my opinion, this thesis it complies the partial fulfillment for awarding the award of the degree of Bachelor of Electrical Engineering with Honours

Signature :

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Date : 5/7/2021

DEDICATIONS

First of all, to the Almighty God who gives them strength and good health while doing this project. The proponents are dedicating this thesis to my family who gave usual our needs in doing this project. For all the sacrifice that they do just to finish this project. They gave all their support to me they believe that we can do it they gave us all the guidance and advice, to all my friends who helped and supported me to finished this thesis, I also dedicate this research work to my supervisor, Professor Madya Dr. Rozaimi Bin Ghazali who never failed to teach and guide me

ACKNOWLEDGEMENTS

بِسْمِ ٱللَّهِ ٱلرَّحْمَٰنِ ٱلرَّحِيمِ

In the Name of Allah s.w.t, the Most Gracious and Most Merciful

With all my might I praise to Allah, for given me this opportunity. As I am given the chance to start my student journey to manufacture my thesis on parameter estimation of electro-hydraulic actuator system. I want to thank the almighty God for giving me the will to go on, a good health and the ability to complete my thesis without any hindrance and to complete it in peace. I like to extend my thanks to my mom, Nargis Bhanu Binti Abdul Kader and my family members who have always supported me with the decision making, literally and raised me. My biggest thank you goes to my supervisor from Faculty of Electrical Engineering, Bachelor of Electrical Engineering with Honors, BEKG, Professor Madya Dr. Rozaimi Bin Ghazali for helping me and the rest of my course mates who have wider knowledge on the know a little more about this thesis process with lot of information and encouragement during this lonely journey. This project would not have been the same without their continued support and interest. Many thanks to all BEKG lecturers who have given massive support and helping with the thesis process and giving opportunity. Lastly, a substantial thank you to my colleagues who have supported me throughout the duration of these past four years.

ABSTRACT

In motion control applications, electro-hydraulic actuators system (EHAs) must be controlled to evaluate the motion of a position rod. A mathematical model is a system description that is based on equations. There are different phases technique which is physical modeling and system identification. Physical modelling have been used Simscape Fluids™ which known as EHA model in this thesis. The attraction of system identification is the ability to obtain a system's model from a set of input and output data without prior knowledge of the system. The objective of this study was to obtain transfer function and identify mathematical model of electro-hydraulic actuator (EHA) system using system identification technique by estimating Simscape Fluids™ model using System Identification Toolbox in MATLAB. The actual performance of the EHA model is subsequently validated to obtained the estimate model. The selected ARX(Auto-Regressive Exogenous) model with the help of the MATLAB System Identification Toolbox. The estimation model known as arxqs model has a best fitting accuracy of more than 90 %. The compare output response of the estimated model is close to the EHA model of the best fitting 93.87 % of electro-hydraulic actuator (EHA) model. The arxqs model has been chosen or selected is fourth-order autoregressive (ARX) model using the arx algorithm because the estimation was achieved.

ABSTRAK

Dalam aplikasi kawalan gerakan, EHA (penggerak elektro-hidraulik) mesti dikawal untuk menilai pergerakan batang kedudukan. Model matematik adalah penerangan sistem yang berdasarkan persamaan. Terdapat teknik fasa yang berbeza iaitu pemodelan fizikal dan pengenalpastian sistem. Pemodelan fizikal telah digunakan Simscape Fluids ™ yang dikenali sebagai model EHA dalam tesis ini. Daya tarikan sistem pengenalan adalah keupayaan untuk mendapatkan model sistem dari satu set data input dan output tanpa pengetahuan sebelumnya mengenai sistem. Objektif kajian ini adalah untuk mendapatkan fungsi pemindahan dan mengenal pasti model matematik sistem penggerak elektro-hidraulik (EHA) menggunakan teknik pengenalan sistem dengan menganggar model Simscape Fluids ™ menggunakan Kotak Alat Pengenalpastian Sistem di MATLAB. Prestasi sebenar model EHA kemudiannya disahkan untuk memperoleh model anggaran. Model ARX (Auto-Regressive Exogenous) yang dipilih dengan bantuan Kotak Alat Pengenalan Sistem MATLAB. Model anggaran yang dikenali sebagai model arxqs mempunyai ketepatan pemasangan yang terbaik melebihi 90%. Respons perbandingan model yang dianggarkan hampir dengan model EHA yang paling sesuai dengan 93.87% model penggerak elektro-hidraulik (EHA). Model arxqs telah dipilih atau dipilih adalah model autoregressive orde keempat (ARX) menggunakan algoritma arx kerana anggarannya dicapai. Respons perbandingan model yang dianggarkan hampir dengan model EHA yang paling sesuai dengan 93.87% model penggerak elektro-hidraulik (EHA). Model arxqs telah dipilih atau dipilih adalah model autoregressive orde keempat (ARX) menggunakan algoritma arx kerana anggarannya dicapai. Respons keluaran perbandingan model yang dianggarkan hampir dengan model EHA yang paling sesuai dengan 93.87% model penggerak elektro-hidraulik (EHA). Model arxqs telah dipilih atau dipilih adalah model autoregressive orde keempat (ARX) menggunakan algoritma arx kerana anggarannya dicapai.

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LIST OF SYMBOLS AND ABBREVIATIONS

MATLAB	-	Matrix laboratory
EHA	-	Electro-Hydraulic Actuator
ARX	-	Auto Regressive Exogenous
ARXMAX	-	Auto Regressive Moving Average
BJ	-	Box Jenkins
OE	-	Output Error
FPE	-	Final Prediction Error
MSE	-	Measure Simulate Error
ρ	-	Type of Mass
m	-	Fluid mass
V	-	Fluid Volume
β	-	Effective Bulks Modulus
K_f	-	Fluid compressibility
Q	-	Liquid Flow in Chamber
x_v	-	Displacement
I	-	Current
K_v	-	Valve Gain
K_q	-	Valve Flow Gain
Q_L	-	Load Flow Rate
P_L	-	Load Pressure Rate
A_n	-	Area of Orifice
P_S	-	Power Supply
P_a	-	Hydraulic Supply Pressure
P_1	-	Fluid Pressure in port 1
P_2	-	Fluid Pressure in port 2
w	-	Gradient of Orifice
d	-	Diameter
F_L	-	External Force
A_p	-	Area of Piston
B_p	-	Constant damper
$\dot{x}_p$	-	Speed of Piston Moving
$\ddot{x}_p$	-	Acceleration of Piston Moving
x_o	-	Position of Piston
V_f	-	Fluid Volume in Chamber
V_c	-	Geometrical Chamber Volume
S_{max}	-	Maximum Passage Area
S_{Leak}	-	Leakage Area
n	-	Specific Heat Ratio of Gas

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CHAPTER 1

INTRODUCTION

1.1 Background

Electro-hydraulic actuators are important instruments for modern applications and are widely used in the industry due to their high performance, fast and flexible response properties and power stability. mining, fatigue testing, aircraft simulation, paper mills, shipping and electrical technology, switches and aluminum manufacturers. High efficiency of electro-hydraulic electric actuators on site, power or pressure is expected for all these applications. Efficient control is required to improve the efficiency of the electro-hydraulic actuator. There are many advantages and disadvantages compared to its common types of systems that given the EHA a superior hand whenever precise movement control is required, while space and weight are limited, as in the mobile industry. Compared to an electric actuator, the EHA can maintain a large load capacity for a long time [1]. This development has opened the way to various industrial applications that use water as a working fluid need the more accurate and faster regulation of higher power levels has created a mix of hydraulic servos for preparation pure mechanical or liquid signals, the electronic medium in the electrohydraulic system allows for easier transmission, processing and processing of information while maintaining power to the hydraulic servo at high speed [2].

In previous research, modeling and regulation of hydraulic actuator systems have also been explored and validation analysis of the models usually involved practical implementation [1-7]. Identification principle focused on the mapping of state space was used to categorize non-linear continuous time systems in which filters were used to recover data from high-frequency noise [8]. Leakage activity was modelled as a turbulent flow with a flow area inversely proportional to the overlap between the coil base and the servo valve body, where a zero-leakage flow rate was used [9]. Moreover, physical law modeling and system identification are two techniques that may be used to create a system model [21]. However, system identification has been used gained a lot of application in many engineering projects that model parameters can be evaluated and obtained easily but derived models are somewhat inaccurate and sensitive to noise [13]. The parameters estimation methods based on custom models or use a ready-made model to estimate and provide accurate models [14]. The two main drawbacks of the previous studies are filtered data used to detect model parameters which also induce major process lags in complex reactions and influence the overall parameter values which it is not clear if the parameters are individually detected without affiliations. If there's some of residual affiliations between the parameters identified or any parameters depend on other specifications, it may be possible that the parameter values are not correctly evaluated but that the accuracy of the model may help reduce in circumstances except those was already conducted within the system identification. This makes it implement a sampling approach to modelling as well as parameter identification of the system, which has good response characteristics.

From discussion above, the analyzes of the results can be obtained by used modification model architectures and design evaluations. Mathematically, by evaluating model predictions using sets of parameter values, we can specify how reliable the model is from the transmission a sample size sufficient with correlations between individual parameters depending on the observations the model to eliminate those correlations and can be seen if the chosen observations are significant to either the classification of parameter values through correlation [10–12]. Several researches had been carried out discussing about the identification and control problem that occurred in the electro-hydraulic actuator system where this type of system is useful in some application that requires an output force from electro-hydraulic actuator system [18-31]. However, not all applications necessitate the same amount of force; some only necessitate a specific amount of force to be applied to the hydraulic actuator system. In contrast, electro-hydraulic actuator system estimation is becoming a popular research topic because it is used in a variety of applications such as construction machinery, robotic applications, and machinery tools that require accurate actuation position control. This is enhanced by an increase in the number of publications pertaining to the system identification of electro-hydraulic actuator systems.

1.2 Motivation

The application of EHA system technology has expanded to many different areas including robotics, aircraft, manufacturing systems, etc. Due to the higher efficiency of the EHA system in terms of position and pressure, the nonlinearity and uncertainty properties must be considered in EHA systems for improvement the EHA system performance. A physical law modelling that can represent the system's behavior must be established in order to have effective control over the EHA system. To gain an effective control over the EHAs system, is not an easy task to obtain a model and it is necessary to create a model that can capture the system's behavior. Two methods such as physical law modeling and system identification that can be used to achieve and to create the estimation model for the system.

1.3 Problem Statement

Electro-hydraulic actuator system has naturally a lot of confusion, a high degree of non-linearity, variability over time and modelling cause impossible to make or classify an effective estimation procedure of an electrohydraulic system. Many academics have proposed another technique for controlling the hydraulic actuator system to improve its tracking performance and such conditions have made the modeling and controller design process a demanding task for the hydraulic actuator system [16-20, 26–32]. The dynamic model coefficients are also calculated by the implementation of physical rules and the execution of measurements using estimation data and simulation data and important aspect of the initial process of dynamic system. However, many coefficients are hard to accurately predict and some of the dynamic effects are often largely ignored so that the problem is solved by using system identification that helps to identify the estimation model with the input and output of the system data [43-48].

1.4 Research Objective

The main objective of this thesis to obtain transfer function of electro-hydraulic actuator (EHA) system. The next objective of the present study is to:

i) create a mathematical model of an electro-hydraulic actuator (EHA) system using system identification.

ii) develop an estimation algorithm for the parameter estimation of electro-hydraulic actuator system.

iii) evaluate the performance of the estimated model for electro-hydraulic system under same operating conditions.

1.5 Scope and limitation

There are several scope and limitation have been outlined to achieve the objective of this study,

i) The model of EHA open-loop system that be used consist a double-acting hydraulic cylinder and 4-way directional-valve.

ii) Rearrange Simscape™ fluids model to identify and obtain available model before estimation process.

iii) System identification toolbox was used to create estimate model for Simscape™ fluids (EHA) model with multi-sine wave supply.

iv) Design the estimation model of electro-hydraulics actuator by using parameter estimation method in system identification toolbox.

1.6 Thesis Outline

There are five chapters that consist in this thesis. The first chapter a describe the brief introduction about the project, motivation, problem statement, research objective and research scoped and limitation. The second chapter focuses on the project's theory and literature review, as well as quoting other previous research that will help to support the project. The third chapter focuses on the project methodology, explaining and discussing the idea on the project flow, method involved, and software used. Furthermore, chapter four presents the project's results and discussion, in which the simulation and experimental results, as well as detailed descriptions and discussions on the obtained results, are presented. Finally, chapter five discusses the project's conclusion and findings, as well as future recommendations for how to improve the project in the future.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter outlines the literature analysis of the EHA (Electro Hydraulic Actuator) method. This stage will review the numerous previous and other work related to this project, such as the history of the EHA system, the EHA system operation, the EHA control strategy and the EHA system controller. The technique for the next chapter will be determined by the observation in this chapter.

2.2 Review of EHA system

Hydraulics may be a term used to research fluids and how it operated, but most people think about how it was used in engineering when they heard the term. Hydraulic system operated by utilizing fluid pressure to move the piston. When pressed, these hydraulic will exerted the pressure using the flowing fluid to produce a significant amount of power. Here's the simple concept of a hydraulic system, a water in the system is pressurized from one side. This pressure presses it against the piston on the other side of the container. This converted the energy to the piston, causing it to raise something upwards. Since the pressure on the water will not allow it to flow backwards, the piston will never be able to move in the opposite direction until the pressure is removed. This helps to ensure that whenever the piston is raised, it will be stayed raised until system operator release it. For example, if the pistons raise the prongs of the forklift, they would stay elevated until the hydraulic pressure is removed by the operator. Hydraulic systems consist of four major elements such as reservoir, pump, valves and actuators.

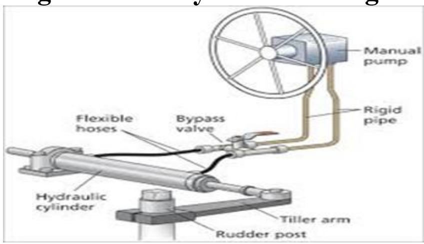
These actuators are devices that take the hydraulic power that is generated and convert it back into active power to perform other functions. This can be done in many different ways. Movements are often used for power, hydraulic fluid known as electric actuators and air actuators. Actuators are the fundamental elements of production processes and projects.

The fluid power system may be used as a "straightforward" mechanical control scheme where information is transmitted by mechanical action coupling and processing, but a more complex mechanical control method may follow multiple data transmission modes, such as mechanical, electrical and optical, which may be inefficient and difficult to regulate by the hydraulic control scheme. As possible solution, these systems could be modified by an electro-hydraulic actuator (EHA) system whereby transfer of data is performed electronically. The electro-hydraulic actuator (EHA) is among the basic control systems used in manufacturing and engineering research. The characteristics of the EHA provided with high strength-to-weight ratio, smooth, fast response and adequate power are its advantages over the mechanical power systems. The electro-hydraulic actuator system (EHA) is one of the widely used actuator systems. An example of an EHA system designed as in Figure 1.1, is an electrical control system in which the flow of hydraulic fluid transported to the actuator is controlled by an electrically operated valve [18].

Figure 2.1 EHA system [18]

The EHA mechanism is also well-known for its non-linear natural environment. The effect of such EHA disturbances is due to the flowability of the compressed air, the complex fluid characteristics of the piston and the stiffness of the dampers. The simulation of the EHA may also be challenging. A number of studies have been conducted in hydraulic modelling, especially on EHA [18]– [21]. As a result of that, the EHA system has a wide variety of uses, such as electrohydraulic positioning systems, commercial hydraulic machines and dynamic suspension control. Table 2.1 shows some of the common applications using the EHA system.

Table 2.1 Some of the common applications using the EHA system

No.	Application of EHA system	Description
1	**Regulation of hydraulic strength**  	Multiply the pressure exerted to the steering wheel when entering the steering wheels (usually at the front) of the vehicle.
2	**Aircraft landing gear** 	To maintain the weight of the airplane while on the ground and provide the required traction for the braking and stopping of the aircraft while landing.
3	**Forklift** 	To lift the load-bearing prongs from the ground. The hydraulic forklift raises and holds the load in the air as the forklift is going. The hydraulic forklift mechanism is the heart of the unit and it is responsible for pushing the pallets
4	**Hydraulic jack car jet** 	Through applying force to the hydraulic cylinder, you can raise heavy loads. The force produced by friction in the cylinder cavity is used to raise loads by hydraulic jacks.