SIMULATION OF DISPLACEMENT CONTROL FOR PIEZOELECTRIC ACTUATOR USING PID CONTROLLER

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This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering (Robotic and Automation) (Hons.)

by

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APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering (Robotics and Automation) (Hons.). The member of the supervisory committee is as follow:

(Engr. Mohd Nazmin Bin Maslan)

ABSTRAK

Projek ini fokus pada simulasi dan pengaturcaraan untuk penggerak piezoelektrik. Pengerak piezoelektrik telah digunakan dengan meluasnya di dalam bidang kejuruteraan untuk menghasilkan nilai voltan diantara elektrik dan mekanikal. Pengerak piezoelektrik ini juga boleh menghasilan anjakan di dalam sesuatu eksperimen yang telah dilakukan ke atasnya. Masalah yang timbul mengenai pengerak piezoelektrik ini ialah anjakan yang dikeluarkan tidak stabil dan memerlukan kawalan yang sesuai untuk menstabilkan anjakan tersebut. Objektif projek ini adalah untuk mengawal anjakan pengerak piezoelektrik dengan mengunakan kawalan PID di dalam sistem gelung terbuka dan gelung tertutup. Anjakan ini telah menghasilkan rangkap pindah yang tidak stabil di dalam sistem tertib kedua. Dua kaedah telah digunakan untuk mengawal anjakan tersebut iaitu kaedah Heurestik dan kaedah SISO. Kaedah SISO adalah kaedah yang terbaik berbanding kaedah Heurestik kerana kaedah ini lebih menjimatkan masa dan nilai untuk kawalan PID lebih tepat. Dimasa akan datang, SIMULINK boleh di gunakan untuk mengurangkan ralat di dalam sistem.

ABSTRACT

This project focuses on simulation and programming for piezoelectric actuator. Piezoelectric mover has been used extensively in engineering to produce the voltage between the electrical and mechanical. Piezoelectric movements also can produce a shift in the experiment has been done on it. The problem arises as to the movements of this is the displacement of piezoelectric issued unstable and require appropriate controls to stabilize the displacement. The objective of this project is to control the displacement of piezoelectric movements using PID control in open loop systems and closed loop systems. This displacement has resulted in an unstable transfer function in second-order system. Two methods were used to control the displacement are Heurestic method and SISO. SISO method is the best method compared than Heurestic method because this method was more time-saving and value was more accurate for PID controller. In the future, SIMULINK will be use to reduce the error of the system.

DEDICATION

This is dedicated to my father Mohd Jabar bin Mardi and my mother Jaimah binti Bakri whom give me supports and gentle prodding while completing my Degree.

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LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

Amp - Amplifier

P - Proportional

I - Integral

D - Derivative

AFM - Atomic Force Microscopy

DC - Direct Current

PLC - Programmable Logic Controllers

DCS - Distributed Control Systems

KP - Proportional Gain

KI - Integral Gain

KD - Derivative Gain

PC - Personal Computer

m. - Matlab Files

u - Volume Velocity

t - Time Variable

r - Reflection Coefficient or Radius

τ - Delay

d - Fractional Part of the Total Delay D

e - Vector of Complex Exponentials

$\int$ - Integral

SISO - Single Input Single Output

µ - Micro

CHAPTER 1
INTRODUCTION

1.1 Background

Piezoelectric actuators are electromechanical device and energy transducer between electrical and mechanical that will produce a value of voltage. The piezoelectric actuators are available for managing small displacements in the certain range. The characteristic of the piezoelectric actuator is fast response, low tear and wear and high stiffness.

Descriptions regarding to piezoelectric actuator, this device is used for high precision mechanical and electrical engineering applications. Many researchers have found that some useful applications for piezoelectric such as detection of sound, electronic frequency and ultrafine focusing of optical assemblies. These applications are used widely in many fields of industrial production. The piezoelectric actuators also used in the structural system to control noise, vibration and shape. The element of piezoelectric in complex actuator can be integrated in robotics design affecting the structural properties of the whole system. Manufactured on the stacking up piezoelectric disks or plates is the application that actuator configuration depend on and when the voltage being applied, the axis of the stack being the axis of linear motion.

The devices that are called tube actuators will become longitudinally and laterally if there is a contact. This situation happens when voltages apply between outer and inner electrodes.

In the shape of planar disk, the device such as disk actuator is used. Disk actuators are called a ring actuator with center bore that make axis of the actuator are accessible for mechanical, electrical or optical purposes. Bimorph styles, block, disk, and bender are included in the common configurations.

However, piezoelectric actuator can also be implemented as an ultrasonic device. The piezoelectric device is used especially for controlling the positioning application, quick switching and vibration. Either amplified or direct is the function of piezoelectric actuator. The force in piezoelectric actuator is needed to elongate to the certain amount.

There are several controllers in control system such as:

1. Proportional controller
2. Derivative controller
3. Integral controller

They are simply gaining value in the proportional controller. This controller is a multiplication coefficient. For controlling based and future values where the signal is going to be in the future, the derivative controller is implemented to account. The integral controller can add up the area under the curve for the past time. This controller can correct based on past errors. Figure 1.1 illustrates an example of a closed loop system that equips with the controller.

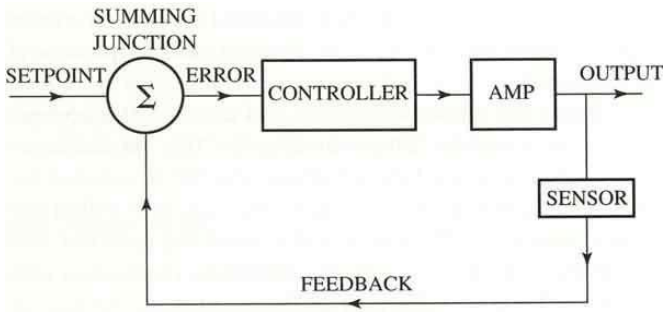

Figure 1.1: Closed Loop System

1.2 Problem Statement

The piezoelectric had inaccuracy behavior to maintain the displacement output from the transfer function given. This project is to control the displacement of piezoelectric actuator using the suitable controller. To choose the suitable controller, we must define the range of PID controller gains on an open loop and closed loop system.

For piezoelectric actuators, first, compare the types of actuators that had existed such as bender and patch, each with their own transfer function. The range of the laser displacement that attach will be determined also based on piezoelectric actuators.

From the previous studies, there are several characteristic of piezoelectric actuators that has such ability to create high forces, a high efficiency, high mechanical durability and short response time. Piezoelectric actuators also have small strains and a high supply needed. This problem also needs to determine the values of controller parameter on piezoelectric actuator. The values of controller parameter will be obtained based on the range of the stability. In that case, the values for the controller parameter will determine by the method approach.

1.3 Objectives

The main objective of this project is to simulate and control the displacement from piezoelectric actuator. MATLAB software is used to create the open loop and closed loop system based on the transfer function from the piezoelectric actuators.

1. To compare and analyze the piezoelectric actuators, ie. Patch and bender.
2. To identify PID controller parameter that use to control with respect to their unique transfer function.

1.4 Scope of the Study

The scope of the project was to compare and analyzes the piezoelectric actuators controller's parameter function that related to open loop or closed loop system. Study the function and the characteristic of piezoelectric actuators such as patch and bender.

This project also focuses on the PID controller and defines the controller parameter such as Kp,Ki and Kd. This parameter will control the displacement for piezoelectric actuator and reduce the overshoot and also get the stable system for open loop and close loop. The transfer function for piezoelectric actuators is not stable and then adds the controller to control the displacement output.

1.5 Summary

The piezoelectric actuator is a device that produces a value of voltage between electrical and mechanical. There several types of piezoelectric actuators such as bender and patch. This project is to simulate the displacement and control it using PID controller. Compare and analyze the suitable piezoelectric that produce the transfer function. PID controller is the suitable controller to control the displacement from piezoelectric actuator.

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

For this project, the literature review had performed in order to simulate of displacement control for piezoelectric actuator using PID controller. This chapter also explored about the recent study of Control System and Matlab. The information, idea and knowledge were obtained from the journal, website, articles and books also as sources in order to complete this study.

2.2 Piezoelectric

From the history of piezoelectric actuator, in 1880, Jacques Curie and Pierre have discovered the effect of piezoelectric. Crystal symmetry and pyroelectricity has relations that led the brother. The relations not only identify pressure for electrification but also identify which crystal classes the effect expected and what direction pressure should apply. (Novotny & Ronkanen, 1997)

Pierre and Jacques Curie have proved the some type crystal can produce a charge of electricity when exposed to mechanical stress. 'Piezoelectricity' is the name that is proposed by Hankel from Greek. The next person that calls Lippmann has talked about the piezoelectric effect that inverse from the considerations of thermodynamic. (Novotny & Ronkanen, 1997)

Before the end of 1881, Curies has verified this term. The effect of the inverse of piezoelectric is the application of the electric field to the crystal piezoelectric has to lead a deformation of physical for the crystal. Piezoelectric ceramic was discovered in the year 1950. The effect of piezoelectric ceramic is much stronger. The polarizing process is the process that undergoes the piezoelectric ceramics and the crystal materials are natural. (Novotny & Ronkanen, 1997)

For the hysteresis of non-linearity behavior, the output displacement yields and input voltage are an independent lag and the residual displacement has near to zero. The non-local memory always effect by the hysteresis between output and input of non-linearity. There are several methods exist to reduce the hysteresis non-linearity of the piezoelectric. This method based on the linear mapping between the driving charge and the displacement of the piezoelectric. (Tzen, et al. 2003)

2.3 Piezoelectric Actuator

2.3.1 Patch Actuator

In previous research, the piezoelectric actuator effectiveness has related to the integral formulation for varying actuator and sensor. Then consider the vibration control of an elastic beam. Assume the beam to patch piezoelectric sensor that laminated it on the bottom of the beam and also the top of the beam. The close loop displacement that has feedback will control the patch. The patch sensor will amplify and sent the signal to the patch actuator. The current technique will solve the problem because the current equation approach is non-standard. (Sloss et al.2001)

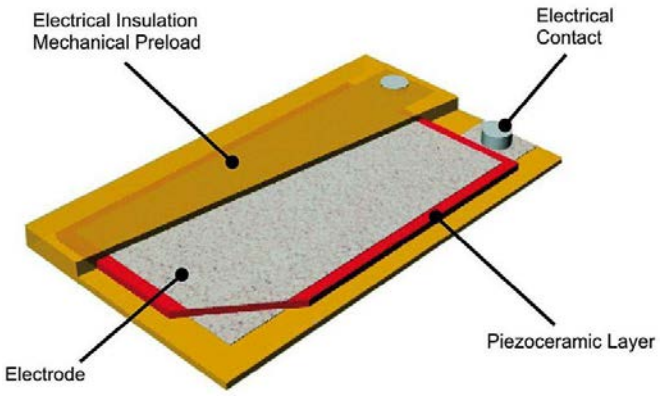

Figure 2.1: Design Principle of Patch Actuator (Physik Instrumente, 2011)

2.3.2 Bender Actuator

Usually, bender actuators are used in many applications such as Atomic Force Microscopy (AFM), force sensor, positioning devices and cantilevers. The process of optimization and design needs numerical and analytical modeling to achieve the desired performance. In the numerical modeling like finite element of analysis, the behavior will shows by the given structure. The analytical model will allow the various parameters in systematic optimization. The tools in finite element can handle the parametric models and can be used to optimize and design piezoelectric benders. To achieve and justify the analytical model, the model characteristic must far and more adaptable to the input parameter. The materials and geometry principle are the example as the corresponding numerical model. (Dunsch & Breguet, 2007)

The bender actuator has the effect due to external loads. The external loads will consider separately. In the mechanical base of all piezoelectric, the result of bender actuator from the compression in the piezoelectric material enforced by the electric field. (Dunsch & Breguet, 2007)