Faculty of Manufacturing Engineering

Comparison of PLC Based Servo Pneumatic System Performance Using PID Controller

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APPROVAL

I hereby declare that I have read this thesis and it is sufficient in terms of the scope and quality to gain the award of Master of Manufacturing Engineering (Manufacturing System Engineering).

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Date	: 1-June-2017

DEDICATION

I dedicate this thesis to my beloved wife, Lena and my children, Yen, Yee and Yin. I hope that this achievement will complete the dream that you had for me all those years.

ABSTRACT

In this study, the performance of a servo pneumatic system is realized and compared by using the proportional-integral-derivative (PID) controllers of two different programmable logic controllers (PLC) experimentally. Different PLCs may have different built-in PID controllers and their performance may different during applications. Omron and Siemens have been used for experimentation. For the servo pneumatic system, instead of pneumatic proportional servo valve, on/off solenoid valves are used to control the pneumatic actuators by applying pulse width modulation (PWM) scheme. The positioning voltage is employed as feedback voltage for the PID controller which is used to compare with reference set value for error value generation. Error minimization is greatly depends on the performance of the PID controller. Experimentally, the feedback positioning voltages are captured and plotted as tracking performance. From the tracking performance plots analyses, the performances of the servo pneumatic system are determined for both PLCs. The experiments results shows that Siemens PLC is better performed than Omron PLC in terms of performane.

ABSTRAK

Dalam kajian ini, prestasi sistem servo pneumatik telah dilaksanakan and dibanding dengan menggunakan proportional-integral-derivative (PID) pengawal dalam dua jenis programmable logic controller (PLC) secara eksperimen. PLC yang berbeza mungkin mempunyai pengawal PID yang berbeza dan prestasi mereka boleh berbeza dalam aplikasi. PLC Omron dan PLC Siemens telah digunakan dalam eksperimentasi. Dalam sistem servo pneumatik ini, injap proportional servo pneumatik diganti dengan injap on/off solenoid untuk mengawal penggerak pneumatik dengan menggunakan skim modulasi pulse width modulation (PWM). Voltan posisi bekerja sebagai voltan maklum balas untuk pengawal PID yang digunakan untuk membandingkan dengan voltan rujukan. Peminimuman ralat adalah banyak bergantung kepada prestasi pengawal PID. Voltan posisi maklum balas ditangkap and diplotkan sebagai prestasi tracking. Dari analisa plot prestasi tracking, prestasi sistem servo pneumatic boleh ditentukan untuk kedua-dua PLCs. Eksperimen telah menunjukkan prestasi PLC Siemens adalah lebih baik daripada PLCs Omron dari segi prestasi.

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CHAPTER 1

INTRODUCTION

1.1 Background

A servo control system is an automatic system that uses error feedback signal to correct the performance of the system's mechanism. Servo control system is widely used for position control and speed control such as motor, hydraulic and pneumatic. In the past, the servo control system in industry was limited to two technologies : electric motors or hydraulic actuators.

Electric servo motors are typically clean and reliable in operation. However, electric motors are usually high-speed, low-torque actuators, and need transmission elements to convert power to a more useful form. Mechanical elements are also required to convert the rotary motion of a motor to linear motion. Hydraulic actuators have favorable force/speed characteristics, and can be directly connected to their payload. However, a hydraulic system often creates workplace hazards. Personnel working around a hydraulic pump require hearing protection, and hydraulic systems are well-known for their leakage. In positive aspect, the operation of electromagnetic and hydraulic actuators is ease of control. The linearity of these two systems provides a good approximation where Proportional-Integral-Derivative (PID) based controllers are often adequate for control purposes.

Pneumatic actuators have properties that can make them favorable for servo applications. The actuators themselves are of simple construction, widely sourced,

and easily maintained, making them low in cost. They have a high power-to-weight ratio, are fast acting, and, unlike electric motors, can apply a force at a fixed position over a prolonged period of time with no ill effects. Compressed air is readily available in most industrial environments. Like electric motors, pneumatic actuators operate cleanly; like hydraulic actuators, they may act directly on a payload. The pneumatic actuator can be driven using valve. Electromagnetic solenoid valve is commonly used to drive the pneumatic actuator in electro-pneumatic system. Control of the valve can be realized using PID-based controller with Pulse Width Modulation (PWM) scheme. The nonlinear behaviors of an air cylinder preclude good control performance through Proportional-Integral-Derivative (PID) control methods.

Nowadays, servo pneumatic systems are so common in industries. With the advancement in technology, the availability of low-cost, high-performance microcontroller, Programmable Logic Controller (PLC) and computer system allows servo pneumatic actuators to take advantage of advanced control algorithms in industrial applications. Several manufacturers already offered industrial servo pneumatic controllers, and the technology is finding new applications. There are still many researchers put their effort in further research into design, modeling and control methodologies for servo pneumatic systems. For example modeling of solenoid on/off valve to incorporate into PWM schemes in order to have a smooth and continuous on/off.

1.2 Problem Statement

Servo pneumatic systems are widely used in automation control system in manufacturing industry. Advanced microcontroller and programmable logic controllers have been developed to be used with pneumatics components to form the more advanced servo pneumatic control system for automation system in manufacturing lines. With the

advanced servo pneumatic system, performances of the servo pneumatic systems have been further improved in terms of speed and accuracy generally where the quality of the products and improved production rate are ensured. The high price of proportional valve and servo valve also being replaced by the low cost on/off solenoid valve with the emerge of PWM scheme.

Despite the availability of the advanced microcontroller or programmable logic controller, the servo pneumatic system still lack in performances. The error generated between the reference signal and feedback signal in the PID controller will affect the accuracy of the positioning which subsequently degrade the system preciseness. Apart from this, the nonlinearity caused by compressed air and friction of the pneumatic cylinder and the switching speed of the solenoid valves need to be improved to cope with the advanced control technology of the controller. The on/off switching speed of the solenoid valve and the nonlinear behavior of the pneumatic cylinder will cause the delay defects and uncertain effects in the servo pneumatic system. Based on applications, improper selection of pneumatics components and control techniques such as PWM scheme and PID controller (regulator) used will affect the overall performances of the servo pneumatic system as well.

By investigating and analyzing the performance of the servo pneumatic system especially the behavior of the pneumatics components and control techniques, the improved control techniques are possible to be developed and high speed switching solenoid valve and good performance pneumatic actuators are possible to be modeled. Experimentally, various PLC will be used to integrate into the servo pneumatic control system for comparison in terms of performances, robustness, portability and cost.

1.3 Objectives of the Study

The main objectives of the research on the servo pneumatic system are as follow :

i. To study the existing control techniques of the servo pneumatic system.

ii. To investigate the relationship of PID controller and PWM for servo pneumatic system with and without disturbances.

iii. To analyze and compare the experimental results using Omron and Siemens PLCs on their performance.

1.4 Scope of Study

The study will be started with investigation on the existing control technique used in servo pneumatic system. A part from the control technique, in the study of servo pneumatic system, some of the main elements of the system were studied such as pneumatic actuator, solenoid on/off valve, displacement/distance and pressure sensor. Solenoid on/off valve is a device to drive the pneumatic actuator. Its characteristics and modeling will be studied during the research. PLC controller is the heart of the system to control the system with PID control technique. Omron and Siemens PLCs were used in the experiment for performance comparison in application such as Printed Circuit Board (PCB) assembly process and micro assembly process. The PWM scheme will be adopted together PID controller during the implementation of experiment. Loading (disturbance) effects also were added to see the responses of the PID controller (regulator). The measured results obtained were used for comparison, investigation and analysis amongst the two.

Various types of pneumatic actuators could be used in the system such as pneumatic cylinder. Displacement and pressure sensors were used for distance and pressure measurement. Any types of displacement and pressure sensors can be used in this system.

1.5 Significant of the Study

This study is to compare the PID controllers' performances of the two PLCs in terms of position accuracy. This is very important in current manufacturing sector as quality, time and cost concerned. The positional accuracy is very significant in automated equipments such as Surface Mount Device (SMD) Printed Circuit Board (PCB) assembly process and micro assembly process. Difference PLC has difference performance, and it depends on the applications and cost to determine the controller type to be used. The study is to verify the PID's performances of various PLCs running on the same experimental system. Thus, it has to be taken into consideration. For other researchers who are interest in this area, this study and results will help them as a reference for their future research.

1.6 Work Plan

The research activities will start from beginning of 3rd semester, September 2016, and end at 4th semester, June 2017. A Gantt Chart for the research activities is shown in Appendix A.

CHAPTER 2

LITERATURE REVIEW

2.1 PLC Based Servo Pneumatic System Using PID Controller

Servo pneumatic systems are widely used nowadays especially in manufacturing industry. Various controllers have been used to control the servo pneumatic systems such as computer with data acquisition card (DAQ), PLC and microcontrollers with the implementation of control strategies or techniques.

PLCs are chosen as the system controller for servo pneumatic systems due to its robustness, portability and easy to program and install especially the applications in production line. Research and studies are being investigated to further improve the performance of various applications of the PLC based servo pneumatic systems such as paint spraying system, production sorting system and etc which lead to cost saving, energy saving, speed, accuracy and etc. Typically, a PLC based servo pneumatic system experimental setup consists of double acting cylinder, solenoid on/off valve, pressure sensor, linear potentiometer, weight, PLC, data acquisition module, computer and DC power supply as presented in (Cajetinac et al. 2012 and Najjari et al. 2012). This setup is used to perform the study and investigation of the entire system performance and subsystem performances such as PID controller performances, dynamic and static response and etc. The block diagram of servo pneumatic system is shown in Figure 2.1 below.

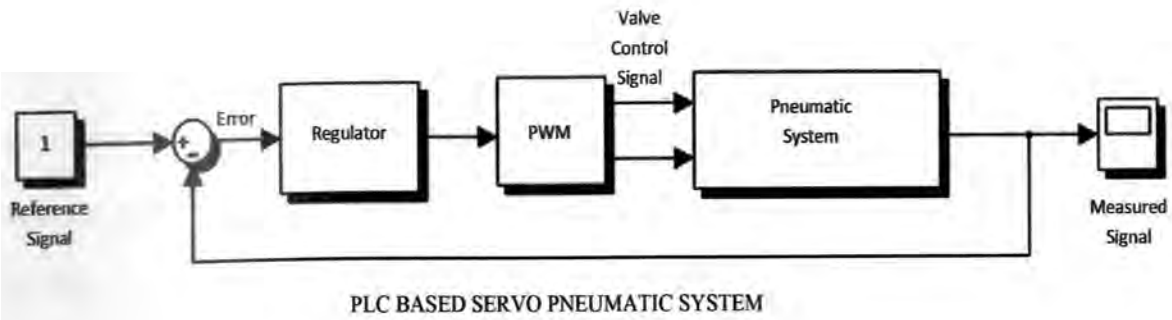

Figure 2.1 PLC based servo pneumatic system block diagram

2.2 Electromagnetic On/Off Solenoid Valve

Due to the costly and complex structure, the high precision and linear behavior's servo/proportional valve is now being replaced by low cost electromagnetic on/off solenoid valve in many applications of servo pneumatic system (Aziz and Bone 1998, Chillari et al. 2001, Belforte et al. 2004, Thomas et al. 2005, Messina et al. 2005, Cajetinac et al. 2012, Shiee et al. 2015, Najjari et al. 2012, Taghizadeh et al. 2009, Gentile et al. 2002, Situm et al. 2007). However, the limitation of the on/off solenoid valve was its discrete on/off nature and non-linearity behavior (Situm et al. 2007, Taghizadeh et al. 2009, Najjari et al. 2012, Cajetinac et al. 2012 and Belforte et al. 2004). In addition, Messina et al. (2005) mentioned that air compressibility, time delays of valves and the internal friction of pneumatic cylinder were also cause non-linearity to the servo pneumatic system. This will lead to the problem in positioning of the cylinder rod. Shiee et al. (2015) also stated the same.

2.3 PWM Schemes

Due to the discrete nature of on/off valves, as mentioned in section 2.2, leads to even more sophisticated control strategies. In order to obtain a continuous behavior from a servo pneumatic system using on/off solenoid valves, pulse width modulation (PWM) based methods have been proposed in (Aziz and Bone 1998, Chillari et al. 2001, Situm et al. 2001, Gentile et al. 2002, Belforte et al. 2004, Thomas et al. 2005, Messina et al. 2005, Situm et al. 2007, Taghizadeh et al. 2009, Cajetinac et al. 2012, Najjari et al. 2012, Endler et al. 2013 and Shiee et al. 2015).

2.3.1 On/Off Method

Since solenoid valve has only two states, Situm et al. (2001) stated that on/off method is the simplest method in controlling the solenoid valve. However, the on/off method is not good enough for solenoid valve control as the time delay, also called valve dead time, in the valve response which make the output unstable and inaccurate position. On/off valve method only applicable where positioning accuracy is not significant. In contrary, if the accuracy is required in the applications, PWM schemes have to be adopted.

2.3.2 Conventional PWM Scheme

Pulse width modulation (PWM) is a method commonly used to control devices that possess on/off switching nature in many applications such as communication and but not least the solenoid valves. In solenoid on/off valves, PWM provide a proper pulses for packages of fluid masses to be transferred to pneumatic actuators. As long as they receive these packages in a time scale significantly faster than the system dynamics or response, the overall controlled system behaves close to an equivalent continuous system that receives the average rate of fluid mass flow. Duty cycle of the PWM pulse is a significant