MODELING AND CONTROL OF INDUSTRIAL SERVO PNEUMATIC ACTUATOR SYSTEM

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MODELING AND CONTROL OF INDUSTRIAL SERVO PNEUMATIC ACTUATOR SYSTEM

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ABSTRACT

Popularity of pneumatics is on the rise and they had received more attention since they offer many advantages over other type of force actuators such as costly effective, cleanliness and high power to weight ratio. Some of their engineering applications are included robotics, suspension system, haptic interface and etcetera. Servo pneumatic actuator system consists of a servo valve and a cylinder where its piston position needs to be controlled through servo valve as a commander in tracking desired trajectory along the stroke. The negative point of pneumatics which makes them difficult to control is their highly nonlinear behaviour. The objective of this study was to obtain mathematical model and control an industrial servo pneumatic system. Obtaining nonlinear mathematical model accurately to be used in controller design needs to determine all physical parameters of the real system which is very expensive and time consuming, to simplifying this procedure, model of system was analysed and obtained using system identification toolbox in Matlab. The system was excited with particular sine wave signal. Parametric approach using ARMAX structure was used to approximate the model. The best model was accepted based on the best fit criterion through SI toolbox. N-PID controller was designed for the model through the simulation. The results showed that N-PID controller provides better output than conventional PID controller. N-PID controller exhibits faster response to the system with desired transient error. But when the N-PID controller was applied on the real pneumatic system it showed very poor result because of existence of friction force. To improve the overall system output a friction compensator and a stabilizer attached to the N-PID controller. The system result illustrates that friction compensator and stabilized are very useful since they sufficiently enhance the controller performance. Self-tuning or robust controller beside of online system parameter estimation could be developed in future to increase the reliability of the controller.

ABSTRAK

Sejak kebelakangan ini, sistem pneumatik menjadi popular dan menjadi perhatian kerana sistem ini mempunyai kelebihan dari segi kosnya yang murah, bersih dan nisbah kuasa kepada berat yang tinggi. Sistem pneumatik banyak digunakan pada robotik, sistem suspensi, peratantaramukaan dan lain-lain. Sistem penggerak pneumatik servo terdiri daripada injap servo dan silender di mana kedudukan piston pada silender perlu dikawal melalui injap kawalan mengikut arahan isyarat masukan pada kedudukan trajektori yang di ingini. Kekurangan pada sistem pneumatik adalah pada ciri-ciri tidak linear yang sukar di kawal. Tujuan utama penyelidikan ini ialah untuk mendapatkan model matematik dan rekabentuk pengawal pada sistem penggerak pneumatik. Untuk mendapatkan model matematik tidak linear yang tepat, kesemua parameter fizikal pada sistem sebenar perlu diperolehi terlebih dahulu. Model dan parameter sistem di analisa dengan menggunakan pakej perisian Matlab dengan pengenalpastian sistem. Isyarat masukan yang digunakan untuk sistem ini ialah isyarat Sine. Pendekatan parametrik menggunakan struktur model ARMAX dunakan untuk menganggar model. Model terbaik adalah berdasarkan kepada kriteria titik terbaik. Pengawal N-PID direkabentuk untuk model melalui kaedah simulasi. Keputusan menunjukkan pengawal N-PID memberikan keputusan baik berbanding pengawal PID biasa. Pengawal N-PID menghasilkan sambutan fana yang pantas dengan ralat yang minimum pada simulasi. Tetapi apabila pengawal N-PID di gunapakai pada sistem sebenar, sambutan yang di hasilkan tidak memuaskan kerana daya geseran yang wujud pada piston silender. Untuk mengatasi masalah ini, pemampas geseran dan penstabil di gandingkan bersama dengan pengawal N-PID. Hasilnya di dapati pemampas geseran dan penstabil tersebut menambahbaik prestasi pengawal N-PID. Pelarasan sendiri atau pengawal robus boleh dibangunkan untuk meningkatkan prestasi pengawal pada kajian akan datang.

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LIST OF ABBREVIATIONS

ARX	- Auto-Regressive with Exogenous
ARMAX	- Auto-Regressive Moving Average with Exogenous
BJ	- Box-Jenkins
ID	- Identification
LS	- Least Squares
N-PID	- Nonlinear Proportional Integral Derivative
OE	- Output Error
P	- Proportional
PI	- Proportional – Integral
PD	- Proportional - Derivative
PID	- Proportional Integral Derivative
SI	- System Identification

CHAPTER 1

INTRODUCTION

1.1 Project background

In industry particularly in the field of robotic and automation control many different type of force actuators namely electromagnetic motors, hydraulic systems and recently due to the development of control engineering and existence of low-cost and high-performance microprocessors, pneumatics are used. Traditionally, in industries electromagnetic motors and hydraulics have been utilized frequently. These types of force actuators have their own advantages and disadvantages. Table (1.1) shows some of their qualifications [1].

Table 1.1: Electromagnetic motors and Hydraulics aspects

	Advantage	Disadvantage
Electromagnetic motors	1. Linear characteristics 2. Fast 3. Clean	1. Rotary motion 2. Transmission elements needed (high-speed and low-torque) 3. High temperature in operation
Hydraulics	1. Linear motion (no interface needed) 2. Can be directly connected to load 3. Very powerful	1. Noisy and makes work place hazards 2. Dirty place because of oil leakage

The desire and favourable aspect of electromagnetic motors and hydraulic actuators is the ease of designing and implementing controller and it is the main reason that they have been employed by industries in servo application for a long time. In the past, though, pneumatics didn't take a part in servo application, but rather had been used to carry a payload between two fixed points, mostly two hard points of end of stroke. As mentioned, recent developments of control and computer science have been resulted in fast increasing demand of modern industries in employing pneumatics in servo systems [2]. Pneumatic actuators have many advantages over other types of mechanical energy converters. Pneumatics don't need any interface device to be coupled to the pay load, like hydraulics, while the electromagnetic motors because of their speed is high and their torque is not sufficient need an interface (gear box). In addition, pneumatics are clean, have easy and fairly cheap maintenance, and to be easily installed like electromagnetic motors while hydraulics are dirty by its nature that they work by oil so are not applicable in some certain clean environments. Moreover, the power to weight ratio of pneumatic actuators is significantly higher than equivalent electromechanical actuators [3]. According to what we just discussed, pneumatic systems can be used for some purposes such as working in dangerous environments, haptic interface, modern teleoperation force applications, and robotic industries [4, 5]. But unlike hydraulics and electromagnetic motors, pneumatic systems have highly nonlinear dynamic characteristics due to compressibility of air and highly nonlinear flow through pneumatic system components such as connecting tubes and valve orifice. Since gases are extremely compressible, there is a delay between the specifications of air flow travels in to the tube with that one which comes out from it at same time. On the other hand, in many application and design the distance between valve and piston is quite large in compare with the connecting tubes diameter and it will increase that time delay and the attenuation in mass flow rate produce some problems in pneumatics operations.

Pneumatic systems are divided into two main categories based on their performance characteristics such as fuel consumption, dynamic response, output power, and cost of design and manufacturing as: piston-cylinder and rotary actuators, which are shown by Figure (1.1) and (1.2) [6].

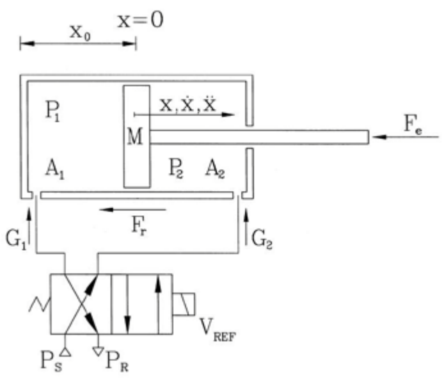

Figure 2.1: Piston-Cylinder Pneumatic Actuator

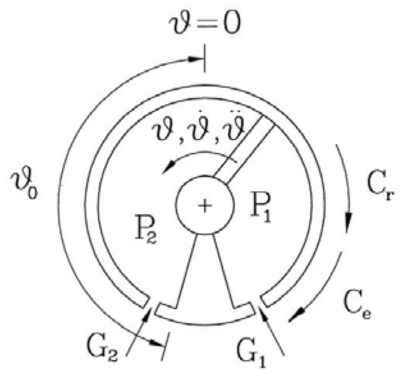

Figure 1.1: Rotary Type Pneumatic Actuator

Piston-Cylinder pneumatic actuators convert the power of medium (air) to linear reciprocating motion, but in vane rotaries the mechanical output energy is in the rotary motion form. Design and manufacturing of piston-cylinder is less expensive compare to rotary type and this fact caused the applying piston-cylinder actuators is more popular in industry than rotaries. On the other word, where simplicity and cost are prior, the piston cylinder is probably the best choice. But if fuel consumption is on the top of consideration, rotary type is indicated. Also have been shown the rotary servo has nearly twice the band pass of the piston cylinder servo [7, 8].

Based on all that mentioned before it can be learnt that pneumatics are a qualified alternative over hydraulics and electromechanical systems if there is a solution to tackle with its high nonlinearity characteristics. Thus, controller design and its implementation for pneumatic servo actuators is one of the challenging problems in control engineering.

1.2 Project Objectives

The project objectives are;

i. To develop a mathematical model that describes the dynamics of servo pneumatic actuator system.
ii. To design and implement a suitable controller for the real industrial servo pneumatic actuator.

1.3 Project scope

The scope of work in fulfilling the project objectives are;

i. To study the characteristics and concepts of servo pneumatic actuator systems by referring to previous investigations through books and papers from past to date.

ii. To construct a mathematical model of a complete servo pneumatic system to be applicable for computer simulation.

iii. To obtain transfer function of hardware using system identification toolbox in MATLAB by processing input output data.

iv. To design an appropriate nonlinear PID controller to improve the close loop system response.

v. To design and implement friction compensator and stabilizer in order to extend the controller to tackle some uncertainties involved in real system to enhance system performance to satisfy all industrial requirements from a servo pneumatic actuator system.

1.4 Project Report Outline

This project report is organized in five chapters. The first chapter gives some overview of the system in this project and some useful information about its possible applications. Some literatures and previous researches with similar title have been reviewed by chapter 2. Chapter 3 covers the flow of the methodology and description of each procedure. Chapter 4 explains the results which obtained from experiment and discuses on the findings. And finally on chapter 5 summary of conclusion and recommendations are presented.

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