MODELING AND CONTROLLER DESIGN OF A HOT AIR BLOWER SYSTEM

KHAIRUL NIZAR SYAZWAN BIN WAN SALIHIN WONG

A project report submitted in partial fulfilment of the
requirements for the award of the degree of
Master of Engineering (Electrical - Mechatronics & Automatic Control)

Faculty of Electrical Engineering
Universiti Teknologi Malaysia

JUNE 2014

Dedicated to my beloved father, mother and family for their never ending support

ACKNOWLEDGMENTS

First First and foremost, I would like to express my sincere gratitude and appreciation to my supervisor, Professor Dr Mohd Fua'ad Rahmat for his invaluable and critical comment throughout this project. His guidance and assistance have given me a strong basis in handling this project.

I would like to take this opportunity to thank my beloved father, Wan Salihin Wong Abdullah, my beloved mother, Zuliani Ghazali and my beloved family for their never ending support. Their supports at times of need are crucial to me.

Finally, i would like to extend my appreciation to my course mates for discussing and supporting each other throughout the whole time.

ABSTRACT

This research describes the modeling and controller design of a hot air blower system (HABS). The purpose of this research is to obtain model estimation best fit over 90%. Furthermore, the purpose of this research is to design controllers which the overshoot percentage close to zero percent and obtain a shorter rise time compare to current hot air blower system. The research divided into 3 area of focus, first focus on the development of Pseudo-Random Binary Sequences (PRBS) controller prototype to use as a System Identification Tool. The development of the controller was designed using PIC controllers. Testing was being conducted to ensure the controller is fully operational. Next, the output data from the hot air blower system (HABS) was captured for analysis. Second, the research focused on the modeling of a hot air blower system using System Identification and Estimation approach. By obtaining the mathematical model of a hot air blower system, tuning can be made possible. The output data was being run on MATLAB to compare between several of model structures. Model structures selected for this research are Auto-Regressive with eXogeneous inputs (ARX), Auto-Regressive Moving-Average with eXogeneous inputs (ARMAX), Output Error (OE) and Box–Jenkins (BJ). Result shows the eXogeneous inputs (ARX) obtained the highest best fit which best resemble the dynamic system of a hot air blower system (HABS) and was selected to be implemented in the controllers. Third area of focus is the simulation design of controllers; controllers which were selected for this research were PID controllers, Self-tuning controllers and Fuzzy controllers. The result obtained are shown in the Result and Analysis chapter, all controllers obtained zero overshoot percentage and have a shorter rise time then the current hot air blower system. Results showed the different in rise time, peak time, delay time and percentage overshoot varies depending on the controller. So, depending on the purpose in the industrial application, engineers can pick any controller to meet their desire task.

ABSTRAK

Kajian ini menerangkan model dan reka bentuk pengawal sistem penghembus udara panas. Tujuan kajian ini adalah untuk mendapatkan anggaran model terbaik lebih daripada 90%. Tambahan pula, tujuan kajian ini adalah untuk mereka bentuk pengawal yang peratusan terlajak hampir dengan sifar peratus dan untuk memendekan masa kenaikan berbanding dengan sistem penghembus udara panas. Kajian ini dibahagikan kepada 3 bahagian, fokus pertama kepada pembangunan Pseudo-Random Binary Sequences untuk digunakan sebagai system alat Pengenalan. Pembangunan pengawalan telah direka menggunakan pengawalan jenis PIC. Ujian telah dijalankan untuk memastikan pengawal itu beroperasi sepenuhnya. Seterusnya, data output dari sistem penghembus udara panas telah disimpan untuk analisis. Kedua, kajian ini memberi tumpuan kepada sistem penghembus udara panas menggunakan Sistem Pengenalan dan pendekatan Anggaran. Dengan mendapatkan model matematik sistem blower udara panas, pembaikan boleh dijalankan. Data akhir dijalankan dalam MATLAB untuk membandingkan antara beberapa struktur model. Struktur model dipilih untuk kajian ini adalah Auto-Regressive with eXogeneous inputs (ARX), Auto-Regressive Moving-Average with eXogeneous inputs (ARMAX), Output Error (OE) dan Box–Jenkins (BJ). Keputusan menunjukkan Auto-Regressive with eXogeneous inputs (ARX) yang memerolehi model tertinggi yang terbaik menyerupai sistem dinamik sistem penghembus udara panas dan telah dipilih untuk dilaksanakan dalam sistem pengawalan. Tumpuan ketiga tumpuan adalah reka bentuk simulasi system pengawalan; pengawal yang telah dipilih untuk kajian ini adalah pengawalan PID, pengawalan Self-Tuning dan pengawalan Fuzzy. Keputusan menunjukkan yang berbeza dalam masa kenaikan, masa puncak, masa tunda dan peratusan terlajak bergantung bergantung pada pengawalan. Jadi, bergantung kepada tujuan dalam perindustrian, jurutera boleh memilih mana-mana pengawalan untuk memenuhi tugas dan keinginan mereka.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

D	-	diameter
h	-	heat transfer coefficient
k	-	thermal conductivity
l	-	length
R	-	resistance
T	-	temperature
U	-	overall heat transfer coefficient

CHAPTER 1

INTRODUCTION

1.1 Introduction

Hot-air blowers are used in all areas in which hot air is conceivable in the manufacturing process: In the automobile industry, the food industry, the packaging industry, in mechanical engineering and etc. Figure 1.0 is examples of hot air blower application which are used in various industrial. Hot air blower applications include wrapping packaging, drying paint, sealing, heating ball bearing and a finishing touch on the items. Many people still underestimate the importance of having an adequate temperature control in place, but failing to have one could mean higher chances of damaging the goods.

In the industrial application, temperature control is a process in which change of temperature of a space is measured or otherwise detected, and the passage of heat energy into or out of the space is adjusted to achieve a desired average temperature. Further enhancements using the accumulated error signal and the rate at which the error is changing are used to form more complex Controllers which is the form usually seen in industry. Increasing the number of hot air blower in the industrial application, lead researcher to boost productivity and efficiency without neglecting the aspect of safety and power consumption.

To accurately control process temperature without extensive operator involvement, a temperature control system relies upon a controller, which accepts a temperature sensor such as a thermocouple or RTD as input. It compares the actual temperature to the desired control temperature, or set point, and provides an output to a control element. The controller is one part of the entire control system, and the whole system should be analyzed in selecting the proper controller.

Figure 1.0 Various applications of a hot air blower in industrial

1.2 Problem Statement

Hot air blower plays in an important role in the industry. Hot air blower use highly amount of electricity to run during the process. In order to increase safety, quality and reduce cost, developing controllers for the current system will benefit the industry and also the environment. So the focus in design area is to avoid overshoot in temperature and shorter the rise time. This approach will benefit in a long run where cost electricity can be reduce significantly and maximize the quality of goods in the same time. The main component of the hot air blower is the temperature control; temperature control will be a challenge since it requires time to respond to temperature. Furthermore, to optimize the current system, faster response time need to be purposed. Hence, in order to optimize, researcher need to achieve the model of the system which best represent the system dynamic. With the aid of software, trial and error way can be avoided to obtain results and it helps to save cost. In order to enhance the current system, a Pseudo-Random Binary Sequences (PRBS) controller prototype needs to be designed in order to obtain mathematical model. The PRBS controller needs to be careful design to fulfill the requirement 0.08 second time sampling for this research. Besides, modeling of hot air blower using System Identification and Estimation approach using the normal GUI approach is time consuming. Finding a way to speed up the estimation and trying all possible combination parameter will be vital to the research. Besides, temperature control in the real world requires time to transfer energy into other particles. The respond time taken for heat to transfer takes longer than other controls. For sensitive goods, the temperature control shall minimize the percentage overshoot compare to other heavy industries which allow some overshoot to happen.

1.3 Project Objective

Objectives of this project are

1) Develop a prototype Pseudo-Random Binary Sequences (PRBS) to use as a system identification tool.
2) Modeling of hot air blower using System Identification and Estimation approach.
3) Design and testing several controllers for a Hot Air Blower System.

1.4 Project Scope and Limitation

This paper consists of three areas of studies. First, the hardware development of the PRBS and injecting PRBS input signal to a Hot Air Blower system. Second, Various model structures is being tested and analyzed to best represent the dynamic model of the system. Both mathematical models are used to estimate the temperature of the pipeline. This is to obtain the Best Fit Curve experimental model which is above 90%. Third, from the model obtained several controllers are simulated by using MATLAB software to best describe a Hot Air Blower system. The result is then shown and discussed. During the duration of the research author encountered some limitation, one of it was the limited size memory of the microcontroller used. The memory size used is 256 kb which only fit 5 series of PRBS. By using a bigger memory size, the controller can fit a lot more series and enhance the studies of the project. Second limitation was the study on nonlinear System Identification of a hot air blower system, the nonlinear model structure used was Nonlinear Auto-Regressive with eXogeneous (NARX) model structure. The research went to a stop after author cannot find suitable software to run the nonlinear model structure.

1.5 Thesis Organization

The preceding sections briefly summarized the introduction and objectives of the research work. This section presents the outline of the thesis. The remainder of the theses is organized into five main chapters. Chapter 2 discusses literature review on modeling and controller design of a hot air blower. It also gives a summary on the approach and the direction of the research. The chapter will tell the overview on the development of the Pseudo Random Binary Sequence (PRBS) prototype, the use of this controller to model a mathematical and the design of controllers to improve the current hot air blower system. The Pseudo Random Binary Sequence (PRBS) prototype was then discussed in detail in Chapter 3. In this chapter the development of the prototype was discussed from start to the end in a deliberate way. For the estimation model by using system identification tool from MATLAB, the approach on how the estimation model was being performed on the software. Then this chapter describes the design and implementation of a linear controller for a hot air blower system. The implementation focused on to eliminates overshoot with the best settling time. Chapter 4 showed the result and analysis of the research by using the method discussed previously. Figures of the controllers, graph outputs and screenshots were displayed in the chapter for easy visual. While Chapter 5 is the conclusion and summarization on the finding discovery during the research.

References

1. [1]Adrian, C.; Corneliu, A.; Mircea, B. "The simulation of the adaptive systems using the MIT rule", 10th WSEAS Int. Conf. on MATHEMATICAL METHODS AND COMPUTATIONAL TECHNIQUES IN ELECTRICAL ENGINEERING (MMACTEE'08), Sofia, Bulgaria, May 2-4, 2008
2. [2] J.A. Vazquez Feijoo, K.; Worden; N.J. Rodríguez, J.; Pozos Osorio,P.; Matadamas O. “Analysis and control of nonlinear systems with DC terms”, Springer Netherlands Nonlinear Dynamics, Volume: 58, Issue : 4, Year: 2012, Pp: 753-775.
3. [3] Kamaruddin, T.N.A.T. ; Mat Darus, I.Z. “System Identification for Internal Combustion Engine Model ”, Modelling Symposium (AMS), 2012 Sixth Asia, Year:2012 , Pp: 17 – 22.
4. [4] Sulaiman, S.F.; Abdul Rahim, H.R.; Johari; Osman K.; Zainal Abidin, A.F.; Rahmat, M.F. “Optimizing the Process Parameters of GMV Controller by PSO Tuning Method”, Australian Journal of Basic and Applied Sciences, Volume: 7, Issue: 9, Year: 2013, Pp : 44-50.
5. [5] Wang, Z; Yang, J; Ahn, T. “The Design of Self-tuning Strategy of Genetically Optimized Fuzzy-PI Controller for HVDC System”, 10th International Conference, KES 2006, Bournemouth, UK, Year: 2006, Pp: 52-59.
6. [6] Zabet, K.; Haber, R. “Equivalence of PI(D) and predictive functional control for aperiodic processes without dead time”, Carpathian Control Conference (ICCC), 2011 12th International, Year: 2011, PP: 459 – 464.