SYNCHRONIZING CONTROL OF A TWIN AXES TABLE DRIVE

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"I hereby declare that I have read through this report entitled "Synchronizing Control On A Twin Axes Table Drive" and found that it complies the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering"

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

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2018

I declare that this report entitled "*Synchronizing Control of A Twin Axes Table Drive*" is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : .....

Name : LEE DAI JIN

Date : .....

To my beloved mother and father,

I would like to thank for the supports and the loves given to me which accompanied me to get through all obstacles and difficulties.

ACKNOWLEDGEMENT

In preparing this report, I was in contact with a lot of people, academicians, lecturers and friends. They have contributed towards my understanding and my thoughts about the final year project I am on to. I would like to express my sincere appreciation to my main supervisor, Professor Madya Dr, Chong Shin Horng, for the guidance, critics, and encouragement. I am also very thankful to my colleagues, Lim Vun Haw who contributes much in helping of the project hardware construction and advices given by him. I woud also like to thank for the panels, Dr. Azrita Alias and En. Muhamad Khairi Aripin for their guidance, advices and motivation. Without their continued support, this project would not have been same as presented here.

My sincere appreciation also extends to all my colleagues and others who have aided at various situations. Their helps are useful indeed. However, it is not possible to list all them in this limited space. I am lastly grateful to all my family members.

ABSTRACT

Twin axes drive table is an application that widely used in carriage purpose and industry. A synchronous control is used for efficient driving on the twin axes drive table which simultaneously driven by two separated DC linear motor. Position error tracking becomes the most important part to be observed in synchronous twin axes drive table. At relatively high velocity, the twin axes drive table needed to obtain zero synchronous error in term of position for both axes. Moreover, synchronization on the mechanically coupled twin axes table is the main challenge as damages may occurs when synchronization failed. This project is aimed to obtain and validate an accurate modelling transfer function by kinematical mathematical wise with an experiment. The modelling transfer function need to be accurate as the accuracy of the modelling transfer function affect a lot on the design of synchronous controller. Besides, this project is aimed to propose a classical PID controller that approximate to zero synchronous errors with simulation in MATLAB. This project included of 3 phases which are hardware setup, system modelling and validation, and also classic synchronous controller. Synchronous control of twin axes drive table project focused on obtaining a modelling transfer function and design by simulation of a classic PID controller that approach zero synchronous error for its performance.

ABSTRAK

Dual paksi meja sistem merupakan aplikasi yang selalu digunakan dalam industri. Kawalan segerakan digunakan untuk pemanduan yang cekap pada meja pemacu paksi kembar yang secara serentak didorong oleh dua motor linear DC yang dipisahkan. Penjejakan ralat kedudukan ialah parameter yang paling penting untuk diperhatikan dalam meja pemacu kembar. Pada halaju yang tinggi, meja pemacu paksi kembar perlu mendapatkan kesilapan sifar dalam kedudukan untuk kedua-dua paksi. Selain itu, penyegerakan pada meja pemacu paksi kembar yang disambungkan secara mekanikal menjadi cabaran utama. Hal ini demikian, kerosakan akan berlaku apabila penyegerakan gagal. Projek ini bertujuan untuk mendapatkan dan mengesahkan matematik fungsi pemindahan pemodelan yang tepat dengan eksperimen. Ketepatan pada matematik fungsi pemindahan pemodelan ini adalah amat penting kerana ia akan mempengaruhi banyak dalam proses mereka pengawal selanjutnya. Selain itu, projek ini juga bertujuan untuk merancang pengawal segerak yang menghampiri kesilapan sifar dengan menggunakan simulasi dalam MATLAB. Projek ini termasuk 3 fasa iaitu persediaan perkakasan, pemodelan sistem dan pengesahan dan juga rekaan pengawal segerak.

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CHAPTER 1

INTRODUCTION

1.1 Overview

Generally, synchronous control on twin axes table drive which configured parallelly has been designed and developed in various projects by using different driving mechanism either with the ball-screw driven system or the direct drive driven system. This chapter will discuss few sub-topics on motivation, problem statement, objective, scope and organization of report.

1.2 Motivation

During this new era, automation is the most important sector developed for the industrial sector. Dual axis ball-screw driven table is widely used in industrial application such as large gantry type machine tools and positioning stages [1]. For the industrial application, the table is coupled on two axis linear guide apart for a long span. For this configuration, synchronization is done to prevent danger and damages that will occur on the system. Synchronous control needed in the dual axis driven table had been applied in various industries such as printing, plastic, textile, rubber, iron and steel [2] which involved large gantry type machine tools. Besides, synchronous control system is applied in automatic field which used to control dual axis brushless direct current motor used in

the electric vehicle. For fast and precise motion, synchronous control is important for the dual axis drive table.

Synchronous control is a method that used for any simultaneously moving hardware as it provide additional corrective action in synchronous performance. In a synchronous control system, zero synchronization error is the optimal requirement. To obtain approximate zero synchronization error, position tracking error is measured and eliminated by a simple algorithm that calculate an error of the difference between reference position and actual position. There are several existing synchronous control methods such as synchronized master command generator control, conventional master-slave motion control, cross-coupled motion control etc.

Ball screw technology is commonly used since industrial era as direct drive system facing challenges in control strategy and materials at early 18's when Wheatstone proposed and developed the first direct drive system. Due to the technology of control system and materials nowadays, development of direct drive system had more application and development. For the requirements of high acceleration and high precision drive system, advantages of direct drive system become more significant while compared with ball screw system [3]. The technical advantages of direct drive system are it provide a gearless system that helps to reduce friction, to eliminate backlashes and is high mechanical stiffness [4]. However, the disturbances occurred from the inertia and forces variations which caused the direct drive system tends to be slow. Besides, direct drive system is easily affected by the problem of magnetic isolation and protection [3]. Comparing with direct drive system, ball-screw driven system is Due to the affordability and resources, a dual-axes ball screw mechanism is decided to be used in this project. Before developing the control system, a modelling of the dual axis drive table is developed by kinematic mathematically wise.

1.3 Problem Statement

The twin axes drive table that driven by the direct drive system that parallel coupled with each other by a table or called stage facing some challenges such as damages caused by synchronization failed and hard to approach the ideal situation of precise synchronization. To prevent the dangers and damages, synchronous control design on the motion of both linear guide motor that mechanically coupled in twin axes table drive becomes the main challenge of the twin axes table drive system. Besides, a most precise synchronous control system that approaches zero synchronous errors at relatively high velocity is also one of the challenge needed to be overcome.

1.4 Objective

Synchronous control on twin axes table drive is aimed;

1. To construct and obtain the parameters of the model of dual axes table driven by ball screw.
2. To obtain the kinematical mathematical model and validate the accuracy of modelling in simulation and experiment.
3. To propose a classic controller design for closed-loop performances evaluation.

1.5 Scope

In the synchronous control on twin axes table drive, the hardware configuration included 30V direct current motors, ball-screw mechanism, linear guides, linear encoders, power amplifier, and accelerometer which produce a twin axes table drive that travel about 200mm with maximum 5m/s. Besides, the table (stage) can afford load at maximum of 20kg during travelling. In this paper, kinematical mathematical wise modelling will be focused more and the synchronous controller design by cross coupled control method will be developed.

1.6 Organization of Report

In this report, it will be written in five chapters which are introduction, literature review, methodology, expected result and conclusion.

Chapter 1 is mainly describing the project outline with the motivation which supported by facts and background of the project, necessary elements covered in problem statement, objectives of this project, and the scope of the project which described the project configuration and works included for it.

Moreover, the project historical background and the theory which related to this project is described and explained in Chapter 2, literature review. In this chapter, the factors of mechanical and electrical components are discussed that affecting the Twin-Axes Table Drive System with the mechanical design and electrical design. It discussed about the comparison between previous projects.

For Chapter 3, methodology shows the hardware design in mechanical and electronic design and offerings the assembly of twin-axes table drive system chosen that were developed.

In Chapter 4, all results will be presented in graphical form and table form with the detailed discussion for the results. The mathematical modelling of twin-axes table drive system is obtained through MATLAB. The synchronous control design is done in simulation environment of Simulink. The simulated controllers will be tested on real plant for performance evaluation.

Lastly, Chapter 5 will provide the summary of this project and the future work that be suggested for improvement purposes.

1.7 Summary

This chapter concludes the importance of synchronous control on the twin axes table drive system. It summarized the limitations of the synchronous motion which the load weight becomes the direct disturbances onto the two axes ball screw mechanism. Besides, the main requirement of position tracking accuracy issue due to both axes driving by separated motor and unbalanced disturbances acting on it. The key to this enabling technology is the development of an optimal synchronous controller and optimum sensing platform which are highly reliable, robust and accurate.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In chapter 2 literature review, project background and the theory that required during the course in previous study related to synchronous control on twin axes table drive system is presented.

In the first section of this chapter, an overview on the project and its history background will be discussed. Next, it deals with the theory and working principle of Twin-axes Table Drive System. Then, the mechanical design for the twin-axes table drive system and the previous works of modelling and synchronous motion control method will be discussed. Lastly, the summary of literature review is written.

2.2 Overview of Twin-Axes Table Drive System

Twin-axes stage application is invented since late 1980s. A twin-axes stage is defined as a mechanism that mechanically coupled of two parallelly arranged linear axes by a stage or a table with a specific span that defined based on the application. This mechanism helps to reduce the potential skewed cause by the unbalanced loads applied on the table comparing to the single axis table drive system [1]. In existing real-world application, the twin axes table drive system is widely used in industry large gantry type machine tools such as large working range CNC mill machine etc.

There are different motors, direct drive motor and ball-screw driven by direct current servo motor are used in previous similar researches. Both motors are suitable for this application according to the requirements and the improvement of technology during this new era. From the previous researches by Yunjun Chen [9], an intelligent control with feed-forward control method is studied and designed for the two-axis strict dynamic synchronous process which moves on a rotating shaft that driven by a servo motor. Moreover, Jung-Hwan Byun and Myung-Soo Choi [10] had also studied on the method for modelling and control of a dual parallel motion stages that driven by a servo motor that coupled with a lead screw system. Other than that, Min-Fu Hsieh [1] has studied on the synchronous control scheme and system modelling technique of a single-axis stage that dual axis ball screws system. Hsieh studied the modelling and control scheme with the method of cross-coupled control algorithm.

Yasufumi Yoshiura and Yasuhiko Kaku [11] have carried a research on the synchronous control apparatus that able to synchronously control the motion of plurality of motors with the usage of linear motor/ direct drive motor. In the synchronous control apparatus study, Yasafumi and Yasuhiko used a prototype of one coupler connecting two parallelly arranged axes of motors.

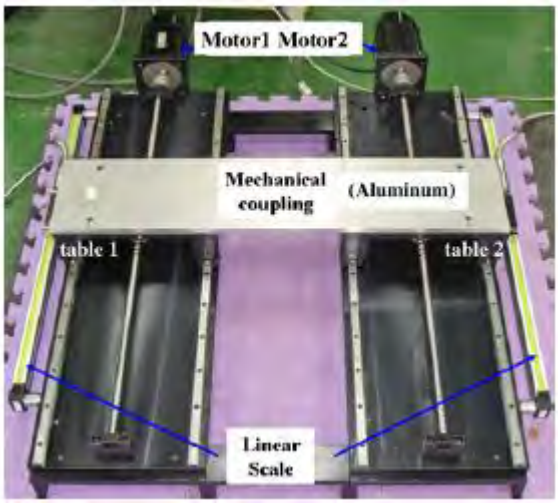

Figure 2.1 Configuration of single axis stage driven by dual axis ball screws system [1]