UNIVERSITI TEKNIKAL MALAYSIA MELAKA

DESIGN OF FUZZY-PID CONTROLLER FOR TRACKING PERFORMANCE OF MACHINE TOOL

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

(Department of Robotics and Automation) (Hons)

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DECLARATION

I hereby, declared this report entitled “Design of Fuzzy-PID Controller For Tracking Performance of Machine Tool” is the results of my own research except as cited in references.

Signature : ……

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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 is as follow:

……

(Dr. Ir. Lokman Bin Abdullah)

ABSTRAK

Laporan ini membincangkan hasil kerja perekaan pengawal untuk prestasi XY bola meja sistem pemaju skru. Terdapat tiga tuntutan penting dalam merekabentuk pengawal bagi pemesinan operasi dalam persekitaran pembuatan. Komponen tersebut termasuk ketepatan pengesanan yang tinggi, ketepatan pengesanan tinggi dan keteguhan. Evolusi peralatan mesin teknologi melalui kemajuan pengawal peralatan mesin menyebabkan permintaan yang berterusan dengan ketetapan pengesanan yang lebih baik dalm industry alat mesin. Objektif projek ini adalah untuk merekabentuk pengawal PID dan pengawal sistem Fuzzy-PID untuk prestasi XY bola meja sistem pemacu skru menjejaki dan bandingkan pengawal tersebut melalui simulasi. Perbandingan keputusan antara simulasi mengguna dua data masuk yg berbeza iaitu data masuk sinus dan data masuk langkah. Selain itu, perbandingan simulasi menggunakan perisian Matlab. Pengawal yang direka berdaasarkan analisis terhadap margin keuntungan, margin fasa, kadar lebar, kestabilan dan sensitiviti. Pengawal direka telah memenuhi peraturan kebiasaan untuk margin keuntungan dan margin fasa. Untuk margin keuntungan, peraturan kebiasaan adalah 4-10 dB manakala margin fasa adalah 30^0-90^0. Lata pengawal sistem Fuzzy-PID yang direka berjaya mengurangkan ralat penjejakan sistem berbanding dengan pengawal PID untuk data masuk langkah. Manakala untuk data masuk sinus dengan suntikan kuasa-kuasa gangguan berbeza ukuran bermula dengan 1500N, 2500N dan 3500N, kemudian pengawal PID berjaya mengurangkan ralat penjejakan sistem berbanding dgn pengawal sitem Fuzzy-PID.

ABSTRACT

This report presents the work done on designing controllers for tracking performance of XY table ball screw drive system. There are three critical demands in designing controller for machining operation in many manufacturing environment. The components include high tracking accuracy, high tracking precision and robustness. The evolution of machine tools technology through advancement of the machine tools controller causes the persistent demand of better tracking accuracy in industry of machine tool. The objective of this project are to design PID and Fuzzy-PID controller for tracking performance of XY table ball screw drive system and to compare the controllers through simulation with two different input signal which is sinusoidal and step input. The comparison of the result between simulation with injected disturbance forces for sinusoidal input, firstly with the value of 1500N, 2500N and lastly 3500N. while for step input based on transient response. The transient response including the percent overshoot, rise time, peak time and settling time. The controllers are designed based on the analysis of gain margin and phase margin, bandwidth, stability and sensitivity. The designed controllers have fulfilled the rule of thumbs for the gain margin and phase margin. For gain margin, the rule of thumb is 4-10dB while phase margin is 30^0-90^0. In step input the Fuzzy-PID controller show the fast response compare to PID controller. It is recommended to add another method of analyzing the designed controller by visualization using image processing which helps to detect the tracking error of the system easily.

DEDICATION

To my beloved parents Halim bin Mustaffa and Norbahani binti Subari.

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First and foremost, all praise to the Almighty, who made this accomplishment possible. I seek his mercy favor and forgiveness.

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Thank You.

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LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

P	-	Proportional
I	-	Integral
D	-	Derivative
SISO	-	Single-Input-Single-Output
GUI	-	Graphical User Interface
FRF	-	Frequency Response Function
LTI	-	Linear Time Invariant
mm	-	millimeter
DSP	-	Digital Signal Processor
CNC	-	Computer Numerical Control
RMSE	-	Root Mean Square Error
GM	-	Gain Margin
PM	-	Phase Margin
dB	-	Decibels
RGB	-	Red-Green-Blue
NL	-	Negative Large
NM	-	Negative Medium

NS - Negative Small

ZE - Zero Error

PS - Positive Small

PM - Positive Medium

PL - Positive Large

CHAPTER 1

INTRODUCTION

This chapter provides an overview about the project entitled, "Design of Fuzzy-PID Controllers for Tracking Performance of XY Table Ball Screw Drive System. Problem statement, objectives, scopes of work and outline of the project are presented in this chapter.

1.1 Background

The quality of products from a machine tool system is largely determined by the tolerances maintained which is a function of how well the desired contour is tracked. Machining is a process to change the size of the materials from bigger to smaller and surface finish of a material through removal that could be achieved by straining the material to fracture or by thermal evaporation. In this paper (Jamaludin, 2008), a good machining is known as a process that perform in constantly with faster and high accuracy. It is crucial for the machine tools industry in parallel with advanced of technology. In addition, to against the various disturbance forces there are some

constraint need to implement into the system which is high accuracy and self-adjusting mechanism. Tracking accuracy is concessional by the effect that comes from the dead zones and the huge friction forces that are generated in a high stiffness electromechanical ball screw and bearing structure.

Fast machining requires rapid situating control of the feed drive system, while its situating exactness and rate decide the machining quality and profitability. Ball screw drives are broadly utilized as the movement mechanism due to their high stiffness and high accuracy. One of the disturbance forces that greatly have an effect on the trailing performance is cutting forces. Cutting forces is that the nature of the edge method and can't be avoided because it is generated from the interaction between the cutting tool and also the work piece. In keeping with, cutting force is influenced by the edge parameters like the depth of cut and spindle speed (Chiew, 2012).

1.2 Problem Statement

Nowdays, the demand for top speed and accuracy of machine tools area unit required in machine tools trade. Thus, smart controller style is crucial so as to get good tracking performance of a machine. Unnecessary vibration can cause quality and poor surface quality. The compensation of cutting forces disturbance is desired so as to get smart tracking performance.

In order to design controller for table ball screw drive system, it needs information and understanding regarding the machining parameters and information on controller design. A rib shaft that gives a volute raceway that role as a preciseness screw is that the essential requirement for the ball screw drive with conditions of putting up with high trust load and low in-house friction. The dependence of the system on the ball screw

drive system to run from one position to a different position is that the result of the need. The main problem is to design controllers which are PID and Fuzzy-PID controller with comparison of simulation and experimental in order to obtain an accurate tracking performance of the system. The controller square measure created supported the look analysis wherever embrace the gain margin and phase margin analysis and stability analysis.

1.3 Objective

The objectives of the project are:

i. To perform system identification of plant XYZ Table Ball Screw Drive system
ii. To design PID and Fuzzy-PID controller for improvement in tracking performance via cutting force compensation.
iii. To compare the tracking performance of controllers in terms of maximum tracking error and root mean square error using input sinusoidal and transient response using input step.

1.4 Scope of Work

The scopes of this project are:

i. System identification of the plant is done using gain value of 0.03.by using XY table ball screw drive system.

ii. The axis that involved the XY table ball screw drive system is X-axis only to improve the tracking performance in a horizontal direction.
iii. The disturbance forces used is cutting force disturbance that only covers 1500rpm, 2500rpm and 3500rpm.
iv. The cutting forces only cover 1500 N, 2500 N and 3500 N of up-milling process.
v. Thus the controller is designed by simulation using Simulink of Matlab software.
vi. The performance of the controller is determined in term of maximum tracking error, root mean square error (RMSE) for sinusoidal input and transient response for step input.

1.5 Structure of Report

This report contains of five chapters that will be explained briefly about this project. The first chapter is about an introduction which contains the project background, problem statement, objectives and scopes of the project. Second chapter supplies a literature review on the previous researches on tracking performance of table ball screw drive system as well as the application and control system approaches. The approaches of the model and different type of controller for cutting force compensation are reviewed in chapter two. Then, Chapter 3 is the methodology of the project that provides the process and description of the project. Next is Chapter 4 where the designed controller, simulation of the model results and tracking performance of the designed controller using different input signal will be presented and discussed in details. Lastly, the outcome of the project will be concluded in Chapter 5. The recommendation for future improvement of the project also will be included in this chapter.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Traditional machining processes consist of turning, boring, drilling, reaming, milling, threading, shaping, planning and broaching as well as abrasive processes such as grinding, ultrasonic machining, lapping and honing while advanced processes include electrical and chemical means of material removal as well as the use of abrasive jets, water jets, laser beams and electron beams (Gutowski, 2009). Milling can be defined as a process of removing materials which cover a variety of operations in manufacturing industry.

In the manufacturing process, the high tracking accuracy and precision are two essential components demanded. Milling operation is one of good example, where a workpiece is fed past a rotating cylindrical tool with multiple cutting edge. It is significantly important since it will lead to good quality at the end product that will deliver to customers. The poor tracking and positioning because of the existence of disturbance force during machining process. The motion tracking controller is designed to track the

existence disturbance during the process. Thus, the objective of the motion controller is to achieve maximum tracking accuracy and robustness against disturbance. (Jamaludin, 2014)

2.2 Motion Control in Machine Tool

In the manufacturing, machine tool is important as a mechanical system that needed to increase the productivity in the performing at high accuracy. Thus to get the precision in positioning of the system, mechanical drive system is one of the progress inside it. Good machine tools will show the process with high speed of processing, low time consumption and high accuracy.

2.2.1 Mechanical Drive System.

Feed drives are used to positioning the machine tool by carrying the cutting component and locate them to the desired location. The quality of the productivity is determined based on their positioning accuracy and speed. The most popular machine tool feed drives have used are ball-screw and linear drives as shown in Figure 2.1(Pritschow, 2011).

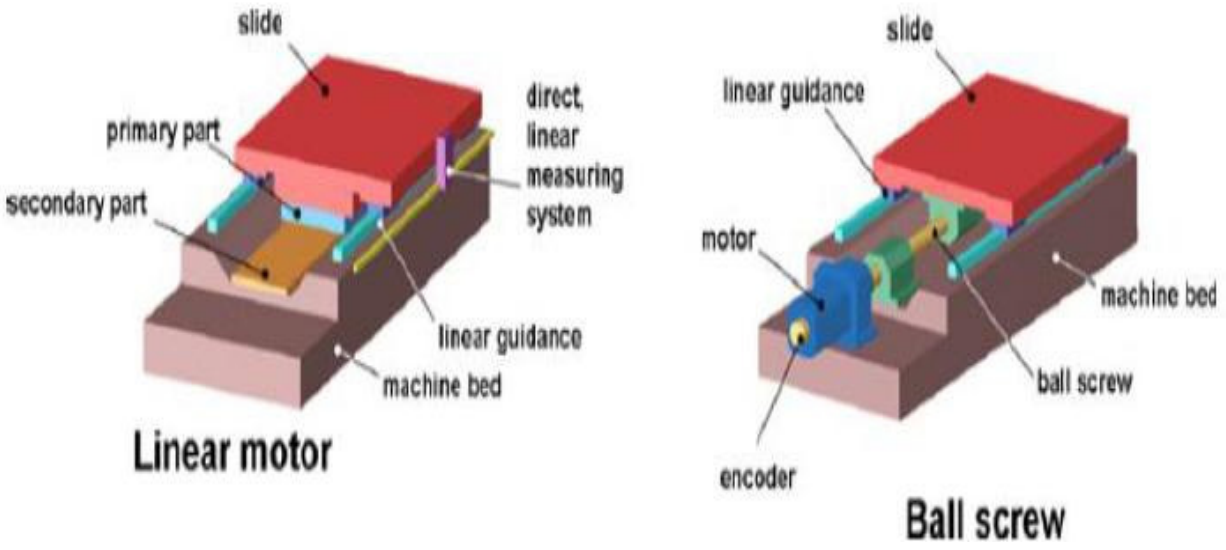

Figure 2.1 Linear and Ball Screw Drive System

For rack-pinion-drives system is linear motion of the straight rack of arrangement that converted from rotary motion of the pinion and can be manufactured either in straight spur, helical teeth or bevel and worm (Collins, Busby, & Staab, 2010). Rack-pinion-drives system is suitable for the machine tool with long path distances. This is because at high torque the rack-pinion-drives system can transfer with low revolution (Y. Altintas, 2011). Figure 2.2 shows the movement of rack and pinion in producing linear movement.

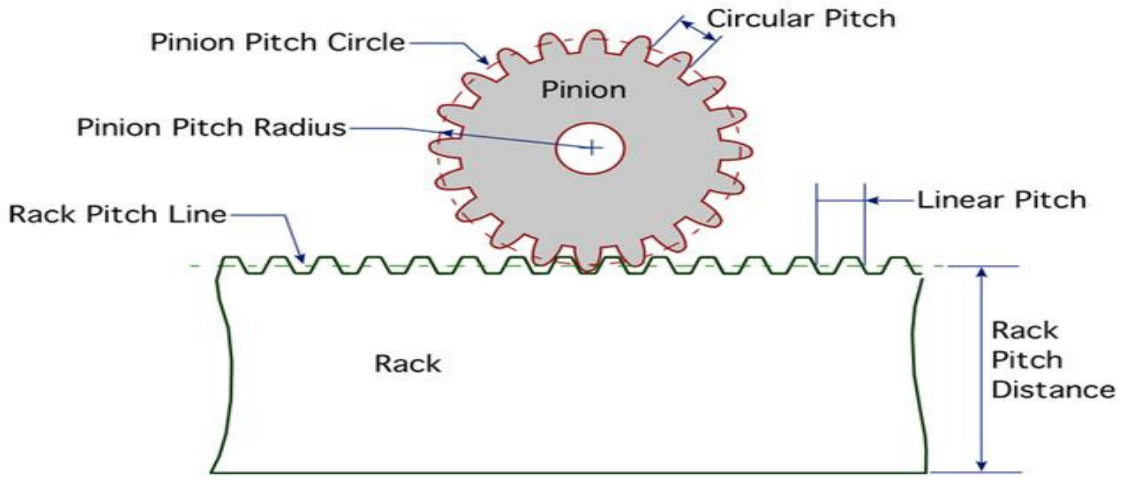

Figure 2.2 Rack ad Pinion Drive system

Then, other drive system to be discussed is ball screw drives system that is the common used in feed drives of machine tools. The ball-screw drive is supported by thrust bearings at the two end, and a nut with recirculating balls. The nut is connected to the end of table. One end of the ball-screw is attached to a rotary motor directly or through gear or belt speed reduction mechanism as shown in Figure 2.3. To avoid backlash by adjusting the spacer, creating offset between the leads or using oversized ball, the nuts is preloaded. The pitch errors are existence as position errors accept they are compensated because of the difficulty to grind the pitch at uniform intervals (Altintas et al, 2011). Ball-screw drives are another mechanical system that can be described as rotary motion convert to linear motion, whereas the rotary motion comes from the rotation of the ball screw before the change into linear direction. Figure 2.4 shows the basic structure of the ball screw mechanism.

Last but not least, other drive system is linear motor drive. Linear motor drive is drives the machine tool feed axis in linear motion and no transmission mechanism are needed. Hence, the linear motor with light payload can reach to high acceleration while the ball screw drive for a larger variation of payload due to reduction of inertia reflected to the rotary motor can maintain the acceleration capacity. Thus, it allow feed speed, high acceleration and rapid positioning with high servo bandwidths over ball screw drives (Altintas et al, 2011). Besides that, the special of linear motor drives, it is synchronous brushless servo motors as their function. According to (Moscrop, 2008), it is one degree of freedom because the moving part of the linear motor is always attached directly to the load.

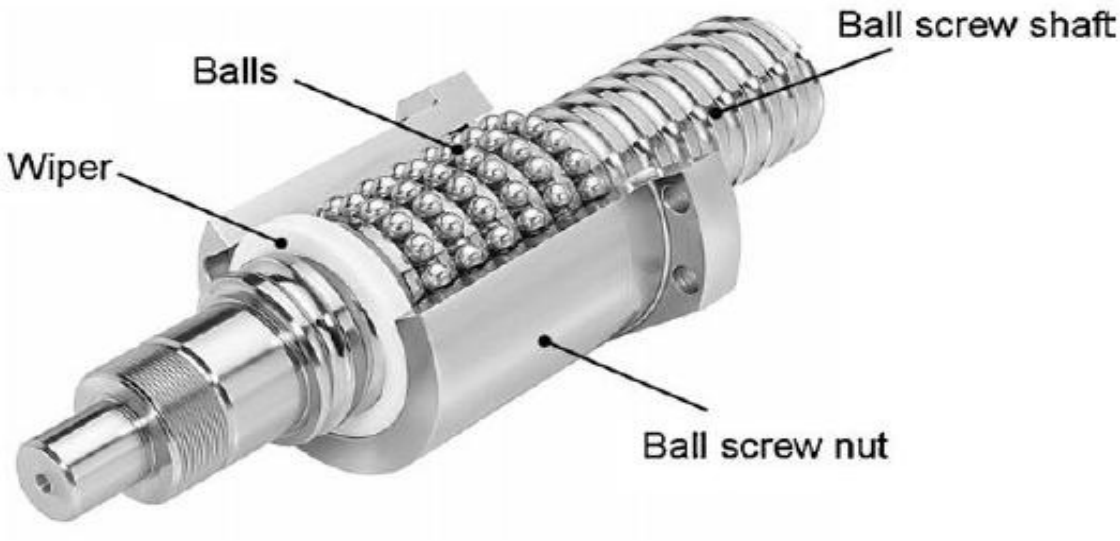

Figure 2.3 Structure of Ball Screw System

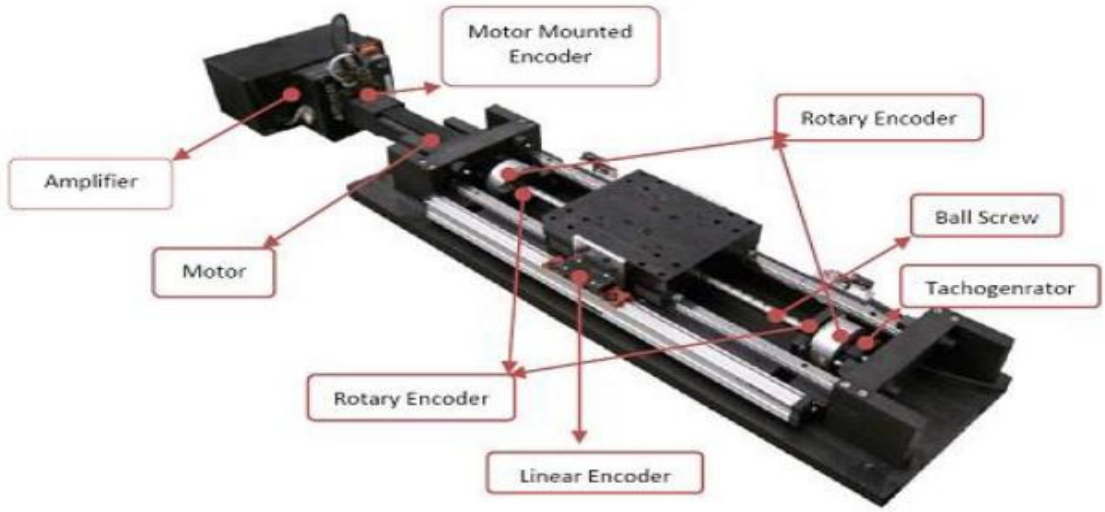

Figure 2.4 Ball Screw Drive System