UNIVERSITI TEKNIKAL MALAYSIA MELAKA

OPTIMIZATION OF PID AND LEAD LAG CONTROLLER PARAMETERS BY USING PARTICLE SWARM OPTIMIZATION (PSO) TECHNIQUE FOR PRECISE POSITIONING MACHINE TOOLS

Submitted in accordance with the requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering (Hons)

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ABSTRAK

Baru-baru ini, penggunaan mesin Computer Numerical Control (CNC) telah menjadi keperluan penting dalam sektor pembuatan terutamanya di sektor automasi, sektor fabrikasi dan sektor aeroangkasa. Perkembangan teknologi dan ke arah Revolusi Industri 4.0 juga menghasilkan mesin CNC canggih yang mampu memproses produk dan juga mempunyai sumbu yang berbeza untuk mencapai reka bentuk yang rumit. Namun, setinggi mana pun mata alat mesin menjadi bagian penting. Dari segi mata alat, terdapat tuntutan sangat besar mengenai ketepatan penjejakan, ketahanan, biaya rendah, kelajuan kualiti permukaan yang lebih baik dan fleksibiliti tinggi. Walaupun begitu, sekiranya terdapat gangguan yang menyebabkan kedudukan alat mesin kurang tepat dan ini juga akan menyumbang kepada ketidaktepatan. Selain itu prestasi penjejakan sistem pemandunya juga menjadi salah satu faktor yang menyebabkan ketidaktepatan alat mesin. Oleh itu, kajian ini terdapat dalam penggunaan pengawal Proportional Integrated Derivative (PID) dan Lead Lag untuk meningkatkan ketepatan prestasi penjejakan. Dalam kes ini, pengawal telah dicuba pada sistem pemacu skru Bola Meja XY kerana sistem pemacu skru Bola Meja XY adalah struktur asas mesin CNC. Ciri utama adalah bahawa keuntungan terkecil perlu dicapai ketika kesalahan terbesar dihasilkan. Kestabilan pengawal terbukti dengan menggunakan SISOTool dalam Matlab Software. Pengawal akan mengesahkan melalui simulasi menggunakan Matlab Software. Pengawal tersebut akan membantu mengimbangi kekuatan gangguan yang ada semasa operasi pemotongan dengan kelajuan gelendong 1500 rpm, 2500 rpm, 3500 pada frekuensi penjejakan 0.2 Hz dan 0.4 Hz. Keberkesanan pengawal yang dicadangkan dikenal pasti berdasarkan ralat penjejakan maksimum dan ralat kuasa dua punca (RMSE). Hasil pengawal yang dicadangkan menunjukkan ketepatan penjejakan yang lebih baik dengan menggunakan pengawal Lead Lag.

ABSTRACT

Recently, the utilization of Computer Numerical Control (CNC) machines become an essentiality in the manufacturing sector especially in automation sector, fabrication sector and aerospace sector. The development of technology towards Industrial Revolution 4.0 has additionally engendered advanced CNC machines that are capable of processing involute product and additionally has multiple axes to achieve an intricate design. However, as advanced as any machine, machine tool play critical part. In term of machine tool, there are immensely colossal demands on tracking accuracy, robustness, low cost, better surface quality speed and high flexibility. Nevertheless, in the presence of disturbance that leads to lack of precision positioning of machine tool and this will also contribute to inaccuracy. Besides the tracking performance of its drive system also become one of the factor that lead to inaccuracy of the machine tool. Therefore this research present in uses of Proportional Integrated Derivative (PID) and Lead Lag controller for ameliorating the accuracy of the tracking performance. In this cases, the controller has been tasted on XY Table Ball-screw drive system because XY Table Ball-screw drive system is a basic structure of CNC machine. The main feature is that the smallest gain is need to be achieve when the largest error is produced. The stability of the controller was proven by using Bode Plot in Matlab Software. The controller will validate via simulation using Matlab Software. Those controller will help to compensate the disturbance force that exist during the cutting operation with spindle speed of 1500 rpm, 2500 rpm, 3500 at tracking frequency of 0.2 Hz and 0.4 Hz. The effectiveness of the proposed controller is identified based on the maximum tracking error and root mean square error (RMSE). The results of the proposed controller show a better tracking accuracy is by using Lead Lag controller. The recommendation for next research is use the other method to find the optimal parameter such as Ziegler- Nicholas (ZN).

DEDICATION

Allah, only with your approval this project has succeeded.

Thank you for praying that never ends, for your support and your advice, for my Mom Ratina Binti Siron and my Dad Mohamed Zain Bin Tonek

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LIST OF ABBREVIATIONS

CNC	-	Computer Numerical Control
FRF	-	Frequency response function
P	-	Proportional
I	-	Integral
D	-	Derivative
PID	-	Proportional-integral-derivative
RMSE	-	Root Mean Square Mean
RPM	-	Revolution per minutes

LIST OF SYMBOLS

Cf	-	Cutting Force
Kp	-	Proportional gain
Ki	-	Integral gain
Kd	-	Derivative gain
T1	-	First time constant
T2	-	Second time constant
α	-	alpha
β	-	beta(time constant)
Kc	-	Lead Lag Gain

CHAPTER 1

INTRODUCTION

This chapter provide explanation about the general overview about this project, beginning with the background of the project. Next, section 1.2 elaborated on the detail of the matter statement of the project and followed by the objectives of the analysis in Section 1.3. Supported the matter statement and also the purposes of the investigation, the scope of the project is legendary in Section 1.4, and additionally, significance study can state in section 1.5.

1.1 Background of Study

Specific machine tools are equipment that ranges in square measure used in general metal cutting operations and include engine shaping machine, grinding machine shaping machine, edge shaping machine, grinder shaping machine, and power hacksaws shaping machine, plane shaping machine, Sloter shaping machine, etc. These machine tools use numerous processes for shaping or machining metal or rigid materials. All machine that focuses on limiting the work and guide the movement of the machine. There's a unit various kinds of machine, and in machine application, most things were thought-about and sorting out area unit the accuracy and precise positioning of the machine. One aspect that lives this accuracy and exactness of a machine can be a chase performance of the drive system. However, once machine accuracy is required right down to the number of a micrometer or higher, a machine ought to have an excellent mechanical vogue, producing, numerical

management, and servo-drive management if optimum machine performance is to be achieved (Junoh et al., 2017).

CNC machining is a production phase that regulates movement tools and machinery through pre-programmed computer software. There are variety of sophisticated machinery can be operated through the process, from grinders and lathes to mills and routers. Nowadays, variety dimensional cutting tasks can be done in a single set of prompts with CNC machining. CNC milling machines are widely used for the production, since there are high demand especially in industrial applications and it fundamental element is an XY Table Ball Screw Drive System. This table is mainly powered indirectly by different types of engines, quite similar to the previous analysis. Friction force, mechanical structure, workpiece mass and cutting force were the factor that lead to nonlinearities of the machine. Therefore there are many type of controller has been designed to overcome this issue.(Junoh et al., 2018)

"Disturbance forces acting on a system can greatly influence both positioning and tracking accuracy. This is especially important in the machining process such as the milling process."(Chiew et al., 2012) The two main types of interference that keep disturb this system the cutting force, and friction force. Those force has been reduced positioning and chase performance. However, cutting force unavoidable because it still involves the cutting process and essence of the milling method (Chiew et al., 2012). Thus, the controller was developed and evaluated by the previous researchers to atone for this disruption to achieve better chase efficiency. To make a more robust chase performance of the system, a vigorous and economical controller must be designed into the system to help boost the merchandise standard. The most common and classic controller used is the PDI controller including the mixture of Kp, Ki, and Kd which can enhance any transient response and steady-state error.

1.2 Problem Statement

There are immense demands of the machine tool for a high measure of accuracy, more top surface quality, robustness, speed, low cost, and high flexibility of machine tool. Beside, one machine tool also is focusing on accuracy on the product and machine tool also works under repeatability motion. However, the foremost essential issue and additional focusing during this analysis are that the accuracy of the machine. Since, the tracking performance is one of the factor that affects the accuracy of positioning of the machine tool. It is because there were several factors that influence the tracking performance such as mechanical structure, workpiece mass, friction force and cutting force.

Therefore, due to the disturbance appear, all accuracy in manufacturing by using CNC machining cannot be achieve. But on this cases, cutting force is most significant issue that cannot be avoided. Cutting force is one of phenomena that always exist because the CNC machining always has the cutting process that lead to vibration and deflect. Thus, in this research only cutting force that will be considered. This research also focused on to optimize the accuracy of the positioning machine tool by using PID and Lead-Lag controller. This project is going to be utilizing the AI approach, just like the PSO technique to work out the optimum value of control parameters in achieving precise positioning of machine tools. An optimization approach is beneficial to make sure the optimum value of parameters of controllers is chosen. By with success decisive, the 'best' setting, can make sure that the output of the machine will get higher results.

1.3 Objective

The research priorities are as follows:

1) To design and utilize an artificial intelligence approach like PSO technique to determine the optimum value of control parameters in achieving precise positioning of machine tools.

2) To validate the controller via simulation using Matlab software using the real plant of the Googol tech XY table ball screw drive system.

3) To compare the result of PID and Lead-Lag to ensure the optimum value of parameters of controllers are selected.

1.4 Scope

The scopes of the research are as follows:

i. The analysis was focused only on the unit operated by the XY Table ball screw.
ii. The disturbance force considered is cutting force disturbance only.
iii. The adjustment for cutting forces at different speeds of the spindle is set to 1500 rpm, 2500 rpm, and 3500 rpm spindle speed
iv. Frequency uses are 0.2HZ and 0.4HZ, with an amplitude of 15 mm.
v. The performance of controllers is compared based on the tracking performance which is tracking error and root mean square error (RMSE).

1.5 Project Significant

The research was conducted to enhance the knowledge about the measure of accuracy, and precise positioning of the machine tool and the better controller will design to maintain and improve the efficiency. The research findings are as follows:

i. Development of a controller based on PID and Lead lag to compensate variable cutting forces based on different spindle speeds, which are 1500rpm, 2500rpm, and 3500rpm.

ii. The designed controller by using Particle Swarm Optimization (PSO) technique to get the precise positioning of the Googol Tech XY table ball screw drive system.

iii. Comparison of the tracking performance of different cutting force compared based on tracking error and root mean square error (RMSE), this will authenticate the controller via simulation using Mat lab software using the real plant of Googol tech XY table ball screw driven system.

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

In order to develop product by using CNC machining, the most important things that the manufacturer was looking for were the accuracy and precision of the machine tool. Since the machine tools have been widely introduced, numerous researchers have examined the reliability of machine tools, including several problems such as thermal issue and vacuum system research covered over the past 15 years. One of the methods to analyze these precision and accuracy of positioning machine tool is by designing the controller. One aspect that involves the accuracy and precision of the machine tool is tracking the performance of the drive system. Cutting force and friction force are the disturbances that always affect this tracking efficiency. Two controller has been designed to improve the tracking performance of this research and concentrates at only one type of interference that is cutting force.

2.2 Disturbance of Drive System

A year later, they found that several problems that affect the motion accuracy. There are several factors in the application of machine tools that can affect the accuracy of machine tools, and this will harm the perfection of the quality of a product. According to (Anang et al., 2017), factors that can affect the accuracy of the machine tool are structural vibrations, nonlinear friction, torque ripples, and external disturbances such as cutting force and friction force. Interestingly, (Jamaludin et al., 2016) stated the tracking performance of the drive system is one measure of accuracy, but this tracking performance is influenced by several factors, which are workpiece mass, mechanical structure, friction forces, and cutting force. From both of the literature, it significant describes that the most disturbance that affects the accuracy of the machine tool is workpiece mass, frictional force and cutting force. Therefore, there was further review of the three aspects that most significant disturbance that affects the accuracy of the machine tool.

2.2.1 Workpieces mass

The workpiece is one of the aspects that can reduce the efficiency of the tracking performance of the drive system. In practice, it will not be possible to ignore this condition if the workpiece mass is several times the table mass. For this condition, the more robust controller needs to be designed to ensure that the machine tool works well in different weights of workpiece mass. Then the mechanical structure of a plant could also reduce the system's tracking performance. The mechanical resonance adversely impacts a system's dynamic and frequency response (FRF) function. The mechanical vibration can reduce the possible bandwidth during the movement of the machine tool and limits the stability margins of the controlled system overall. On the next subtopics, the last two factors will be further discussed (Jamaludin et al., 2016).

2.2.2 Friction force

As discussed before and according to (Jamaludin et al., 2016), there are two significant disturbances in the machine tool that have a considerable impact on the tracking performance of the system. A traction strength is one of the disorders, and friction force is the force that occurs when contact is made between two surfaces and slides against each other. The force will be affected by force impelling together as well as the texture of the surface. The object position and angle influence the amount of frictional force. The frictional force that performs on the system will be classified into three situations in the machine tool aspect. First, there was the frictional force against the rotational motor's direction. Second, friction also occurs when it moves between the table and the table guide, and third, the friction force occurs between the cutting tool and the workpiece during the machining process.

2.2.3 Cutting force

Cutting force is one of the disturbances that assists in decreasing the tracking performance of the system. Cutting force can be described as the amount of force needed to perform the cutting operation in Newton. It also acts towards cutting speed and provides the energy to cut the piece of work (Jamaludin et al., 2016). In-play more emphasis (Jamaludin et al., 2016) claim that the existence of cutting force during the cutting process in the application of machine tools. Cutting force will affect the life of the tool as well as cut quality. It is, therefore, necessary to monitor and compensate for the reduction in force. Cutting force is one of the severe disturbances that need to be analyzed and cannot take it as a simple thing. It can lead to vibration and deflection when there is an excessive cutting force. When left unchecked, this will affect the operators and will reduce the quality of the surface finish. The cutting force has been identified by several processes based on research written by (Jamaludin et al., 2016). This research also focuses on how to use spectral analysis to evaluate cutting force data. This spectral analysis helped to determine the specific cutting force under a frequency set and completed this research. The result obtained from this