DESIGN OF NPID DOUBLE HYPERBOLIC FOR PRECISE POSITIONING OF MACHINE TOOL APPLICATION

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

by

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2018

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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Tajuk: DESIGN OF NPID DOUBLE HYPERBOLIC FOR PRECISE POSITIONING OF MACHINE TOOL APPLICATION

Sesi Pengajian: **2017/2018 Semester 2**

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I hereby declared this report entitled "Design of NPID Double Hyperbolic for Precise Positioning of Machine Tool Application" is the results of my own research except as cited in reference.

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APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering (Hons.). The members of the supervisory committee are as follow

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ABSTRAK

Dalam alat mesin, terdapat permintaan yang besar dari segi ketepatan pengesanan. Kekukuhan, kos rendah, permukaan yang lebih baik dan kelenturan yang tinggi. Walau bagaimanapun, kehadiran gangguan dalam alat mesin membawa kepada ketepatan yang rendah dan kedudukan mesin yang tidak tepat. Salah satu faktor yang menyumbang kepada ketidaktepatan alat mesin adalah prestasi penjejakan sistem pemacunya oleh itu penyelidikan ini memperkenalkan pengawal PID Nonlinear (NPID) untuk meningkatkan ketepatan pengesanan sistem pemacu bola XY. Sistem pemacu XY skru bola jadual adalah struktur asas Komputer Kawalan Numerik (CNC). Satu nama pengawal baru NPID Double Hyperbolic telah dicadangkan untuk memastikan prestasi pengesanan sistem yang lebih baik. Dalam pengawal ini, fungsi hiperbolik telah dimasukkan. Dua algoritma hiperbolik bertukar digunakan untuk derivatif tak bersandar dan tidak linear. Atribut utama adalah memberikan nilai yang lebih kecil apabila kesilapan terbesar dihasilkan. Kestabilan pengawal telah dibentangkan oleh kriteria kestabilan popov. Pengawal akan disahkan melalui simulasi menggunakan matlab dan kerja eksperimen menggunakan sistem pemacu skru bola XY googoltech. Pengawal ini akan membantu untuk mengimbangi daya gangguan yang berlaku dan memberi tumpuan kepada gangguan daya pemotongan dengan kelajuan gelendong 1500 rpm, 2500 rpm, 3500 pada frekuensi pengesanan 0.2 Hz dan 0.4 Hz. Keberkesanan pengawal yang dicadangkan diukur berdasarkan kesilapan pengesanan maksimum dan kesilapan (RMSE). Keputusan menunjukkan, pengawal baru yang dicadangkan memiliki ketepatan pengesanan yang lebih baik dengan peningkatan 94.48% dan 94.15% berbanding pengawal NPID dan pengawal PID.

ABSTRACT

In machine tool, there are huge demands in term of tracking accuracy, robustness, low cost, better surface quality speed and high flexibility. However, the presence of disturbance in machine tool leads to low accuracy and precise positioning of machine tool. One of the factors that contribute to the inaccuracy of a machine tool is the tracking performance of its drive system so this research introduces the controller of Nonlinear PID (NPID) for improving the tracking accuracy of XY Table Ball-screw drive system. XY table ball screw drive system is a basic structure of Computer Numerical Control (CNC) machine. One new controller name of NPID Double Hyperbolic was proposed in order to ensure the better tracking performance of the system. In this controller, the hyperbolic function was included in general form of the controller. Two reciprocal hyperbolic algorithms are utilized for a nonlinear integral and nonlinear derivative. The main attribute is it will provide the smaller gain when biggest error is produced. The stability of the controller was presented by popov stability criterion. The controller will validate via simulation using matlab and experimental work using googol tech XY table ball screw drive system. This 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 with an improvement of 94.48% and 94.15% compared to the NPID controller and PID controller respectively.

DEDICATION

Ya Allah, only with your permission this project successful completed
Special appreciation to my mom and dad
Hamidah binti Ali and Mohmad Khalid bin Gzali
Thank you for your praying that never ending, your support and your advice. Hope both of you always gets blessed from Allah.

Special thank to my siblings
Siti Maisarah binti Mohmad Khalid
Muhammad Alif Syafiq bin Mohmad Khalid
Nur Syazwani binti Mohmad Khalid
Muhammad Hilman Hakim bin Mohmad Khalid
Thanks for the support and advice.

Lastly thanks to all my friend, supervisor, other lecturers and staffs.

ACKNOWLEDGEMENT

Alhamdullilah, thank to Allah, for giving the strength and hope to me while completing this project. I was able to complete the project that I have done for two semesters. On this occasion, I Nur Zalikha Binti Mohmad Khalid student of University Technical Malaysia Melaka from Faculty of Manufacturing Engineering, I would like to thank my respected supervisor, Dr. Ir Lokman bin Abdullah for giving me the guidance, advice, time and support me in realizing this project. Without the generous assistance from him, my project could not be complete successfully.

I would also like to thank the lecturers of the University Technical Malaysia especially from Bachelor of Manufacturing Engineering and all the lecturers and staffs that involved for assisting in term of facility and moral support. Thanks, for given me guidance and advice to me to be more progressive and successful. I would also like to give special thank to coordinator of this program Dr, Mohd Shukor bin Salleh for providing the session on how to conduct the project and provide the guideline for the project report. His supports and guidance are greatly appreciated and indebted.

Last but not least, I would like to extend my thankfulness to the most precious persons in my life, my father and mother for their prayers, loves, moral support and financial support, which gave me the strength to complete this project. Furthermore, I would also like to thanks to all my friends who have helped me in preparing the Final Report. Finally, I would like to thank those who helped me directly or indirectly.

TABLE OF CONTENTS

CHAPTER 2: LITERATURE REVIEW

CHAPTER 3: METHODOLOGY

CHAPTER 4: RESULT AND DISCUSSION

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATION

CNC	-	Computer numerical control
FRF	-	Frequency response function
FFT	-	Fast fourier transform
NcasFF	-	Nonlinear cascade feedforward
P	-	Proportional
I	-	Integral
D	-	Derivative
NPID	-	Nonlinear proportional –integral-derivative
PID	-	Proportional-integral-derivative
RMSE	-	Root mean square error
RPM	-	Revolution per minute
SISO	-	Single input single output

LIST OF SYMBOLS

F	-	Cutting force
ω	-	Angular frequency
α	-	Angular acceleration
d	-	Delta
d(t)	-	Disturbances
N(t)	-	Noises
T_d	-	Time delay
K_p	-	Proportional gain
K_i	-	Integral gain
K_d	-	Derivative gain
K_e	-	Nonlinear gain
e_{max}	-	Range value of error variation

CHAPTER 1
INTRODUCTION

This chapter will gives a brief explanation about the project, starting with the background of the project. Section 1.2 elaborates the detail of the problem statement of the project and followed by the objectives of the research in Section 1.3. Based on the problem statement and the objectives of the research, the scope of the project can be known in the Section 1.4 and also significance study will state on section 1.5. Finally, the organization of the project is discussed in the Section 1.6 and the overall summary on section 1.7.

1.1 Research Background

A machine tool is one of the equipment that used to perform machining operation such as milling, turning, drilling and so on. These machine tools use various processes for shaping or machining the metal or rigid materials. All machine tool focusing on constraining the work piece and provide guidance for the movement of the machine tool. There are various types of machine tool and in machine tool application the main things were considered and looking for are the accuracy and precise positioning of machine tool. One aspect that measure these accuracy and precision of a machine tool is a tracking performance of the drive system. However, there exist several factors that could affect tracking performance of the drive system, such as the mechanical structure of the machine tools, mass variation and disturbance forces (S.C.K.Junoh et al., 2016).The presence of disturbance can lead to low accuracy of positioning machine tool and its performance.

The two main types of disturbances are cutting force and friction force and the cutting force is the disturbance that more affecting the positioning and tracking

performance of machine tool. Therefore, in order to compensate this disturbance the controller was designed and analyzed by previous researcher in obtaining the better tracking performance. An active and efficient controller needs to be designed into the system for achieving the better tracking performance of the system and help to improve the quality of product. The most common and classical controller used is PID controller which included the combination of Kp, Ki and Kd that can enhance both transient response and steady state error.

1.2 Problem Statement

As mentioned above one of the aims of machine tool is to ease the work that required repetitive motion and provide accuracy in the products. There are huge demands of the machine tool for high measure of accuracy, better surface quality, robustness, speed, low cost and high flexibility of machine tool but the most essential thing and more focusing in this research is the accuracy of machine tool. The tracking performance of the drive system is the factor that affects the accuracy of machine tool. However, this tracking performance is influenced by the following factors (Jamaludin, 2008) :

i. Mechanical structure
ii. Workpiece Mass
iii. Friction Forces
iv. Cutting Force

This research is more focusing on cutting force disturbances because the cutting force is the significant factor of machine tool. The cutting force is the one of the disturbance forces that may affect the positioning accuracy of machine tool system (Jamaludin et al., 2016). Cutting force will exist whenever there is cutting process involved but excessive cutting force can lead to vibration and deflection. If these been left unchecked will cause harm to operators and quality of surface finish will reduce.

1.3 Objectives

The objectives of the research are as follows:

i. To design NPID Double Hyperbolic controller for precise positioning of machine tools application.
ii. To validate the controller via simulation using Matlab software and experimental work using real plant of Googol tech XY table ball screw driven system.
iii. To compare the result of maximum tracking error and RMSE between three different controller of PID, NPID and NPID Double Hyperbolic

1.4 Scopes of the Research

The scopes of the research are as follows:

i. The research is applied on XY Table ball screw driven system only.
ii. The disturbance force considered is cutting force disturbance only.
iii. The compensation of cutting forces at different spindle speed are limited to spindle speed 1500 rpm, 2500 rpm and 3500 rpm.
iv. Frequency uses are 0.2HZ and 0.4HZ with amplitude of 15 mm.
v. The performance of controllers are compared based on the tracking performance which are tracking error and root mean square error (RMSE)

1.5 Significance of Studies

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

i. Development of a controller that based on NPID to compensate variable cutting forces based on different spindle speeds which are 1500rpm, 2500rpm and 3500rpm.
ii. The designed controller with the aim to get the precise positioning of 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 validate the Controller via simulation using Mat lab software and experimental work using real plant of Googol tech XY table ball screw driven system.

1.6 Thesis Organization

The research is focusing on development of one controller based on cutting force compensation at different spindle speed of 1500rpm, 2500rpm and 3500rpm and the aim to obtain the accuracy and precise positioning of Googol tech XY Table ball screw drive system. The organizations of the research are as follows:

i. Chapter 1 consists of research background, problem statement, objectives, scope of the research and the significant studies about the purpose of this thesis.
ii. Chapters 2 comprises the literature review of previous research about machine of Googol Tech XY table ball screw drives system, the disturbance force in drive system and knowledge about several controllers.
iii. Chapter 3 describes all the methodology of this research work. In general, it includes the overall flowchart on how the research was carried out step by step in designing the controller and the step in conducting the simulation and work experimental explained in details.
iv. Chapter 4 discusses about the information collected after running testing through simulation using Matlab and work experimental using real plant Googol Tech XY table ball screw drives. The discussion focuses on validation aspects of the controllers.
v. In Chapter 5, conclusion and recommendation about this research are explained.