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POSITION CONTROL FOR LINEAR MOTION SERVO SYSTEM VIA NOMINAL CHARACTERISTIC TRAJECTORY FOLLOWING CONTROLLER

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SESI PENGAJIAN: 2008/2009

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NOOR HISHAM BIN JALANI

A project report is submitted as a partial fulfilment
of the requirements for the award of the
Master's Degree in Electrical Engineering

Faculty of Electrical and Electronics Engineering
University Tun Hussein Onn Malaysia

NOVEMBER 2008

"We declared that we read this project and in our point of view this project is qualified in terms of scope and quality for purpose of awarding the Master's Degree in Electrical Engineering."

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Date : 13 NOV 2008

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Supervisor II : MR. JAMALUDDIN BIN JALANI
Date : 13 Nov 2008

"I declare that this project is the result of my own work except the ideas and references which I have clarified their sources."

Signature : ....

Name of Writer : NOOR HISHAM BIN JALANI

Date : 11 Nov 2008

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2. Jamaludin Jalani, Noor Hisham Jalani and Jiwa Abdullah (2008). Position Control for Linear Servo System via Nominal Characteristic Trajectory Controller (NCTF). Bronze Medal, Applied Research Category, Research and Innovation Festival 2008, Universiti Tun Hussein Onn Malaysia, 14-16 October 2008.

ABSTRACT

Motion control system is a challenging problem in the area of control systems. It is very useful to demonstrate concepts in linear control such as the stabilization of unstable systems. Motion control system plays important roles in industrial equipment such as machine tools, semiconductor manufacturing systems and robot systems. One type of motion control systems is point-to-point (PTP) positioning system, which is used to move an object from one point to another point. Linear motion servo system is a machine that move cart from one point to another point. This system consists of a cart driven by a DC motor, via a rack and pinion mechanism to ensure consistent and continuous traction.

Up to now many types of controllers have been proposed and evaluated for positioning systems. Two type of controller that discussed in this thesis are Proportional-Velocity (PV) and Nominal Characteristic Trajectory Following (NCTF). The experimental results showed that the PV was successfully implemented which controlled the settling time, rise time and steady-state error of the desired position. However, the overshoot performances show its disadvantages. Additionally, the PV controller design is time consuming process, since model and parameters of the linear motion servo system are needed. Therefore, the needs for higher performance controller become important for the simplicity of the controller design. Hence, the investigation proceed with the non-model based NCTF controller was to control the cart position of the linear motion servo system. The NCTF controller consists of a Nominal Characteristic Trajectory (NCT) and PI compensator. The NCTF controller was designed based on a simple open-loop experiment of the object. The experimental results showed that the NCTF controller is more effective for controlling position of linear motion servo system than the PV controller.

ABSTRAK

Isu utama di dalam sistem kawalan ialah bagaimana untuk mengawal pergerakan supaya kedudukan yang dikehendaki dapat dicapai. Ianya menjadi sangat penting terutama sekali di dalam industri peralatan seperti pemesinan, sistem pembuatan semikonduktor dan sistem robotik. Salah satu contoh sistem kawalan pergerakan ialah pergerakan satu titik ke satu titik lain, seperti pergerakan objek dari satu tempat ke satu tempat yang lain. Untuk mengkaji isu ini, ujikaji telah dijalankan ke atas sistem servo pergerakan linear, yang menggerakkan kart dari satu titik ke satu titik lain. Sistem ini mengandungi kart yang dipacu oleh motor AT, melalui landasan dan mekanisme pinan untuk memastikan pergerakan yang konsisten dan berterusan.

Sehingga kini, banyak jenis pengawal yang dibangunkan untuk tujuan mengawal ketepatan kedudukan. Di dalam tesis ini, dua jenis pengawal yang dibincangkan ialah *Proportional-Velocity* (PV) dan *Nominal Characteristic Trajectory Following* (NCTF). Keputusan ujikaji menunjukkan bahawa pengawal PV berjaya mengawal masa pengenapan, masa naik dan ralat keadaan mantap untuk kedudukan yang dikehendaki. Bagaimanapun, prestasi untuk lajak adalah kurang memuaskan. Tambahan pula, rekabentuk pengawal PV mengambil masa yang lebih disebabkan model dan parameter sistem yang perlu diketahui dahulu. Oleh itu, keperluan untuk pengawal yang berprestasi tinggi menjadi penting. Maka, penyelidikan terhadap pengawal NCTF dicadangkan untuk sistem ini. Pengawal NCTF mengandungi NCT dan pemampas PI. Ianya direkabentuk berasaskan ujkaji sistem gelung buka terhadap objek. Keputusan ujikaji menunjukkan pengawal NCTF lebih berkesan mengawal kedudukan sistem servo pergerakan linear berbanding pengawal PV.

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LIST OF SYMBOLS

A	Curve area
B_{eq}	Equivalent viscous damping coefficient at the motor pinion
B_p	Viscous damping coefficient at the pendulum pivot
e	Error
F_{ai}	Armature rotational inertial force, acting on the cart
F_c	Cart driving force produced by motor
h	Maximum error rate
I_p	Pendulum moment of inertia
I_m	Motor armature current
J_m	Rotor moment inertia
K_g	Planetary gearbox gear ratio
K_i	Motor torque constant
K_m	EMF constant
K_p	Proportional gain
K_i	Integral gain
K_v	Velocity gain
l_p	Pendulum length frompivot to center of gravity
L_m	Motor armature inductance
m	Inclination of the NCT near origin
M_p	Pendulum mass
PO	Percent overshoot
r_{mp}	Motor pinion radius
r_{pp}	Position pinion radius
R_m	Motor armature resistance
s	Laplace operator
t	Continuous time

t_p	Peak time
T_m	Motor torque
u_p	Difference actual error rate and NCT
u_r	Rated input to the actuator
V_m	Motor nominal input voltage
x	Cart linear position
α	Simplified object parameter
η_g	Planetary gearbox efficiency
η_m	Motor efficiency
ω_m	Motor shaft angular velocity
ω_n	Undamped natural frequency
ξ	Damping ratio

LIST OF ABBREVIATIONS

DAQ	Data Acquisition Card
PID	Proportional Integral Derivative
PD	Proportional Derivative
PV	Proportional Velocity
NCTF	Nominal Characteristic Trajectory Following

CHAPTER I

INTRODUCTION

1.1 Background

Motion control system is a challenging problem in the area of control systems. It is very useful to demonstrate concepts in linear control such as the stabilization of unstable systems. Motion control system plays important roles in industrial equipment such as machine tools, semiconductor manufacturing systems and robot systems. One type of motion control systems is point-to-point (PTP) positioning system, which is used to move an object from one point to another point.

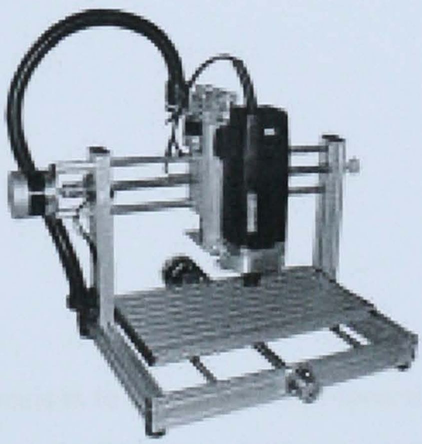

Figure1.1: Position control based machine

1.2 Problem Statement

Up to now many types of controllers have been proposed and evaluated for positioning systems. These controllers will give good positioning performance if the controller was designed by an expert on motion control system whereby they use exact model and real value for all parameters. Advanced controllers tend to be complicated and requires in depth knowledge on theory and design. However, in practicality, engineers are often asked to design this controller. Exact modeling and parameter identifications are generally troublesome and time consuming tasks.

1.3 Objectives of Project

The objective of this study is to investigate the appropriate control method for linear motion control system. The appropriate controller is expected to have simple structure and easy to design, which does not require an exact model and its parameters. The design of the proposed controller is based solely on the information from a simple open-loop experiment.

1.4 Scopes of Project

The focus of this thesis is to investigate a proposed linear motion controller based on Nominal Characteristic Trajectory Following (NCTF). The proposed controller will be used to control the position of a cart horizontally. The design of proposed controller will be implemented on Quanser IP02 Liner Motion Servo

Module. Some hardware limitations would be imposed in the cart system. The Digital-to-Analog voltage for data acquisition board is limited between -10V and 10V. The safety watchdog is turned on where the allowable cart displacement is 0.35m from the centre of the track.

1.5 Thesis Layout

The thesis is organized as follows:

Chapter 1: In this chapter will explain an introduction to the linear motion servo system. The introduction consists of background, problem statement, and objective, scope of project and research methodology.

Chapter 2: This chapter consists of the previous study and the information of the linear motion servo system. Its will cover the literature research based on positioning control of linear motion system.

Chapter 3: In order to achieve the objectives of this study, this chapter will explain the methodology of the project.

Chapter 4: This chapter will explain how the linear motion servo system is modelled mathematically. The mathematical modeling which consists of the model derivation and parameter identification is explained.

Chapter 5: The performance of PV controller as a benchmark controller is discussed in this chapter. The design and implementation of PV controller for linear motion servo system is also described in this chapter.

Chapter 6: Since the PV controller shows that the poor result on overshoot, a new controller which is called NCTF is proposed and discussed in this chapter. The NCTF controller was designed based on a simple open-loop experiment of the object. The basic concept, design and implementation of the NCTF controller are explained. The performance of the NCTF controller was analysed and concluded.

Chapter 7: This chapter summarizes all the results obtained in the previous chapter. The recommendation for future study is suggested.

CHAPTER II

LITERATURE REVIEW

2.1 Introduction

Literature survey has been carried out in order to gain enough knowledge regarding the project. The comparison and selection of the best designing technique will then be done accordingly. The objective of this chapter is to critically review the existing controller methodology, characteristics and features. Particular emphasise will be given to PV and NCTF controller design. Recently published papers will be considered.

2.2 Control Theory

Control theory is an interdisciplinary branch of engineering and mathematics, that deals with the behavior of dynamical systems. The desired output of a system is called the *reference*. When one or more output variables of a system need to follow a certain reference over time, a controller manipulates the inputs to a system to obtain the desired effect on the output of the system (wikipedia.org/wiki/control, 2008).