**UNIVERSITI TEKNIKAL MALAYSIA MELAKA**

# Study on DC Motor Control System

Thesis submitted in accordance with the requirement of the Technical University Malaysia, Melaka for the Degree of Bachelor of Engineering (Honours) Manufacturing (Robotic & Automation)

By

**Moahamad Ariff bin Mohd Arshad**

**Faculty of Manufacturing Engineering**
**April 2007**

**UNIVERSITI TEKNIKAL MALAYSIA MELAKA**

## BORANG PENGESAHAN STATUS TESIS*

JUDUL: STUDY ON DC MOTOR CONTROL SYSTEM

SESI PENGAJIAN : 2003 / 2007

Saya MOHAMAD ARIFF BIN MOHD ARSHAD

mengaku membenarkan tesis (PSM/Sarjana/Doktor Falsafah) ini disimpan di Perpustakaan Kolej Universiti Teknikal Kebangsaan Malaysia (KUTKM) dengan syarat-syarat kegunaan seperti berikut:

1. Tesis adalah hak milik Kolej Universiti Teknikal Kebangsaan Malaysia.
2. Perpustakaan Kolej Universiti Teknikal Kebangsaan Malaysia dibenarkan membuat salinan untuk tujuan pengajian sahaja.
3. Perpustakaan dibenarkan membuat salinan tesis ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. **Sila tandakan (√)

| | | |
|---|---|---|
| ☐ | SULIT | (Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia yang termaktub di dalam AKTA RAHSIA RASMI 1972) |
| ☑ | TERHAD | (Mengandungi maklumat TERHAD yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan) |
| ☐ | TIDAK TERHAD | |

Disahkan oleh:

(TANDATANGAN PENULIS) (TANDATANGAN PENYELIA)

Alamat Tetap:
No 24 Jalan Kenanga , Felda Lepar
Hilir 3, 26300 Gambang, Pahang

Cop Rasmi:
SHARIMAN BIN ABDULLAH
Ketua Jabatan (Robotik & Automasi)
Fakulti Kejuruteraan Pembuatan
Kolej Universiti Teknikal Kebangsaan Malaysia
Karung Berkunci 1200, Ayer Keroh
75450 Melaka

Tarikh:16/5/2007

Tarikh: 17/05/07

* Tesis dimaksudkan sebagai tesis bagi Ijazah Doktor Falsafah dan Sarjana secara penyelidikan, atau disertasi bagi pengajian secara kerja kursus dan penyelidikan, atau Laporan Projek Sarjana Muda (PSM).
** Jika tesis ini SULIT atau TERHAD, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan dengan menyatakan sekali sebab dan tempoh tesis ini perlu dikelaskan sebagai SULIT atau TERHAD.

# DECLARATION

I hereby, declare this thesis entitled "Study on Dc Motor Control System" is the result of my own research except as cited in the reference.

Signature : ……………………………
Author's Name : Mohamad Ariff bin Mohd Arshad
Date : 14 April 2007

**APPROVAL**

This thesis submitted to the senate of KUTKM and has been accepted as fulfillment of the requirement for the degree of Bachelor of Manufacturing Engineering (Honours) (Robotic and Automation). The members of the supervisory committee are as follows:

……………………………………………..

(MR SHARIMAN BIN ABDULLAH)
Main supervisor
Faculty of Manufacturing Engineering

# ABSTRACT

This case study describes the physics of a standard dc motor. From this general understanding, differential equations are developed to describe the motor's dynamic behavior. State space equations and Laplace transforms are then developed for further analysis. Typical data for a specific motor are included within a Matlab/Simulink program to illustrate the basic time domain behavior of the system. System modeling methods for analysis, design and regulation purposes have conventionally employed lumped linear and non-linear methods to provide the dynamic and steady state information required. Adequate though this may be when the components employed are largely concentrated, physically, as system dispersion and slenderness ratios increase, the dynamics arising from spatial distribution assume increasing relevance. Recognition of this and attempted accommodation, via the promotion of approximation and empiricism, has often resulted in a lack of confidence in the computed predictions obtained.

## ABSTRAK

Tesis ini adalah kajian mengenai instrumentasi dan kawalan motor arus terus. Motor arus terus digunakan bersama dengan gear, alat penghubung, dan *power screw* untuk membentuk satu elektro-mekanikal sistem. Seterusnya mencari *transfer function* utuk sistem tersebut. Simulasi menggunakan perisian MATlab digunakan untuk menganalisis sistem tersebut berdasarkan *transfer function* yang telah diperolehi. Keputusan yang diperolehi dikaji untuk melihat sama ada apabila motor arus terus berkuasa 12 voltan dibekalkan, apakah jumlah yang terhasil. Sistem dianalisis dan dipertingkatkan untuk mendapatkan hasil yang terbaik dimana jumlah voltan yang dibekalkan sama dengan jumlah yang terhasil.

**ACKNOWLEDGEMENTS**

Appreciations are expressed to those who have given generous contributions within the period of this thesis development to fulfill the requirement of the Degree of Bachelor of Engineering (Honours) Manufacturing (Robotic and Automation) program.

Here I would like to express my deepest appreciation to my supervisor, Mr. Shariman, also acts as chief of department robotic and automation of faculty of manufacturing engineering in Universiti Teknikal Malaysia Melaka.

His constant guidance and support during my thesis writing is invaluable to me. His continuous direction and opinion regarding the flow of the project has a mass contribution to achieve the objective of the project. Furthermore, the guide and help of him on how to make this thesis a more effective reference are followed with my sincere gratitude.

Finally, I would like to thank to all lectures, technicians and colleagues who had involved directly or indirectly in my thesis.

Mohamad Ariff Mohd Arshad

May 2007

**TABLE OF CONTENTS**

# LIST OF FIGURES

## LIST OF TABLES

## LIST OF ABBREVIATIONS, SYMBOLS, SPECIALIZED NOMENCLATURE

| | |
|---|---|
| DC | - Direct Current |
| EMF | - Electric Motive Force |
| PWM | - Pulse Width Modulation |
| AC | - Alternating Current |
| SISO | - Single-Input-Single-Output |
| MIMO | - Multi-Input-Multi-Output |
| BIBO | - Bounded-Input-Bounded-Output |
| PDF | - Pseudo-Derivative Feedback |
| PID | - Proportional-Integral-Derivative |
| SCR | - Silicon Controlled Rectifier |
| RPM | - Revolution per Minute |
| SM | - Single loop Margin |
| DM | - Double loop Margin |
| MM | - Multi loop Margin |
| y(t) | - Output Of The System |
| r(t) | - Reference Value Through The Measurement Performed By A Sensor |
| C and P | - Linear And Time-Invariant For A Simple Feedback Control Loop |
| $C(s)$ and $P(s)$ | - Transfer Function For A Simple Feedback Control Loop |
| x[n] | - Impulse Response |
| $i$ | - Electric Current |
| $l$ | - Flowing In A Wire Of Length |
| B | - Magnetic Field Of Strength |
| F | - Force |
| $K_t$ | - Equivalently |
| $I_a$ | - Current Flow |
| $A$ | - Area |
| $v_b(t)$ | - Induced Voltage |

| | |
|---|---|
| $i_a(t)$ | - Wire Carrying Current |
| $T_m(t)$ | - Torque for DC Motor |
| $R_a$ | - Resistance |
| $L_a$. | - Inductance |
| $\theta_m(t)$ | - output angular displacement for DC Motor |
| $V_a$ | - Voltage Source In Electrical Characteristic |
| $k_v$ | - Velocity Constant Determined By The Flux Density Of The Permanent Magnet |
| $\omega_a$ | - Rotational Velocity of The Armature |
| Te | - Electromagnetic Torque in Mechanical Characteristic |
| Tw | - The Torque Due To Rotational Acceleration of The Rotor in Mechanical Characteristic |
| Tw’ | - Torque Produced From The Velocity Of The Rotor in Mechanical Characteristic |
| $T_L$ | - Torque Of The Mechanical Load in Mechanical Characteristic |
| $\Omega_{ref}$ | - Speed In Closed-Loop |
| $\Omega_f$ | - Speed Feedback Signal |
| $C_S$ | - Critical Speed |
| D | - Root Diameter Of Screw (Inches) for Power Screw |
| L | - Length Between Supports (Inches) for Power Screw |
| F | - End Support Factor (See Diagram) for Power Screw |

# CHAPTER 1
# INTRODUCTION

## 1.1 Introduction to The Project

A permanent magnet direct current (dc) motor is a very common component within many dynamic systems. This case study describes the physics of a standard dc motor. From this general understanding, differential equations are developed to describe the motor's dynamic behavior. State space equations and Laplace transforms are then developed for further analysis and for application to a light tracking system. Typical data for a specific motor are included within a Matlab/Simulink program to illustrate the basic time domain behavior of the system. System modeling methods for analysis, design and regulation purposes have conventionally employed lumped linear and non-linear methods to provide the dynamic and steady state information required. This approach although simple and appealing assumes that the system components have no spatial dimensions, each element, for example, comprising stiffness, inertia and frictional dissipation characteristics, all of which exist at some undefined point in space. Adequate though this may be when the components employed are largely concentrated, physically, as system dispersion and slenderness ratios increase, the dynamics arising from spatial distribution assume increasing relevance. Recognition of this and attempted accommodation, via the promotion of approximation and empiricism, has often resulted in a lack of confidence in the computed predictions obtained. Finite element (fe) methods, for example, are often incorporated in efforts aimed at replicating the effects of spatial dispersion. However, this approach generates large matrix models, computational errors, and erroneous modes of response and decay rates. To overcome these difficulties combined distributed lumped modeling was investigated for mechanical, power transmission system modeling, were also researched and accurate, compact, computationally efficient realizations, for controller design and real-time diagnostics, were derived. At this time single loading effects and the dynamics arising from flexible beams, shafts and rotor-bearing assemblies were addressed. Whirling speed applications studies continued in parallel with this work using frequency response and numerical minimization methods. In this contribution previous work will be advanced with a novel combined torsion and tension loading, machine tool modeling method. The technique involved will be to describe significantly distributed elements of the machine, such as the lead screw, using distributed parameter procedures. This approach to the mathematical construction process enables greater reality, accuracy and integrity to be achieved. Essentially, the system dynamics arising from the combined, distributed lumped description enable all of the incident, traveling and reflected waveform effects to be replicated in the final realization. Effectively, the response signatures generated by the model will be shown to correspond closely with those from the actual system. In particular, the effects of spatial dispersion and combined, lead screw, torsion and tension loading provide a broadband realization, capable of generating the low and high frequency behavior of the system's, x-axis dynamics. This is enhanced by the incorporation of lumped nonlinear effects. Details of these characteristics were obtained, in this study, from manufacturer's data and from measured, experimental results. Following, the detailed derivation for the x-axis traverse, motor drive and the multivariable lead screw model, for combined torsion and tension loading will be presented. Thereafter, an overall, interactive representation, for the complete distributed–lumped system configuration, will be derived. Finally, the simulated response transients for the system, following voltage step changes on the lead screw, motor drive, will then be computed.

## 1.2 Problem Statement

Certain high-speed document handling machines manufactured exhibit the undesirable phenomenon of high frequency ringing and vibrations. This is attributed to compliance in the system. The objective of this project was to study and analyze a simple test that had all the relevant attributes of the more complicated machines. The dynamics and control of a load driven by a DC motor was to be investigated in the context of high-speed high precision motion control. High performance was desired without risking close-loop stability. One particular addition of interest is a Simulink graphical model which automatically performs the appropriate block diagram arithmetic and generates a state space model for use in a standard Matlab simulation. This model is used here to relate the output angular velocity of the motor to the input applied voltage. It is also used as a subsystem in a Simulink model of the complete the simple mechanical design.

## 1.3 Objectives, Aims and Scopes of the Project

### 1.3.1 Objectives

1. To demonstrate the use of electrical blocks, in combination with Simulink blocks, in the simulation of an electromechanical system with a control system. The electrical part of the DC motor drive, including the DC source, and the DC motor, is built using blocks from the Elements, Machines, and Electronics libraries in the Matlab Software. The DC Machine block models both electrical and mechanical dynamics. The load torque-speed characteristic and the control system are built using Simulink blocks.
2. Describe various methods of controlling the speed and direction of a DC motor.
3. Learn the operation and modeling of DC motor systems.
4. Learn the driver circuitry for DC motors.
5. Understand the types and specification of DC motor.

### 1.3.2 Aims

Analyze the output voltage of DC motor that produce for the simple mechanical design that have power screw. Be able to using the Matlab software to simulate the design and test to see that the requirements and specification are met.

### 1.3.3 Scope of the Project

This project is to study on 'Dc Motor Control System'. The project scope is to 'Study the Control Element in Single Axis Positioning with Consist of Motor, Gearing, Coupling, and Power Screw'. The software that recommended in this research is Matlab 6.5.1. The main of this research is to explore and design the mechanical element. From the mechanical equations, transfer to the control system equations. Then, find the specification of the element at calculate the value of the dc motor output voltage. Construct the block diagram using Matlab software and simulate the design.

## 1.6 Gantt Chart

Table 1 Gantt Chart PSM 1.

| CONTENTS | W 1 | W 2 | W 3 | W 4 | W 5 | W 6 | W 7 | W 8 | W 9 | W 10 | W 11 | W 12 | W 13 | W 14 | W 15 | W 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Project Selection | | | | | | | | | SEMESTER BREAK | | | | | | | |
| Information research | | | | | | | | | | | | | | | | |
| Write a literature review | | | | | | | | | | | | | | | | |
| Discuss on simple robot that using dc motor | | | | | | | | | | | | | | | | |
| Draft the objective and select the instrument that need to be used in the project | | | | | | | | | | | | | | | | |
| Study on MATlab Software | | | | | | | | | | | | | | | | |
| Design and solve mechanical diagram | | | | | | | | | | | | | | | | |
| Draft report preparation | | | | | | | | | | | | | | | | |
| Final draft report preparation | | | | | | | | | | | | | | | | |
| Presentation and report submission | | | | | | | | | | | | | | | | |

Table 2 Gantt Chart PSM 2.

| CONTENTS | W1 | W2 | W3 | W4 | W5 | W6 | W7 | W8 | W9 | W10 | W11 | W12 | W13 | W14 | W15 | W16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Find the specifications | ■ | ■ | | | | | | | SEMESTER BREAK | | | | | | | |
| Find the transfer function | | ■ | ■ | | | | | | | | | | | | | |
| Simulation using MAtlab software | | | | ■ | ■ | ■ | ■ | ■ | | ■ | ■ | | | | | |
| Analysis the result | | | | | ■ | ■ | ■ | ■ | | ■ | ■ | ■ | | | | |
| Make a discussion | | | | | ■ | ■ | ■ | ■ | | ■ | ■ | ■ | | | | |
| Gathering all information and sources | | | | | | | | | | ■ | ■ | ■ | ■ | | | |
| Draft report preparation | | | | | | | | | | ■ | ■ | ■ | ■ | | | |
| Final draft report preparation | | | | | | | | | | | | | ■ | ■ | | |
| Presentation and report submission | | | | | | | | | | | | | | | ■ | ■ |

**CHAPTER 2**

**LITERITURE REVIEW**

## 2.0 Introduction

An electric motor converts electrical energy into kinetic energy. The reverse task, that of converting kinetic energy into electrical energy is accomplished by a generator or dynamo. In many cases the two devices differ only in their application and minor construction details, and some applications use a single device to fill both roles. For example, traction motors used on locomotives often perform both tasks if the locomotive is equipped with dynamic brakes. Most electric motors work by electromagnetism, but motors based on other electromechanical phenomena, such as electrostatic forces and the piezoelectric effect, also exist. The fundamental principle upon which electromagnetic motors are based is that there is a mechanical force on any current-carrying wire contained within a magnetic field. The force is described by the Lorentz force law and is perpendicular to both the wire and the magnetic field. Most magnetic motors are rotary, but linear motors also exist. In a rotary motor, the rotating part (usually on the inside) is called the rotor, and the stationary part is called the stator. The rotor rotates because the wires and magnetic field are arranged so that a torque is developed about the rotor's axis. The motor contains electromagnets that are wound on a frame. Though this frame is often called the armature, that term is often erroneously applied. Correctly, the armature is that part of the motor across which the input voltage is supplied. Depending upon the design of the machine, either the rotor or the stator can serve as the armature.