DEVELOPMENT OF AN EMBEDDED CASCADING PID CONTROLLER OF DC MOTOR USING MATLAB/SIMULINK

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

(Engineering Robotics and Automations)(Hons.)

by

MOHAMAD SHAFIK BIN NASSHARUDDIN

B051410036

930531-05-5483

FACULTY OF MANUFACTURING ENGINEERING

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DECLARATION

I hereby, declared this report entitled "Development of an Embedded Cascading PID Controller of Dc Motor Using MATLAB/Simulink" is the results of my own research except as cited in references.

Signature :……..

Author's Name : MOHAMAD SHAFIK BIN NASSHARUDDIN

Date : ……..

APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of UTeM as a partial fulfilment of the requirements for the degree of Bachelor of Manufacturing Engineering (Robotics & Automation) (Hons.). The member of the supervisory is as follow:

.....
(Dr. Shariman bin Abdullah)

ABSTRAK

Tujuan projek ini adalah untuk menghasil sistem lata PID yang bertujuan untuk mengawal motor dengan menggunakan MATLAB / Simulink dan memindahkan system lata PID tersebut ke dalam pengawal mikro untuk tujuan ujian. Lata PID mempunyai dua pengawal PID dan dua gegelung. Setiap pengawal PID terletak didalam gelung-gelung yang terdapat didalam lata PID. Objektif projek ini adalah untuk membuat ujian rig dan menganalisa setiap keputusan daripada lata PID berdasarkan beban yang dikenakan. Ujian rig tersebut telah direka bentuk di dalam perisian 'SolidWorks' dan difabrikasi dengan menggunakan mekanisma mengangkat. Kemudian, proses ujian dijalankan dengan pelbagai beban dari sifar gram hingga 150 gram. Keputusan bagi setiap ujian dianalisis dari segi masa penetapan dan juga halaju motor.

ABSTRACT

The aim of this project is to develop the cascade PID motor control by using MATLAB/Simulink and embed the cascade PID system into a microcontroller for testing purpose. Cascade PID consist two of PIDs controller and two loops. Each PID controller is located in those two loops. The objectives of this project is to develop the test rig and analysed the output responses of cascade PID controller based on the load tested. The test rig was design in the SolidWorks software and fabricate with the implementation of lifting mechanism. Manual tuning method was used to determine the gain value of the cascade PID. The testing was carried with different loads which are from zero gram to 150 grams on the test rig. The response of the motor for each testing were be analysed in term of the settling time and also the velocity of the motor.

DEDICATION

The only one

My beloved father, Nassharuddin Bin Basri

My lovely mother, Shamsiah Binti Abd. Latiff

My brother, Mohamad Syukri Bin Nassharuddin

For giving me moral support, encouragement and also understandings.

Thank You So Much & Love You All Forever

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TABLE OF CONTENT

Abstrak i

Abstract ii

Dedication iii

Acknowledgement iv

Table Of Content v

List Of Figures x

List Of Tables x

List Of Abbreviations And Symbols xii

CHAPTER 1: INTRODUCTION

1.1 Introduction 1

1.2 Background 1

1.3 Problem Statement 2

1.4 Project Objective 3

1.5 Scope of Project 3

1.6 Summary 4

1.7 Organization of the Thesis 4

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction 5

2.2 Control System 6

2.2.1 Proportional Integral Controller (PI) 8

2.2.2 Proportional Derivative Controller (PD) 11
2.2.3 Proportional Integral Derivative Controller (PID) 15
2.2.3.1 Cascade PID controller 20
2.3 Embedded System 23
2.3.1 Microcontroller 25
2.4 Numerical Computing Software 27
2.4.1 MATLAB/Simulink 27
2.4.2 MATLAB with PID 30
2.5 Motor Control 31
2.5.1 Servo Motor with Encoder 32
2.5.2 Motor Driver 33
2.5.3 PWM Signal 34
2.6 Design of Test Rig PID 35
2.7 Summary 36

CHAPTER 3: METHODOLOGY

3.1 Introduction 37
3.2 Process Flow of Project 38
3.3 Development of Cascading PID controller 39
3.3.1 MATLAB/Simulink 39
3.4 Embedded Controller into Microcontroller 40
3.4.1 SKds40A Board 40
3.4.2 Microcontroller dsPIC30F4011 41
3.4.3 MPLAB Software 42
3.5 Set up the Circuit 42
3.5.1 DC Servomotor with Encoder 44
3.5.2 Motor Driver 10Amp DC Motor 45

3.5.3 Power Supply 46
3.6 Set Up and Testing Test Rig 47
3.7 Analyses the Data 47
3.8 Summary 48

CHAPTER 4:RESULTS AND DISCUSSIONS

4.1 Introduction 49
4.2 Test Rig 49
4.3 Block Diagram of Cascade PID in Simulink 51
4.3.1 PID for Position 53
4.3.1 PID for Velocity 54
4.4 Output Response from the Testing 55
4.4.1 Output Response for Free Rotation 55
4.4.2 Output Response when Motor was attached to Test Rig 56
4.4.3 Output Response for 50 g of Load 57
4.4.4 Output Response for 100 g of Load 58
4.4.5 Output Response for 150 g of Load 59
4.4.6 Summary for Each Testing 60
4.6 Summary 60

CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

5.1 Introduction 61
5.2 Conclusion 61
5.3 Recommendations 62

REFERENCES 63

APPENDICES 69

A GANTT CHART OF PSM 1 69

B GANTT CHART OF PSM 2 70

LIST OF FIGURES

Figure 2.1	Process that be controlled	6
Figure 2.2	Example of open loop control system	7
Figure 2.3	Example of closed loop control system with feedback	7
Figure 2.4	Example of simple PI controller	9
Figure 2.5	Example of simple PD controller	12
Figure 2.6	Example of simple PID controller	15
Figure 2.7	First order and second order of PID controller by using MATLAB/Simulink	30
Figure 2.8	Linear motor feed drive system	35
Figure 2.9	Test rig for vibration	36
Figure 3.1	Project Process Flow	38
Figure 3.2	SKds40A board	41
Figure 3.3	dsPIC30F4011 Microcontroller	41
Figure 3.4	Connection in the circuit	43
Figure 3.5	DC servomotor with encoder	44
Figure 3.6	Encoder Connection	44
Figure 3.7	Dimension of the Motor Driver 10Amp	46
Figure 4.1	Design of the test rig using SolidWorks software	50
Figure 4.2	Actual test rig after be fabricated	50
Figure 4.3	Microchip block set in Simulink	51
Figure 4.4	Block diagram inside the controller	52
Figure 4.5	Block diagram in PID1	53
Figure 4.6	Block diagram in PID2	54
Figure 4.7	Output response for free rotation	55
Figure 4.8	Output response when motor was attached to the test rig	56
Figure 4.9	Output response when 50 g of load tested	57
Figure 4.10	Output response when 100 g of load tested	58
Figure 4.11	Output response when 150 g of load tested	59

LIST OF TABLES

Table 2.1	Advantages and disadvantages of servomotors	32
Table 3.1	Detail of dsPIC30F4011	42
Table 3.2	Specification of Servomotor	45
Table 4.1	Parameter in PID1	53
Table 4.2	Parameter in PID2	54
Table 4.3	Data from each testing	60

LIST OF ABBREVIATIONS AND SYMBOLS

PI	-	Proportional Integrator
PD	-	Proportional Derivative
PID	-	Proportional Integrator Derivative
PWM	-	Pulse Width Modulation
ζ	-	Damping ratio

CHAPTER 1
INTRODUCTION

1.1 Introduction

In this chapter provide a short overview about the project which the title is "Development of an Embedded Cascading PID Controller of DC Motor Using MATLAB/Simulink". The problem statement is defined based on the current problem that been faced as the control system engineer nowadays. The objectives are the main goals of this project and need to be something that can achievable. And lastly the scope of project is a limitation that need to be considered when the project is conducting.

1.2 Background

In this era, there are various type of controllers used in the industry for controlling machine and equipment. Control system is needed in all type of controller which is the control system need to manages, instruct, coordinate and also need to adjust the behaviour of the system or devices when the controller is implement. In the control system, there are many type of controller that exist such as Proportional controller (P), Integral controller (I), Derivative controller (D) and many more. However, the controller also can be combine into one controller such as PID controller which contain the Proportional controller, Integral controller and Derivative controller. There are many factors that should be considered when

to selecting the controller. Over 50 years, the PID controller still the mostly used in the industry (Åström and Hägglund 2004). This PID controller still popular to the industry because of the simplicity of the structural and also the robustness performance of the controller in the commonly operating conditions (Hamamci and Koksal 2010) . Faster response controller is most desired in the most applications. However, to achieve the faster response the controller that be used need to selected wisely and correctly tune. There is cascade controller been exist after the PID controller which this cascade controller have more advantage than the PID controller. The cascade controller has two controller in the single system and can be in any controller such as P controller, PI controller, PD controller and also PID controller. The overshoot in the system can be reduce when the cascade PID controller is applied.

In this project, two PID controller are used in the system since this project need to develop a cascade PID controller. The cascade has two loops in the system and each system has the PID controller that reacts with the operation. These two loops known as inner loop or secondary loop and outer loop or primary loop. The secondary loop will react first before the primary and it will affect the primary loop. The response of the controller will be the result of the project when the controller react with variety of load when the testing process is carry on.

1.3 Problem Statement

With the existence of many types of controllers make the engineers in nowadays have facing the problem in choosing the most suitable controller that need to be used in the systems. The most crucial part is when an engineer need to select the suitable controller in order to make the system functioning. A controller that have faster response is need to be selected in order to achieve the faster result and goal. However, there are consequences if the controller had been wrongly selected such as the system may be malfunction and cannot be operate. Thus, a simple and systematic method need to be done in order to determine the most suitable controller that need be used in the control system environment. PID controller is the commonly used in the most application. However, for this project PID controller is not

be used because of the PID controller only deal with the position loop and its will neglect the velocity loop. Therefore, cascade PID controller will be used in this project since the cascade PID controller can deal with the position loop and also velocity loop. In order to evaluate the performance of the cascade PID, test rig will be design and set up.

1.4 Project Objective

The objectives of this project are:

1. To develop the test rig for the testing purpose.
2. To test the test rig for evaluating load response of cascade PID controller with the embedded controller.
3. To analyse the effect of output response against the controller according to a variety of load.

1.5 Scope of Project

The scopes of this project is to design and simulate a cascade PID controller using MATLAB/Simulink software. Besides that, the project is to develop a block diagram cascade PID controller for dc motor by using the Simulink that is included in MATLAB/Simulink software. The block diagram of cascade PID is embedded into the 16-bit memory microcontroller and implement to the servomotor that equip with the encoder for measure the position. Focusing on a comparison the response of the controller with the variety of number of loads which is from 0g to 150g. However, this project does not include the studies of force or torque due to lack of torque or force sensors.

1.6 Summary

In this chapter, the background of this project is describe and also the problem statement. The problem that currently that face by the control engineers in selecting the suitable controller that to be implement the system also been describe in this chapter. There are two objectives that need to be achieve at the end of this project. And the scope of this project also been describe in this chapter.

1.7 Organization of the Thesis

This project thesis is comprised of further four chapters as follows:

- Chapter 2. Literature Review: this chapter conducted by using contextual investigations, specialised report, book, journal and article. This chapter reviews the previous project to find out the expected result.

- Chapter 3. Methodology: this chapter describe the method involved to develop the cascade PID controller and the process flow of project will be determine in this chapter.

- Chapter 4. Results and Discussions: present and discusses the result of motor response from the test rig testing.

- Chapter 5. Conclusions and Recommendations: verify either the objectives are archived or not archived. And also recommendation for future works.

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

In this chapter, the literature studies that related in development of an embedded cascading PID controller of DC motor using MATLAB/Simulink was approached. The section includes the following elements such as control system, embedded system, numerical computing software, motor control and test rig design. In the control system section, definition, and type of controller were described. Issue regarding the selecting and the limitations of microcontroller are discussed at embedded system section. In numerical computing section, software and tools that used to perform the project were described. The theory of motor control and the application of the motor control were discussed at motor control section. Lastly, the design of test rig was cover about the previous design of the test rig.

The information was acquired from various sources such as books, journal articles, relevant previous research papers and also online articles. Most of the references are based on the journal articles that related to this project.

2.2 Control System

An interconnection of segments framing a framework arrangement calls control framework, which is a wanted framework reaction will be given. The reason for analysis of a framework is the establishment gave by linear framework theory, which a cause-impact is expected relationship for the part of a framework. A controlled process can be portrayed by a block diagram. (Dorf and Bishop.2008)

Figure 2.1: Process that be controlled

The term input that is appeared in Figure 2.1 is the jolt, excitation or charge connected to a control framework, normally from an outer vitality source, more often in order to produce a predetermined reaction from the control framework, though, the term of output is the real reaction acquired from a control framework and it could possibly be same or equivalent to the predefined reaction inferred by the input. (Distefano *et al.*1990)

There is two general category in control system which is open-loop control system and closed-loop control system. An open-loop control framework is one in which the control activity in free of the output and the closed loop control framework is one in which the control the activity is by one means or another reliant on the output. (Distefano *et al*.1990)In other term of these two categories is an open-loop control framework uses an inciting device to control the process specifically without utilizing feedback, while the closed loop utilizes a measurement of the output and feedback of signal to contrast it with the wanted output. (Dorf and Bishop.2008)

The open loop control framework additionally called as linear control framework or non-feedback control framework. This open loop control framework will process its input to a framework utilizing a specific estimation of set point from the input and its model of the framework. The characteristic for the open loop controller is that it does not feedback to figure out whether its input has accomplish the wanted objective. This implies the framework does not watch the output of the processes that it is controlling. Figure 2.2 show the basic of the open loop control system.

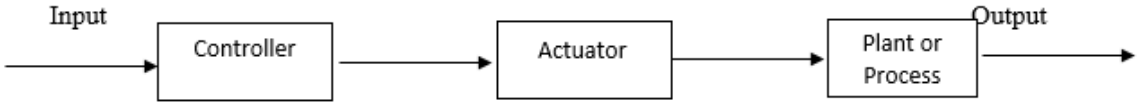

Figure 2.2: Example of open loop control system

(Dorf and Bishop.2008)

Closed loop control system is an opposite of an open loop control system. This closed loop control system also called as a feedback signal. A feedback control framework is a control framework that has a tendency to keep up a recommended relationship of one framework variable to another by looking at the capacity of these factors and utilizing the distinction as a method for control. (Dorf and Bishop.2008)

A closed loop control framework is one in which an input compelling is resolved to some part by the framework reaction and make the measured reaction of a physical framework is contrasted and a wanted reaction. Figure 2.3 show the closed loop control system.

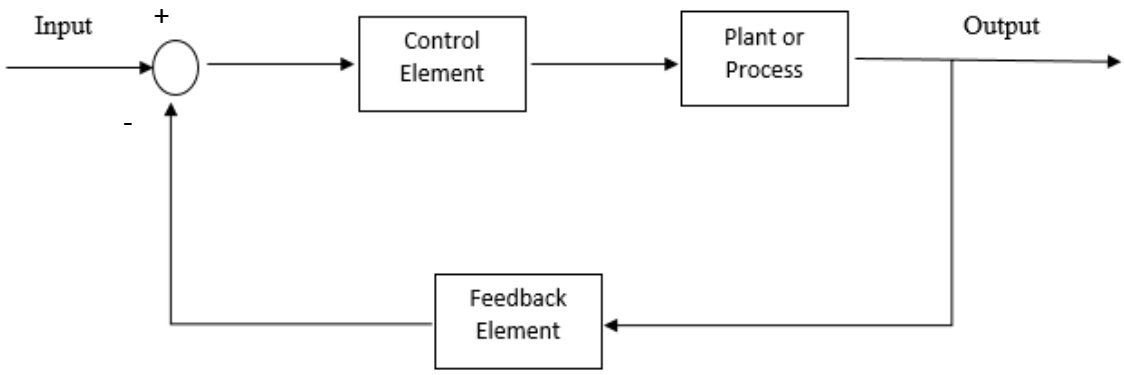

Figure 2.3: Example of closed loop control system with feedback

(Distefano *et al*.1990)

By implementing the closed loop control system, the system has many advantages despite of the cost and complexity of the system increases. The following advantages of closed loop control system are the diminished affectability of the framework to variation in the parameter of the process and enhanced dismissal of the unsettling influences. Besides that, the closed loop control system will give an improved in measurement noise attenuation and enhanced in diminishment steady state error of the framework. And lastly, the simple in control and adjustment of transient reaction of the framework can be gotten while actualizing the closed loop control framework. (Dorf and Bishop.2008)

2.2.1 Proportional Integral Controller (PI)

The proportional integral controller is commonly used to eliminate the steady state error, but small integral is mostly used to avoid the closed loop system become destabilizing. In various systems K_i is in charge of driving the error to zero. Be that as it may, when the Ki is set too high it may cause oscillation or instability or integrator windup or actuator immersion. As term of speed and general strength of the framework, it has a negative effect. Since the PI controller has no ability to foresee the future error of the framework, it can't diminish the rise time and take out the oscillation. (Temel *et al*. 2013)

The PI controller is unquestionably the most commonly used control algorithms. This controller has traditionally been tuned empirically by the method that described in Ziegler and Nicholas. The method that is described by Ziegler and Nicholas has a great advantage of requiring very little information about the process. However, a significant disadvantage because the method, inherently gives a very poor damping, typically $\zeta \approx 0.2$

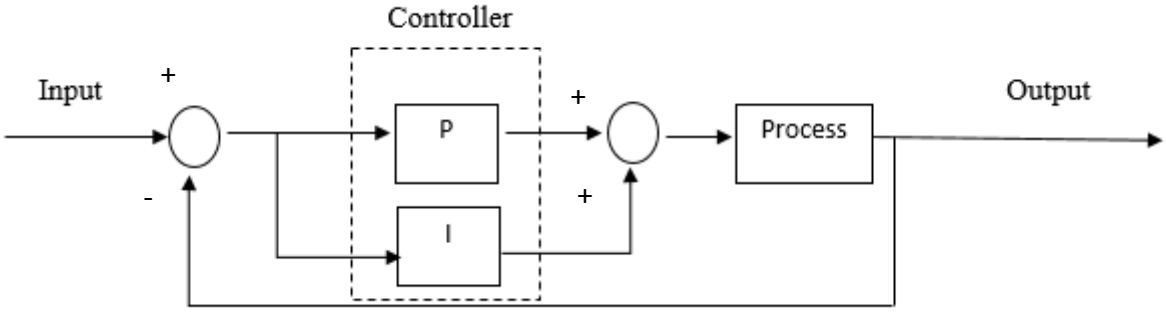

Figure 2.4: Example of simple PI controller

Based on the Figure 2.4, the proportional controller is set parallel with the integral controller. There are a few reasons to search for better techniques in designing the PI controllers. One reason is the noteworthy effect it might give on because of the spreading utilization of the controllers and another reason is that developing auto-tuners and tuning devices can benefit significantly from enhanced outline techniques. However, there are required to have an efficient design method. One of the prerequisite is, it ought to be applicable to an extensive variety of frameworks and it ought to have the likelihood to present details that catch the pith of real control issues. The technique ought to be vigorous as in it gives controller parameters if they exist, or if the determinations can't be met a fitting appropriate diagnosis ought to be displayed.(ÅStrÖM *et al.* 1998)

According to Wang *et al*. (2014), PI controller for auto tuning is really demanding in this current situation, without knowing the varying the operating parameters. A technique that is very powerful in solves problem in designing the PI controller. The technique is used

based on an adaptive estimation algorithm. In (Santra *et al.* 2016) mention that the PI controller is one of the controller that is commonly used controller in industrial automation. Due to the functional simplicity of the PI controller compared to the conventional control make the PI controller is more attractive and the advantages rather than conventional controllers and also successful applications in industry. Besides that, a controller without integral action in a feedback control system may make the steady state error of external disturbance and set-point adjustment, these actions is one of the proportional feedback control law. Hence, they obtain a robust feedback in time varying input delay with a delay-dependent sampled data of PI law and which ensures the asymptotic stabilization for the uncertain time delay. Direct and local feedback measurement are required by PI controller, thus it's suitable for industrial applications.

According to He and Liu (2011), single-input and single-output (SISO) system are applied in most PI controller. These because most of the control scheme of traditional PI controller is a frequency-based domain. Withal, in engineering multiple-input and output (MIMO) always in PI controller. To solve the constrained tracking system problem, a generalized PI control strategy in discrete-time context is applied especially for stochastic systems. In the study, there are some cases that some of system states are not measurable when the feedback of the PI controller is failing to achieve the stability. In the industrial control process, the applications of PI control method is comprehensively be implemented. Also in the study, to get stabilize the uncertain Markovian Jumping System (MJSs), the PI controller is needed to design effectively.

In Zaky (2015) mention that PI controller is commonly practiced in industry because of its simple command structure, ease of conception and also because of the low monetary value of PI controller. But the good step reference tracks and good load torque rejection are unable to meet simultaneously in the PI controller. Moreover, PI controller face some disadvantage which is the PI controller has a sluggish response, large in overshoots and oscillations. These disadvantages occur when the action to tune the PI controller gains because widespread in the PI controller is highly desirable. Tune likes the drive system exhibits satisfactory transient and also steady state response under varying operating system is unitary of the ways to PI controller control the addition of its controller. The shortcoming