THE DESIGN OF A TORQUE FEEDBACK CONTROLLER USING PID CONTROLLER FOR AN UPPER LIMB ROBOTIC ARM

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A report submitted in partial fulfillment of the requirements for the degree of Bachelor in Mechatronic Engineering

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JUNE 2013

"I hereby declare that I have read through this report entitle "The Design of a Torque Feedback Controller using PID Controller for an Upper Limb Robotic Arm" and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Mechatronic Engineering"

Signature : ....

Supervisor's Name: DR. MARIAM BINTI MD.GHAZALY

Date : ……………………………..

I declare that this report entitle “The Design of a Torque Feedback Controller Using PID Controller for an Upper Limb Robotic Arm” is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ....

Name : KARTIKESU A/L VIJAYAN

Date : ………………………………….

To my beloved father and mother

ACKNOWLEDGEMENT

First of all, I would like to thank almighty God for the strength and blessings. I would also like to express my deepest gratitude to my supervisor Dr. Mariam Binti Md.Ghazaly for guiding me through my final year project development. The knowledge has been given by her highly motivated me to successfully complete this project. The information, suggestions and ideas given by her played huge role in developing the project.

I would also like to thank my parents. They have given me moral support. Their support gives me the strength to endure this final year project and successfully complete it. Finally, I am also grateful and would like to thank my friends who had helped me directly or indirectly and their help had given me a lot of ideas on troubleshooting the problems that rises during the development of the project.

ABSTRACT

A robotic arm is a mechanical controlled device which is designed to do movement of a human arm. The robotic arm can be design by many actuators like pneumatic, hydraulic and motor. Due to the arm movement, it requires a type of controller for performing the movement. In this past, the types of controller use on robotic arm like PD controller and PI controller are used on robotic arm. Although, the next generation robotic arm need a suitable controller to control output force which able to produce a significant reduction of performance error. While this works well, the robot arm will perform movement with proportional torque which gives benefit in surgical and industrial application. In this project, proportional-integral-derivative (PID) controller will be applied into the upper limb robotic for control the output torque. Hence, the purpose of this project is to design a controller equipped with robotic arm for control the torque of arm movement and avoid any disturbance of the system. The Matlab/Simulink application used to analysis the data acquired from the simulation. The controller system is scoped on the proportional torque acquired to perform the robotic arm movement.

ABSTRAK

Lengan robot ialah satu alat kawalan mekanikal yang direkabentuk untuk pergerakan tangan manusia. Lengan robot boleh direka oleh beberapa penggerak seperti pneumatik, hidraulik dan motor. Dalam sesuatu pergerakan lengan robot, satu pengawal diperlukan untuk mengawal pergerakan. Pada generasi lepas, pengawal seperti pengawal PD dan pengawal PI sering digunakan di dalam lengan robot. Walaubagaimanapun, lengan robot memerlukan sejenis pengawal sesuai untuk mengawal pengeluaran daya kilas dengan sekata serta dapat mengurangkan ralat dalam prestasi sesebuah sistem. Dengan menggunakan pengawal ini, lengan robot akan mengawal sesuatu pergerakan dengan daya kilas yang berkadaran. Ia juga memberi bermanfaat dalam penggunaan aktiviti pembedahan dan perindustrian. Dalam projek ini, pengawal jenis PID akan digunakan ke dalam lengan robot untuk mengawal keluaran daya kilas. Oleh itu, tujuan projek ini dilakukan ialah untuk merekakan pengawal PID yang dilengkapi dengan lengan robot untuk mengawal daya kilas gerakan lengan. Penggunaan aplikasi "Matlab" dan "Simulink" akan digunakan untuk menganalisis data daripada simulasi.

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DC	-	Direct current
PC	-	Personal Computer
K_P	-	Proportional Gain
K_i	-	Integral Gain
K_D	-	Derivative Gain
m	-	Mass
a	-	Side of Surface
Kg	-	Kilogram
m	-	Meter
τ	-	Torque
α	-	Angular Acceleration

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CHAPTER 1

INTRODUCTION

1.1 Project Background

The robotic arm is a useful device for surgical and industrial application which able performs movement on certain situation. The robotic arm movement and torque are measured based on the kinematic design. A robotic arm is a mechanical controlled device which is designed to do movement of a human arm. The robotic arm can be design by many actuators like pneumatic, hydraulic and motor. Due to the arm movement, it requires a type of controller for performing the movement. In this past, the types of controller use on robotic arm like PD controller, PI controller, and PID controller are used on force feedback arm robotic. Robotic arms are used in the medical field to carry out certain precise operations. The robotic arm also used in light and heavy industrial application as shown in Figure 1.1.

Figure 1.1: Industrial arm robotic

1.2 Motivation

Within past few decades, there has been an explosion of interest in robotic arm. Robotic arm are being utilized in high-performance application like manufacturing, surgical and many more. There are many difference robotic arm use in an application which has good and bad attributes. The bad attributes in a system which has cause the lag of efficiency. However, the next generation of robotic arm will need to estimate the proportional torque in industrial and surgical industry. The robotic arms are composed with Direct Current (DC) motor as an actuator. The DC motor can be implementing by using control strategies to control the output torque of the robotic arm.

1.3 Problem Statement

In the recent year, the robotic arm use rapidly increases in medical and industrial application. The robotic arm occurs problem like estimating the proportional torque in the motor. The inconsistent of voltage supplied into the motor cause the output torque produce is unstable. The main challenge in this project is to controlling the proportional output torque of robot arm.

There are a few types of controller for an upper limb robotic arm but in this project, the proportional-integral-derivative (PID) controller is chosen as the controller for the DC motor. This is because PID controller or proportional–integral–derivative controller helps get the output, short position time, with small overshoot and small error.

1.4 Objective

The main objective of this project is to design a proportional-integral-derivative (PID) controller using DC motor for able to control the output torque of an upper limb robotic arm. The objective includes the development of controller, simulation, excitation circuits, and hardware interfacing. The summary of the objectives of this project are listed as follows:

1. To design and develop an upper limb robotic arm.
2. To design and develop a proportional-integral-derivative (PID) controller that able control output torque of an upper limb robotic.
3. To compare experimental result and simulation for the controller and DC geared motor.

1.5 Scope

In order to achieve the objective of the project, there are several scope had been outlined. The scopes are as follows:

1. To design and fabricate an upper limb robotic arm.
2. To design a proportional-integral-derivative (PID) controller that control output speed and torque of an upper limb robotic arm.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this section, the kinematic of robotic arm, actuator, controller and literature review will be delivered. Robotic arm is a device used to many applications in industry and surgical. The development of an upper limb robotic arm is passively important and needed to research based on the type of application perform, actuator and the controller.

2.2 Upper Limb Robotic Arm

The idea of a robotic arm has been introduced since around the 1960's [1]. The device can assist human for several fields; i.e. for military, industrial, medical and space purpose. The development of robotic arm or exoskeleton arm has many benefits and able to assist human in their daily life.

2.2.1 Kinematic of Upper-Limb Robot

A five degrees of freedom exoskeleton with wearable structure and anthropomorphic which cover the entire motion of human arm for upper-limb rehabilitation in virtual reality [1]. The proposed robot automatically assists by a button mainly based a controller able force at the center of human palm through a handle grasped by the user. The Light Exoskeleton (L-EXOS) is characterized by a serial kinematic which consist five rotational joint as shown in Figure 2.

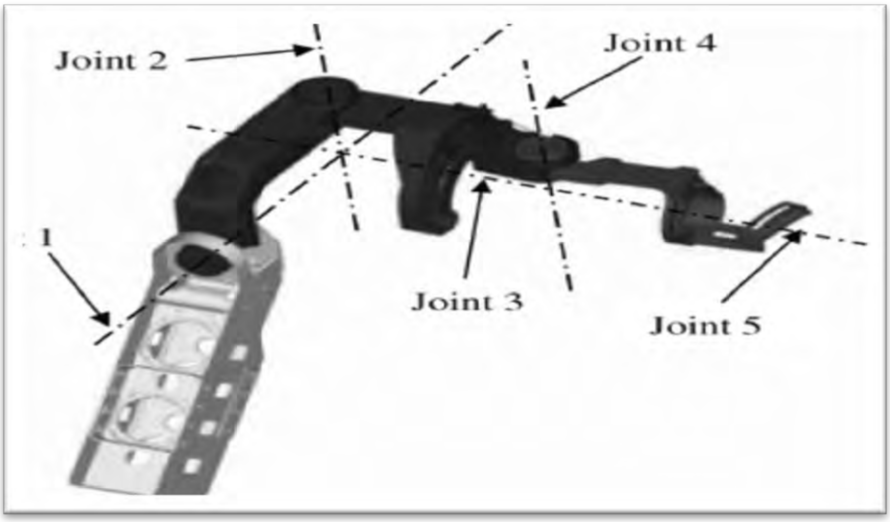

Figure 2.1: The kinematics of light weight exoskeleton (L-EXOS) [1]

The first degree of freedom is actuated and built in sensor, and the fifth degree of freedom is equipped with potentiometer. The first three rotational joint is mutually orthogonal which emulated a spherical joint the same center of rotational on the human shoulder. The orientation of the first joint are optimized, therefore it will maximize the workspace of should joint and avoid interference between mechanical link and user. The third joints are coincident with the axis of ideal upper limb. Meanwhile the fourth and fifth is coincident with the elbow joint and forearm. The condition of the forearm and elbow joint is assuming zero position. The range of motion can be achieve by the lightweight exoskeleton (L-EXOS) is 2.5º to 105º. The Denavit –Hartenberg parameter by Lightweight Exoskeleton (L-EXOS) is filled as shown in Table 1.

Table 1: Denavit-Hartenberg parameters for the light weight exoskeleton (L-EXOS system) [1]

i	θ_i	α_i	a_i	d_i
1	$\frac{\pi}{2}$	$\frac{\pi}{2}$	0	0
2	$\frac{\pi}{2} - \Psi$	$\frac{\pi}{2}$	0	0
3	$\frac{\pi}{2} - \Phi$	$\frac{\pi}{2}$	0	-L1
4	$\frac{\pi}{2} - \Phi$	$\frac{\pi}{2}$	0	0
5	0	0	0	L2

2.3 Actuator

An actuator is a device which converts electric energy into a physical motion. The actuator produce rotation or linear motion based the application applied in the industry. There are several types of actuator use in robotic arm like hydraulic, pneumatic or electronic signals. The most popular actuator use in a robotic arm is DC motor. The DC motor is electric motor that runs on direct current electrically.

The DC motor converts electrical energy into mechanical energy. The stator is stationary in space by definition and subsequently current. The present in the rotor is switched by the commutator to additionally be stationary in space. The relative point between the stator and rotor attractive flux is maintained close to 90 degrees, which creates the highest torque. There are many type of DC motor use as actuator in robotic arm which are brushless DC motor, stepper, servo and many more. The most frequent motor use as actuator in robotic arm is Brushless DC motor (BLDC).

2.3.1 DC Motor

A position control of brushless using DC (BLDC) motor proposed. DC (BLDC) motor is a synchronous electric motor which is controlled by direct current power (DC) and which has an electronically controlled system, rather than a mechanical replacement system dependent upon brushes [2]. In the brushless DC motor, the element like current, torque, voltage and rpm are directly identified. The advantage of brushless DC motor is good reliability, longer lifetime, reduced noise and more efficient in terms of power consumption. The disadvantage of brushless DC motor (BLDC) is higher initial cost due to its construction. Second, it required an electric controller in order to operate a Brushless DC Motor.

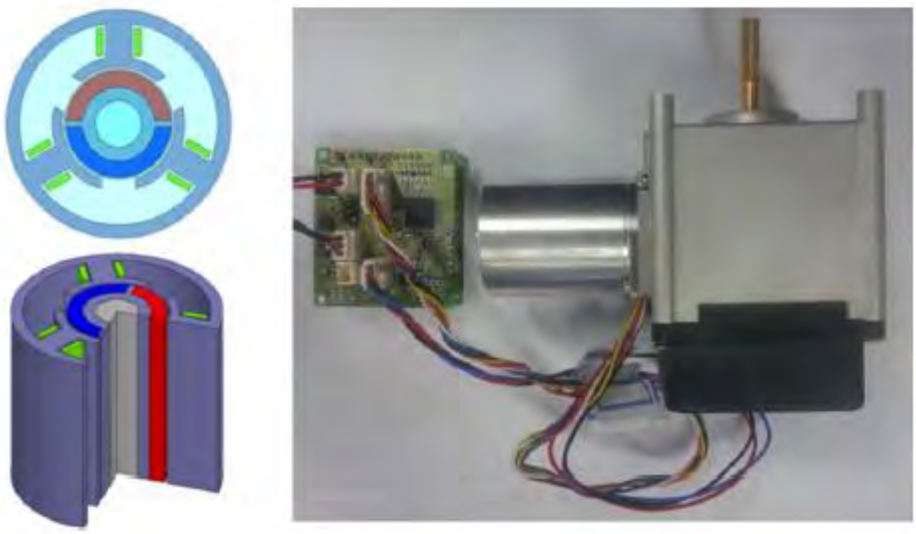

Figure 2.2: Brushless DC motor (BLDC) [2]

2.4 Sensory System

2.4.1 Hall Sensor

Based on the Hall Effect sensor characteristic, the rotor rotation information can be acquired. The position and speed of the rotor can be calculated by using Hall Effect signal [3]. In the experiment, the hall sensor are placed in the brushless DC motor to knowledge the position of the motor. The hall is place with 120-degree interval in the motor operation. When the magnet poles of the interface to hall sensor, the signal is generated. There are three hall sensor planted to the brushless DC motor since it has 120-degree interval. For a one complete rotation, it has to reach 360-degree for determine the position of the brushless DC motor. The operating principle of hall sensor can be explained based on the Figure 2.3 shown.

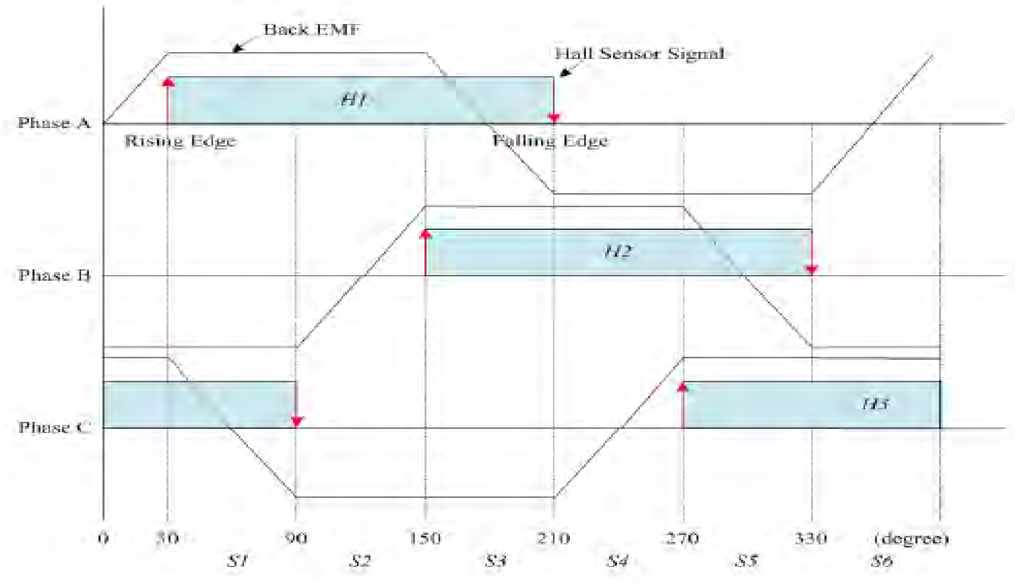

Figure 2.3: Back EMF and Hall Effect sensor signal [4]

2.4.2 Torque Sensor

Torque sensor is a characteristic of human arm where it can feel the external power. In order to know precisely the intentions of a human interacting with a robot, it is possible to use a force/torque sensor to measure the forces and moments applied on a handle. The advantage of this type of sensor, in comparison with a sensitive robotic skin covering the whole manipulator, is that it allows the precise measurement of the applied moments and shearing forces instead of the normal forces alone.

The commercially available force/torque sensors are built from strain gages, which have the disadvantage of providing a noisy signal. This is problematic because control algorithms used in human-robot interaction often require the variation rates of efforts. It differentiating noisy signals with respect to time is often only possible by filtering the signal, which reduces the performances of a collaborative robot [5]. Furthermore, force/torque sensors based on strain gages output signals which drift over time even if the applied efforts remain constant. Thus, a collaborative robot could detect small forces applied on it and start moving even if nobody touches it.

A robust torque control is proposed for one degree arm robot which is equipped with torque sensor for controlling the output torque [5]. The mechanical structure of a one degree of freedom flexible joint robot is shown as Figure 2.4. A motor generate a driving torque and the torque is increase by speed reduction part. The speed reduction part is consisting of timing belt, pulley and harmonic drive. The joint torque is measure by a torque sensor which mounted between harmonic drive and robot arm link.

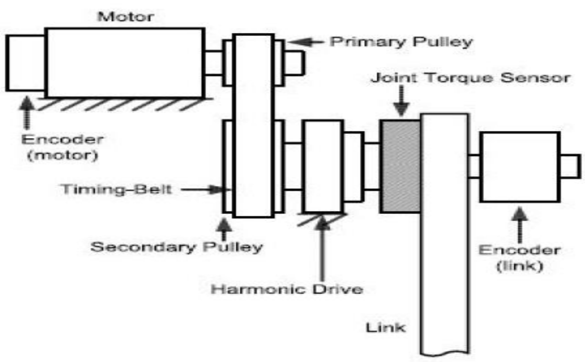

Figure 2.4: The mechanical structure of a one degree of freedom flexible joint robot [5]