REAL TIME MODEL VALIDATION AND CONTROL OF DC MOTOR USING MATLAB AND USB

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To my precious wife. Without her help and
encouragement it simply never would have been.

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ABSTRACT

Mechatronics system needs motion or action of some sort. It is created by a force or torque that results in acceleration and displacement. To produce this motion or action, actuators are the device being used. There are many types of actuators and one of the common types of electromechanical actuators is the direct current (DC) motor. The main goal of this project is to estimate the actual model of DC motor and control its speed using an embedded system interfaced to computer. The model identification is achieved using simple and low cost data acquisition system. An Arduino Uno embedded board system is used to collect the data from the sensors, send it to the computer, and control the model. The data processing is performed using MATLAB/SIMULINK. The validation for both the model and the controller are verified through simulations and experiments. The identification and the controllers results were coherent and successful.

ABSTRAK

Sistem Mekatronik memerlukan pergerakan dan tindakan atau serupa. Ia dicipta oleh daya atau ‘torque’ dalam menghasilkan pecutan dan jarak. Untuk menghasilkan sesuatu pergerakan atau tindakan, aktuator adalah alat yang digunakan. Terdapat pelbagai jenis aktuator dan salah satu jenis aktuator elektromekanikal adalah arus terus (DC) motor. Objektif utama projek ini adalah untuk menganggar model sebenar DC motor dan mengawal kelajuannya menggunakan sistem embedded yang dihubungkan dengan komputer. Pengenalan model akan dicapai dengan menggunakan ‘data acquisition’ disebabkan kos rendah dan mudah. Sistem Embedded Arduino Uno digunakan untuk mengumpul data daripada sensor, kemudian dihantar kepada computer dan mengawal model. Pemprosesan data dijalankan dengan menggunakan MATLAB/SIMULINK. Pengesahan untuk kedua-dua model dan kawalan (controller) disahkan melalui simulasi dan eksperimen. Pengenalan dan hasil system kawalan adalah sesuai dan berjaya.

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LIST OF ABBREVIATIONS

DC	-	Direct Current
PID	-	Proportional Integral Derivative
LQR	-	Linear Quadratic Regulator
USB	-	Universal Serial Bus
MMN	-	Multilayer Neural Network
MLP	-	Multilayer Perceptron
NARMAX	-	Nonlinear Autoregressive Moving Average with eXogenous input
RLC	-	Recursive Least Square
GA	-	Genetic Algorithm
FLC	-	Fuzzy Logic Controller
PSO	-	Particle swarm optimization
SMC	-	Sliding Mode Controller
ISM	-	Integral Sliding Mode
DSM	-	Dynamic Sliding Mode
MFCC	-	Mel-Frequency Cepstral Coefficient
VQ	-	Vector Quantization
PPR	-	Pulses Per Revolution
SRAM	-	Static Random Access Memory
EEPROM	-	Electrically Erasable Programmable Read-Only Memory
RPM	-	Revolutions Per Minute
PWM	-	Pulse Width Modulation

LIST OF SYMBOLS

T_m	-	Motor torque
i_a	-	Motor armature current
K_m	-	Motor torque constant
e_a	-	Back e.m.f. voltage
θ	-	Angular position
ω_m	-	Angular velocity
J_m	-	Motor moment of inertia
b	-	Motor viscous friction constant
v_a	-	Motor armature voltage
R_a	-	Motor armature resistance
L_a	-	Motor armature inductance
K_P	-	Proportional gain
K_I	-	Integral gain
K_D	-	Derivative gain
$\mathcal{J}$	-	Performance index
X	-	Motor state vector
u	-	Motor input vector
Q	-	State cost matrix
$\mathcal{R}$	-	Performance matrix

CHAPTER 1

INTRODUCTION

1.1 Overview

Many applications such as blowers, elevators, conveyors and robotics manipulators use DC motors to control their speed; because it has the property of simplicity and the capabilities of high torque and easy control as well. DC motors are extensively utilized in control systems area as an actuator or a control element in the process control systems. It converts the output signal from the controller into torque or an angular displacement to control the magnitude of the energy or the object coming to the process. The main goal of this project is to estimate the actual model of DC motor and control its speed using an embedded system interface to computer. The mathematical model is developed and nonlinear effects are taken in consideration in order to simulate the reality as possible. The control methods used are the Proportional Integral Derivative (PID) controller and Linear Quadratic Regulator (LQR). For this project, the controller and the motion of DC motor are simulated using MATLAB and SIMULINK. The validation for both models and the controller are verified through simulations and experiments. The results were successful.

1.2 Basic Construction of DC Motor

Generally, whether AC or DC motors, have several basic components in common, as shown in Figure 1.1 which illustrates the basic components of DC motor.

(i) A stator

Represents the static part of the motor that includes the field windings and provides the fixed magnetic field.

(ii) A rotor

Represents the rotation part that causes the mechanical rotation.

(iii) Auxiliary components

Like a brush/commutator where it's main function is to relay the current form the mains to the armature windings.

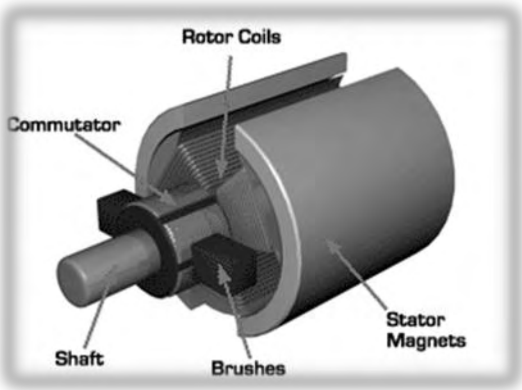

Figure 1.1 Basic components of DC motor (www.electrical4u.com)

1.3 Theory of Operation

The operation theory of DC motor can be summarized according to the practical application of Faraday's law since the mid-nineteenth century; which states that electric current is produced when there is relative motion between a conductor and magnetic field. When the supply current is relayed to armature windings through the brushes, it causes a magnetic field to be produced. This field leads to rotate the rotator and result a torque.

1.4 DC Motor Characteristics

When the speed control is required, motors with DC power sources have many applications. There are three major sectors that these motors can be categorized in; series, shunt or compound machines. These categorization is based on how armature is connected to the field windings. Some certain applications need permanent magnetic DC motors. Operational characteristics of a motor can be determined by measuring the amount of mechanical load applied to the motor's shaft.

By increasing the mechanical load, there would be a decrease in the speed of a motor. As speed decreases, the voltage made by generator action and induced to the motor's conductors decreases. This depends on the number of rotating conductors as well as the rotation speed. However, by increasing the working (supply) voltage, the amount of current flowing through the armature windings will increase. Meanwhile the motor's torque is directly proportional to the armature current, so it means that the more torque the more armature current. Conversely, when the mechanical load is decreased, all the above will be opposite.

1.5 Types of DC motors

Motors are commercially available in four types:

(i) Permanent-magnet motors
(ii) Series-wound motors
(iii) Shunt-wound motors
(iv) Compound-wound motors

The common part in all motors including AC motors are the armature or rotor. A drum-like armature is the most practical type of that. By this configuration the coil windings on the armature will be permitted to be efficiently introduced to the magnetic field.

Since the armatures of these motors are similar, their categorization is often based on the magnetization and wiring of the filed poles. It is needed to comprehend the generation of different fields and the pros and cons of each.

(i) Permanent-Magnet Motors

Commonly, for low-torque applications this type of motor is used. In this motor, brush/commutator assembly is designed in order to connect the DC power supply directly to the armature conductors. Permanent magnets fixed on the stator have a duty to produce the magnetic field. The rotor of permanent magnet is a wound armature. There are several benefits and advantages of Permanent-magnet motors against conventional types of DC motors.

One is the reduced cost; they are totally cheaper than conventional ones. The permanent-magnet motor is similar to the shunt-wound motor in speed characteristics. Gear motor can be considered as one of the most common permanent-magnet motor. One of their advantages is offering the rotation perpendicular to the motor's rotation.

(ii) Series-Wound Motors

In this motors, the way of connection of the armature and filed circuit of a DC motor defines its basic characteristics. This is true for the series-wound motor, when there is a series wiring between armature and field circuit. So, there would be just one particular way for the current to flow from the DC voltage source. Consequently, by a few turns in the large diameter wire, the filed will be wound, and giving the field a low resistance. The current through the filed changes with variation of the mechanical load applied to the shaft.

Increasing the load, the current will increase, hence, a stronger magnetic field will be created. The motor’s speed differs from very fast to very slow, at no load and heavy loads respectively. In the series motor a high-torque output is the result of flowing large currents through the low-resistance field. Thus in the case of heavy load applications with no regulation needed for speed, these motors are ideal, such as an automobile starter motor. There should be always a load on the large series-wound motors, because the high speed will commonly cause damage to the brushes or commutator.

However, in small series-wound motors this drawback is solved by producing enough internal friction. Hand tools such as drills, saws, etc., kitchen application like blenders, mixtures, etc., as well as winches and hoists are the common applications for this type of motor. One of the most benefits of these types of motors is that they can operate under both DC and AC power supplies.

(iii) Shunt-wound Motors

The most common type of DC motors is Shunt-wound motors. In this configuration, the wiring of armature and field coils is parallel. There is a relatively high resistance due to the wound field coils. They are wound by many turns of thin wire. There is a fact that high resistive field and the armature are parallel, this caused a very low current flowing through the field coils. The shunt motor flows through the armature circuit draw about 95 percent of the current.

It is important not to forget the properties that controls the magnetic field produced by the electromagnetic. The current flow through the conductor or the turns of wire around the conductor may increase the field. Due to the, a large magnetic field is created due to the filed windings which is produced by large number of wire turns. The field current can be changed by employing an adjustable resistance in series with the field windings.

Increasing the resistance, results a decrease in field current, so that the strength of the electromagnetic field reduces. When the field flux is decreased the speed of armature rotation will be faster. This is because of the interaction of the reduced magnetic-field. Therefore, by employing a field rheostat the speed of the shunt motor can simply be changed.

Speed control is good in this type of motor, however, by increasing the load, there would be a slight decrease in the speed. The speed reduction is not such important aspect, because it is so slight. The industrial applications like machine tools, are one of the most common application of this type of motor due to the excellent speed control and low resistance.

(iv) Compound-Wound Motors

There are two sets of field windings in this type of motors, both series and parallel with armature. The desired advantages of the series and shunt-wound motors are combined in one motor. Both cumulative and differential methods are used in compound motor. In cumulative compound motor, series and shunt fields help each other. Conversely, in differential compound motor they oppose each other. By increasing the armature current, there are different behaviour of the torque and speed of these two methods. However, both of them have the high torque characteristics similar to the series motor, and the speed control of shunt motor. It is expensive and this is the only drawback for this motor. In comparison to the previously DC motors, a compound motor is much more expensive.

1.6 Problem Statement

The error between simulated and measured outputs of DC motor is obvious. Many studies were done in order to reduce this error. Nevertheless the performance of the results depends on the accuracy of the system model estimated and also sensors. In general, an accurate model of a DC motor is difficult to find, and the model obtained from the system identification may be only approximated model.

1.7 Objectives

The project objectives as listed below are expected to be able to answer and provide solutions to the problem statements mentioned above:

(i) To develop a mathematical model of a DC motor by using a system identification approach.
(ii) To carry out model identification using experimental data.
(iii) To design and implement a DC motor speed controller.

1.8 Scope

The project objectives as listed below are expected to be able to answer and provide solutions to the problem statements mentioned above:

(i) A transfer function of a DC motor is developed.
(ii) A system identification approach is used to construct a DC motor model.
(iii) Relevant measurements are made via USB connector.
(iv) The controller is validated through practical experiments.

1.9 Structure of Project

In this project, objectives, procedure of the project development as well as the literature of topics that are concerned and relevant will be stated.

Chapter I which is the introduction chapter states the world of DC motors, it includes a brief introduction, construction and theory operation of DC motors, also the background of the project which includes objectives, scope, significant of project and problem statement. Chapter II explores the literature materials that show different methods and techniques tried to identify the parameters and control the speed of DC motors. Chapter III exhibits the research methodology used in this project, which will show the steps in order to complete this project. Chapter IV shows the results and discussion of estimating the model, control it, and then validate the results. Finally, Chapter V indicates contribution of the study, and suggestions for future works.

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