

Parameter Identification of a Class of DC Motor

A. A. Bature¹, Mustapha Muhammad², Auwalu M. Abdullahi³

¹(Department, Electrical Engineering/ Bayero University Kano, Nigeria)

^{2,3}(Department, Mechatronics Engineering/ Bayero University Kano, Nigeria)

ABSTRACT: This paper presents parameter estimation for a class of DC motor using cheap and simple data acquisition system. The parameters estimated are the motor armature-winding resistance, back e.m.f constant, motor torque constant, moment of inertia, and the viscous friction. A FIO STD development board is used as the data acquisition device which communicates with the sensors and the computer. MATLAB Simulink environment was used for data processing and computations. The validity of the estimated parameters is verified through experiments and simulations.

Keywords-Parameters estimation, DC motor, FIO STD development board, sensor

I. Introduction

DC motors are widely used in industrial control systems, and many other fields. This is due to their easiness in modelling and control. To design an effective controller for physical systems such as DC motor an accurate model of the system is required; hence accurate parameters of the motor are required. The values of the motor parameters usually provided by the motor manufacturer may not be considered adequate, especially for cheaper DC motors which tend to have relatively large tolerances in their electrical and mechanical parameters; hence there is need for accurate parameter estimation for the DC motor [1].

General system identification methods [2–5] can be applied for DC motor model identification. Several techniques are currently employed for parameter identification [6]–[7]. Various works have been reported in literature on parameter identification of DC motor [1, 8–9]. In [1], the parameters of the DC motor are computed based on the Taylor series expansion of the motor speed response under an input of constant voltage, whereas in [8] the angular acceleration and the derivative of the armature current were first estimated using Kalman filter and then the result was used in AC equation of the motor to identify the parameters. An offline identification method was used by [9] to estimate the motor parameters.

In this paper, the parameters of the DC motor will be estimated using the torque equation of the DC motor and the experimental data of armature current, motor speed and motor acceleration. The validity of the parameters will be demonstrated via simulations and experiments.

The rest of the paper is organized as follows; section 2 describes the DC motor model, section 3 shows the experimental setup and describes the specifications of the equipment's used, while section 4 shows how the data is measured, section 5 includes experimental results and the performance of the proposed system. Finally, Section 6 concludes the findings of this work.

II. DC Motor Model Description

The general position-voltage transfer function of a DC motor is given by equation (1) [10].

$$\frac{\theta_m(s)}{E_a(s)} = \left(\frac{(K_t/R_a J_m)}{s \left[s + \frac{1}{J_m} (D_m + \frac{K_t K_b}{R_a}) \right]} \right) \dots \dots \dots (1)$$

where θ_m is the angular position in radians, E_a is input voltage in volts, K_t is torque constant in Nm/A, K_b is back e.m.f constant in Vs/rad, J_m is motor inertia in kg-m², D_m is motor damping in N-m s/rad, R_a is armature resistance in ohms.

Equation (1) can be written as:

$$\frac{\theta_m(s)}{E_a(s)} = \left(\frac{K}{s(s + \alpha)} \right) \dots \dots \dots (2)$$

based on which the speed-voltage transfer function can be written as:

$$\frac{\dot{\theta}_m(s)}{E_a(s)} = \left(\frac{K}{s + \alpha} \right) \dots \dots \dots (3)$$

The general torque equation of a DC motor is given by:

$$T = J\ddot{\theta} + D\dot{\theta} \dots \dots \dots (4)$$

The torque developed by the motor can be written in terms of the current (I) drawn by the motor as:

$$T = k_t I \dots \dots \dots (5)$$

Substituting (5) in (4) gives:

$$k_t I = J \ddot{\theta} + D \dot{\theta} \dots \dots \dots (6)$$

In this paper equation (6) will be used for the DC motor parameters computations while equation (3) will be used for the parameters validation via simulation.

III. Experimental Setup

Figure 1 illustrates the block diagram of the experimental setup used in this work. It consist of FIO STD development board and a personal computer which serves as the data acquisition system, a current sensor and a rotaryencoder as the sensors for measuring the current drawn by the motor and motor speed respectively, the motor driver which is served as the servo-amplifier and the DC motor itself.

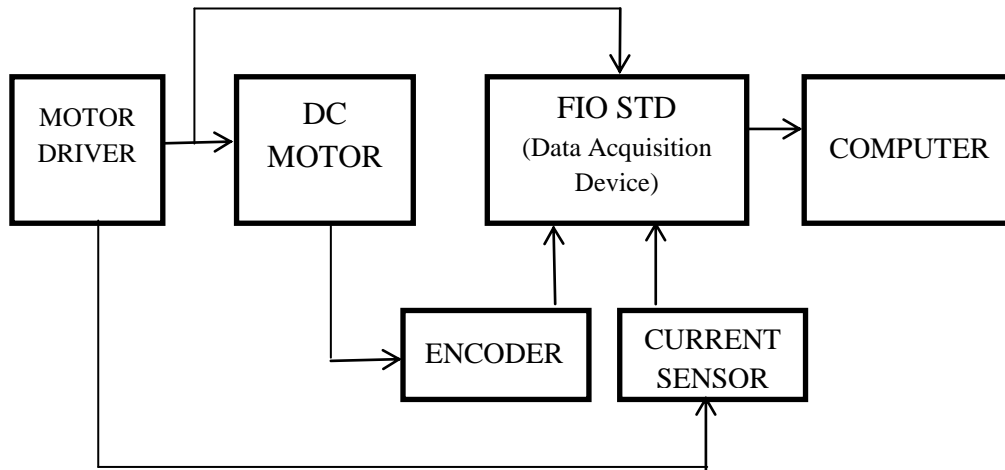


Fig.1 Experimental block diagram

The DC motor considered in this paper is MY1016Z2-250W manufactured by YeuqingOnlybo Instruments. The specifications of the motor are given in table 1.

Table 1. DC motor specifications

Operating voltage (v)	24
No load speed (rpm)	434
No load current (A)	1.8
Maximum current (A)	9.74
No load torque (Nm)	0.39
Maximum torque (Nm)	11.5

The rotary encoder used in the experiment is B106 Rotary Encoder [12] manufactured by Cytron Technologies, and has the following specifications: Operating Voltage: 5V to 24V, Pulse: 500P/R and maximum shaft speed: 6000RPM. It is designed to provide pulse feedback when the shaft is rotated. The shaft of the rotary encoder is connected to the DC motor and the pulses are recorded using the FioStd development board which sends the pulses to MATLAB Simulink via computer where the actual angular speed ($\dot{\theta}$) and angular acceleration ($\ddot{\theta}$) of the motor are computed. The current sensor used is ACS756 Current Sensor IC [13] which is also manufactured by Cytron Technologies. It gives a dc voltage which is proportion to the current drawn by the motor. For this current sensor an output of 2.5V represents 0A, whereas 0V and 5V represents -50 and 50A respectively. The output of the current sensor is fed to the data acquisition system where the actual current (I) drawn by the motor is computed. A MDS40ASmartDrive40 motor driver [14] also manufactured by Cytron Technologies was used as the motor driver which drives the motor and provide power signals to the rotary encoder and current sensor.

IV. Data Measurement

The motor armature resistance R_a of the motor is measured directly using ohmmeter, while the motor constants K_t, K_b are calculated with no load current measured value and using the no load torque from the manufacturer. Various readings of current (I) drawn by the motor, actual angular speed ($\dot{\theta}$) and angular

acceleration ($\ddot{\theta}$) of the motor are measured and recorded and average values J_m and D_m are computed using equation 6. The estimated parameters are shown in shown in table 2.

Table 2. Estimated parameters of the DC motor

Torque constant K_t (Nm/A)	0.2063
Back emf constant K_b (V-s/rad)	0.2063
armature resistance R_a (ohms)	0.5000
Motor inertia J_m (kg-m ²)	0.3550
Motor viscous friction coefficient D_m (Nm s/rad)	0.0124

Substituting the values of the parameters in table 2 in equation 3 and simplifying, the numerical voltage-speedtransfer function of the motor is obtained as:

$$\frac{\dot{\theta}_m(s)}{E_a(s)} = \left(\frac{34.1}{s + 16.1} \right) \dots \dots \dots (7)$$

V. Results and Validation

To validate the parameters estimated, simulations were carried out and the results were compared with those obtained from the experiments. The experimental results were obtained using the experimental setup in figure 1, while the simulated result was obtained using equation 7 in MATLAB Simulink environment. The input signal used which is random DC voltage is shown in figure 2, and the results for the output speed response are compared as shown in figure 3.

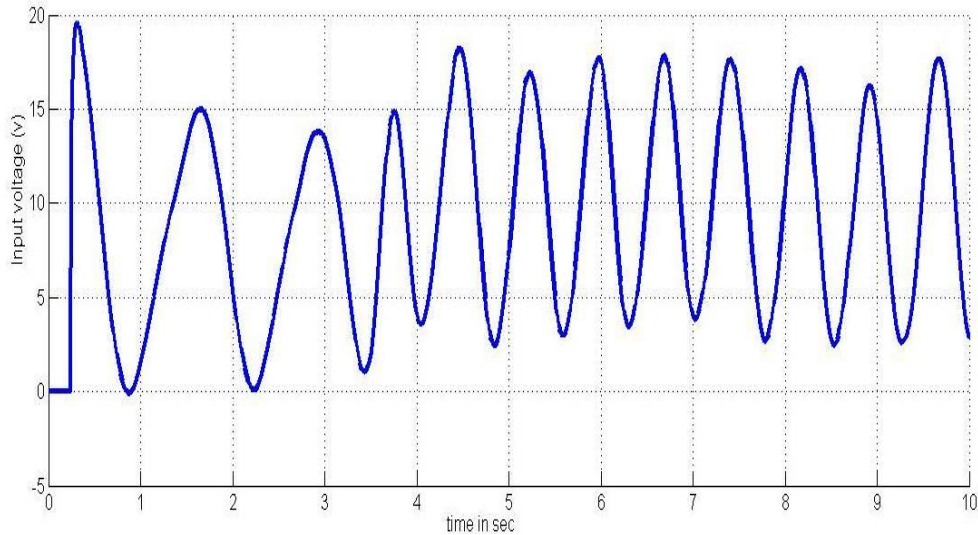


Fig. 2 Random input voltage

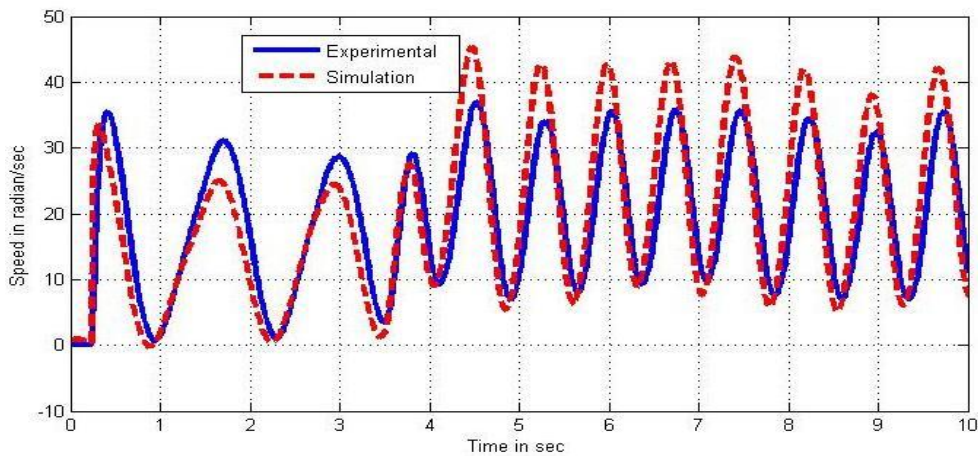


Fig. 3 Speed response comparison

From the speed response in figure 3 it can be observed that the experimental result agrees with the simulated result, and the error between output signals of simulated system and actual system is acceptable; hence the parameters estimated are valid

VI. Conclusion

An effective and convenient, parameter identification approach is presented which estimates the DC motor parameters using easy and cheap data acquisition system. A MATLAB Simulink environment is used to acquire the data, process and compute the parameters, and the great open loop test results were presented. The estimated motor parameters can be used to verify the DC motor performance or be used to build a model of the motor for the subsequent controller design or system optimization.

References

- [1] Research Article "DC Motor Parameter Identification Using Speed Step Responses" *Modelling and Simulation in Engineering* Volume 2012, Article ID 189757, 5 pages
- [2] L. Ljung, *System Identification: Theory for the User*, Prentice Hall, 2nd edition, 1999.
- [3] H. Unbehauen and G. P. Rao, "A review of identification in continuous-time systems," *Annual Reviews in Control*, vol. 22, 1998, pp. 145–171.
- [4] G. F. Franklin, J. D. Powell, and M. L. Workman, *Digital Control of Dynamic Systems*, AddisonWesley, 2nd edition, 1990.
- [5] J. C. Basilio and M. V. Moreira, "State-space parameter identification in a second control laboratory," *IEEE Transactions on Education*, vol. 47, no. 2, 2004, pp. 204–210.
- [6] S. Sastry, and M. Bodson, *Adaptive Control Stability, Convergence, and Robustness*, Prentice-Hall *Adv. Reference Series*, 1989.
- [7] K. J. Astrom, and B. Wittenmark, *Adaptive Control*, Addison- Wesley Series in *Electrical Engineering: Control Engineering*, 1989.
- [8] S. S. Saab and R. A. Kaed-Bey, "Parameter identification of a DC motor: an experimental approach," in *Electronics, Circuits and Systems, 2001. ICECS 2001. The 8th IEEE International Conference on*, 2001, pp. 981-984 vol.2.
- [9] DUB, M., JALOVECKY, X & R. DC motor experimental parameter identification using the Nelder-Mead simplex method. *Power Electronics and Motion Control Conference (EPE/PEMC)*, 2010 14th International, 6-8 Sept. 2010, S4-9-S4-11.
- [10] N. S. Nise, *Control Systems Engineering*, 6 ed.: John Wiley & Sons, Inc, 2011.
- [11] *FiOStd Datasheet* Available: http://site.gravitech.us/DevelopmentTools/Matlab-Simulink/FiO-Std/fiostdy20_datasheet.pdf 2010.
- [12] *CytronB016 Rotary Encoder*. Available: www.cytron.com.my/viewProduct.php?pcode=B 2010, 106-23983
- [13] *I. Allegro MicroSystems. (ACS756 Current Sensor IC)*. Available: www.allegromicro.com 2011.
- [14] *CytronMDS40ASmartDrive40*. Available: www.cytron.com.my/viewProduct.php?pcode=MDS40A, 2011.