Model Parameter Identification for DC Motor using Rapid Control Prototyping System

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Abstract—In this paper, an alternative parameter identification scheme for the direct current (DC) motor is implemented using the rapid control prototyping (RCP) system. Unlike the existing method the proposed RCP based parameter identification scheme measures actual output, modifies and verifies model parameters on the RCP system with DC motor in similar environments to the real ones, and thus can evaluate identification performances before entering the embedded implementation stage. The proposed RCP based parameter identification scheme automates many of the demanding and repetitive tasks and allows corrections and changes to be made early when they are easy, which can reduces the development time and effort.

Index Terms—Parameter Identification, Rapid Control Prototyping, DC Motor.

I. Introduction

Rapid control prototyping (RCP) has been widely used in many engineering fields such as automobiles, motion control, mechatronics, and so on, as an efficient control design strategy [1]- [3]. With RCP, mathematical models are automatically imported typically from MATLAB/Simulink into a real-time simulator configured with input/output interfaces, before being connected to real-world systems.

Meanwhile, because of their high reliability, flexibility and low cost, where motor's speed and position control are required, the direct current (DC) motor has been successfully applied for industrial applications, robot manipulators and home appliances [4]- [7]. However, the large number of DC motors used is attended by a large amount of time and resources devoted to inspecting them at the end of their production cycle. The time needed for this process should be kept as brief as possible so that the inspection procedure is not the slowest part of the production process. Due to the increasing mass production of these motors, procedures for inspecting them have been developed which are able to determine the test objects' characteristic curves within seconds. Such procedures are known as parameter identification procedures. The parameter identification for the DC motor is the process of computing DC motor model's parameter values from measured output and can be applied to different types of mathematical models, including statistical models, parametric dynamic models, etc. The incorrect calculation of the DC motor parameters leads to the weakness in the control and its instability, so the accuracy in extracting the parameters is a real problem [8]- [10].

In this paper, an alternative parameter identification scheme for the DC motor is implemented using the RCP system. As shown in existing works, three processes are required to obtain model parameters: measuring actual output from DC motor and modifying model parameters until the results of simulations match measured output, and verifying obtained model parameters on actual DC motor system. These three processes are all carried out separately in different experimental environments. On the other side, the proposed RCP based parameter identification scheme measures actual output, modifies and verifies model parameters on the RCP system with DC motor in similar environments to the real ones, and thus can evaluate identification performances before entering the embedded implementation stage. Thus, the proposed RCP based parameter identification scheme provides a fast and cost-effective way for control engineers. Such early verification through the proposed scheme enables control engineers to easily adjust their designs until they are satisfied with the results, allowing them to have confidence that their designs will work in the field. That is, the proposed RCP based parameter identification scheme automates many of the demanding and repetitive tasks and allows corrections and changes to be made early when they are easy, which can reduces the development time and effort.

II. DC Motor and RPC Systems

Fig. 1 shows a DC motor speed control system using the RCP system. The DC motor has been used as a common actuator in control systems. The DC motor,

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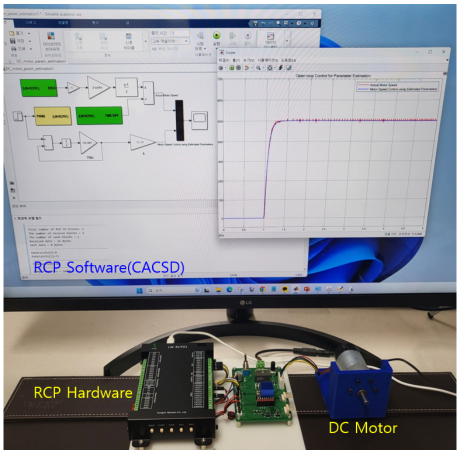


Fig. 1: Configuration of DC motor speed control using RCP system

coupled with wheels or drums and cables, directly provides rotary motion and can provide transitional motion.

In general, the torque generated by a DC motor is proportional to the armature current and the strength of the magnetic field. In this paper, the magnetic field is assumed to be constant and thus the motor torque is proportional to only the armature current by a constant factor. The following dynamic equations can be derived using Newton's 2nd law and Kirchhoff's voltage law:

$$\begin{aligned} J_m \dot{w}(t) + B_m w(t) &= Ki(t), \\ L_a \dot{i}(t) + R_a i(t) &= v(t) - Kw(t). \end{aligned} \tag{1}$$

In addition, the transfer function of the DC motor system can be represented by.

$$\frac{W(s)}{V(s)} = \frac{K}{(J_m s + B_m)(L_a s + R_a) + K^2} [\frac{rad/s}{V}]. \tag{2}$$

As shown in (1) and (2), the DC motor system consists of many kinds of variables and parameters, which are defined in Table I. Values of physical parameters used for the control system design are required.

The RCP system in this paper consists of a PC based computer-aided control system design (CACSD) tool for

TABLE I: Variables and parameters of DC motor system

Variables	
$w(t)$	rotational speed $[rad/s]$
$i(t)$	armature current $[A]$
$v(t)$	armature voltage $[V]$
Parameters	
J_m	moment of inertia of the rotor $[kg \cdot m^2]$
B_m	motor viscous friction constant $[N \cdot m/(rad/s)]$
K (K_e)	electromotive force constant $[V/(rad/s)]$
K (K_t)	motor torque constant $[N \cdot m/A]$
R_a	electric resistance $[\Omega]$
L_a	motor torque constant $[H]$

computing the control action and small-sized embedded hardware for I/O operation and data transfer through built-in high-speed USB interfaces [1]. Excluding the DC motor, the RCP system consists of two subsystems. The one is a PC system where MATLAB/Simulink is running under Microsoft Windows. The other is an embedded microcontroller board(such as Arduino Due based on the Atmel SAM3X8E ARM Cortex-M3 CPU) with built-in high-speed USB interface. The PC performs control computations and the embedded microcontroller board is in charge of I/O operation through its peripherals such as analog-digital-converter, encoder counter, digital-analog-converter, and pulse width modulation. The PC runs a Simulink controller model in which the sensor data sent from the embedded microcontroller board are received through input blocks supported by the proposed RCP system, the control values are computed using the received sensor data, and the computed control data are then sent to the embedded microcontroller board using the output blocks, which are also supported by the RCP system. Data communication between the PC and the embedded microcontroller board is done through high-speed USB communication in order to minimize the latency. The kinds of sensors and control data to be received from and transmitted to the embedded microcontroller board are determined by the I/O blocks provided by the RCP system in a controller model constructed using Simulink. Two software programs are required to implement the RCP system. One program runs on the embedded microcontroller board and the other program runs on a PC within the Simulink environment. Two programs interact with each other.

III. Parameter Identification using RCP system

In modeling a general DC motor, it is assumed that the motor torque constant L_a generally has a very small value compared to the electric resistance R_a, so the influence of L_a is ignored. Then, the dynamic equations (1) can be modified by

$$\begin{aligned} J_m \dot{w}(t) + B_m w(t) &= Ki(t), \\ R_a i(t) &= v(t) - Kw(t). \end{aligned} \tag{3}$$

and its transfer function can be represented by.

$$\frac{W(s)}{V(s)} = \frac{K}{(J_m s + B_m)R_a + K^2} [\frac{rad/s}{V}]. \tag{4}$$

The transfer function (2) can be simplified by

$$\frac{W(s)}{V(s)} = \frac{\beta}{s+\alpha} = \frac{k}{\tau s + 1} \tag{5}$$

where timing constant τ and system gain k are defined by

$$\alpha \triangleq \frac{1}{\tau}, \quad \beta \triangleq ka. \tag{6}$$

The proposed RCP based parameter identification scheme measures actual output, and then modifies and verifies model parameters τ and k on the RCP system with DC motor in similar environments to the real ones, and thus can evaluate identification performances before entering the embedded implementation stage.

To compare controlled motor speed with parameter identification and actual measured motor speed, an open-loop control is implemented on the RCP system with DC motor using the Simulink model. The open-loop control is easy and conceptually simple. For the open-loop control to achieve desired motor speed, a static control input must be set using a couple of ways. The first way is to find a suitable control input corresponding to the desired output by increasing it from a small value. In other words, the open-loop system is tuned to make the actual output go the desired output through trial and error. The second way is to apply the final value theorem of Laplace transform to the open-loop transfer function (2).

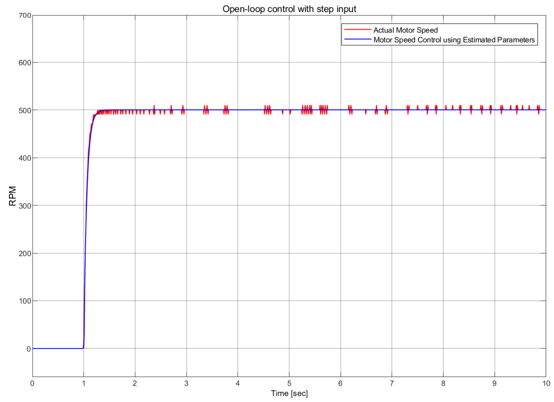
In this paper, since the open-loop control is performed for the parameter identification rather than actual control, unit step input and sinusoidal wave input are applied to the DC motor without applying any external load. Model parameters for the DC motor are tuned to make the controlled motor speed go the actual motor speed through several iterations. Then, the parameters τ and k can be obtained at this time are as follows:

$$\tau = 0.061, \quad k = 11.17 \tag{7}$$

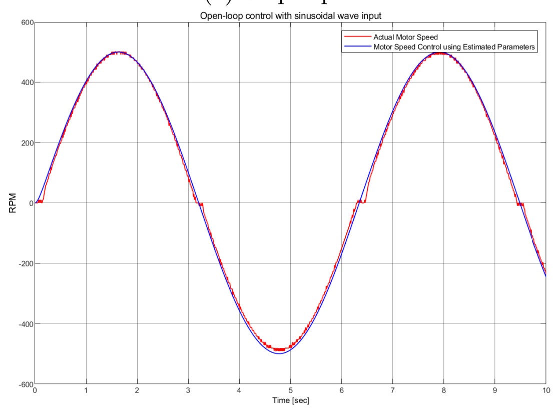
and thus the transfer function can be represented by

$$\frac{W(s)}{V(s)} = \frac{183.115}{s + 16.393}. \tag{8}$$

The open-loop controlled motor speed with parameter identification tracks well the actual motor speed for both unit step input and sinusoidal wave input.



(a) Step input



(b) Sinusoidal wave input

Fig. 2: Open-loop control for parameter identification

IV. Conclusions

In this paper, an alternative parameter identification scheme for the DC motor has been implemented using the RCP system. In existing works for parameter identification, three processes are required to obtain model parameters: measuring actual output from DC motor and modifying model parameters until the results of simulations match measured output, and verifying obtained model parameters on actual DC motor system. These three processes are all carried out separately in different experimental environments. On the other side, the proposed RCP based parameter identification scheme has measured actual output, modified and verified model parameters on the RCP system with DC motor in similar environments to the real ones, and thus can evaluate identification performances before entering the embedded implementation stage. Therefore, the proposed RCP based parameter identification scheme can provide a fast and cost-effective way for control engineers by reducing the development time and effort.

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