MECE-606 Systems Modeling Project

April 3-12, 2016, Rochester, NY, USA

**DC Motor & Inertia Modeling**

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**ABSTRACT**

The DC motor‘s dynamic model behavior is observed through different scenarios such as second order and first order with and without connecting to the shaft/load. The first order case is when armature inductance is assumed zero. When there is no load connected to the motor, the values of motor data sheet are used. When there is a load, the inertia and damping values must be estimated optimizing the cost function for just speed or both speed and current.

**INTRODUCTION**

The armature controlled DC motor schematic can be seen as below.

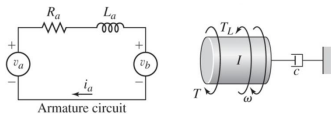


Figure 1. Armature controlled DC motor schematic

From the figure 1, Using Kirchhoff’s Law

\_\_( 1 )

Using Newton’s 2nd Law,

where D is the viscous damping

\_\_( 2 )

The motor transfer functions are

\_\_\_\_\_(3)

\_\_\_\_(4)

\_\_\_ (5)

\_\_\_(6)

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The equation 1 and 2 can be used to implement the Simulink model. For this lab system,

**ANALYSIS`**

The differential equations are derived below.

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and are state variables.

The state space representation as below is used in Simulink and Matlab to find the viscous damping and J, the inertia. in this project.

The Simulink being derived from equation 1 and 2 is implemented to find the cost function since it takes less time than the state space representation to simulate. When using Matlab optimization toolbox ‘fminsearch’ command, the state space model is used for its convenience.

**SIMULATION**

The simulation for the second order case optimizing only the speed can be seen in seen in figure 1 and 2



Figure 2. The simulation of the second order case



Figure 3. The simulation of the 2nd order validate case

Optimizing both speed and current is as below.



Figure 4. The simulation of the second order case



Figure 5. The simulation of the 2nd order validate case

The simulation can have better fit by changing the Ra parameter since Ra value seems to be a bit off for the lab. 2D parameter sweep is used to find the cost function for inertia and viscous damping.



Figure 6. The cost function of optimizing speed only

The graphs of the other cost functions optimizing both speed and current, and functions using fminsearch for optimizing both cases are similar as the above figures. 

Figure 7. Simulation of motor connected La=0

Figure 8.Simulation of first order motor validation data set



Figure 9. Simulation of motor disconnected  Figure 10. Simulation of motor disconnected validation

From figures 6 to 9, it can be seen that the validation data fit along with the output of angular speed and current. From the real output data and simulated output data, root mean square RMS can be evaluated to determine which model or which optimization fits better.



Figure 11. Simulation of first order motor disconnected 

Figure 12. Simulation of motor disconnected validation



Figures 13. Simulation of motor connected using fminsearch for optimizing both speed and current, and speed only.

|  |  |  |
| --- | --- | --- |
|  | J Inertia | D viscous Damping |
| Connected: speed only | 0.000647 | 9.17E-04 |
| Connected: both speed and current | 2.47E-04 | 0.002717 |
| disconnected, speed only | 4.70E-05 | 1.70E-05 |
| fminsearch, speed only | 0.002593 | 1.52E-04 |
| fminsearch both speed and current | 0.0025931 | 1.52E-04 |

Table 1. J and D values for connected, disconnected and fminsearch cases

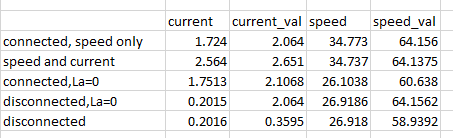


Table 2. RMS values for current and speed with validation sets

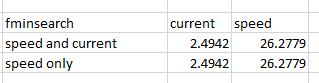


Table 3. RMS values for fminsearch



Table 4. RMS values for FOPDT with load and no load

The RMS of speed being greater than that of the current can be clearly observed in table 2. From table 2 and 3 comparison, the user defined cost function performs better than the Matlab toolbox. The first order case fits better than second order in general. Optimizing speed only is better than optimizing both speed and current due to current spikes.

For First Order Plus Dead Time (FOPDT), the system gain K is obtained diving the steady state output by the steady state input. The time constant T is the time it takes to reach from step response to 63% of its final value. The no load case K is 13.54 and the time constant is .15 secs. The load case K is 5.5128 and time constant is .03 secs.



Figure 14. The loaded case of FOPDT simulation

**CONCLUSION**

The lab objective was accomplished applying Kirchhoff’s law, Newton’s 2nd law, using differential equations, finding the approximate values of viscous damping, and inertia through trial and error, and confirm the result with the validation data set simulation. To conclude, the lab is successfully completed utilizing Matlab state space modeling and Simulink.