MECE-606 Systems Modeling

Computer Project #3: *DC Motor & Inertia Modeling*

Goal: Develop a dynamic model of the DC Motor connected to a steel shaft that is simply supported by two ball bearing mounts. Estimate the moment of inertia of the shaft and the linear viscous damping coefficient of the bearings. First, derive the second order model and use the parameters provided by the motor manufacturer to fit the experimental data. Then repeat the simulation with the reduced order model when the armature inductance is assumed zero. Compare both models to the modeling and validation data sets.

Measurements: Angular position from a rotary encoder (500 CPR) & Armature current from a non-contact hall-effect sensor (LEM HAS-50). The current sensor may have a small DC bias at zero voltage command that can be subtracted.

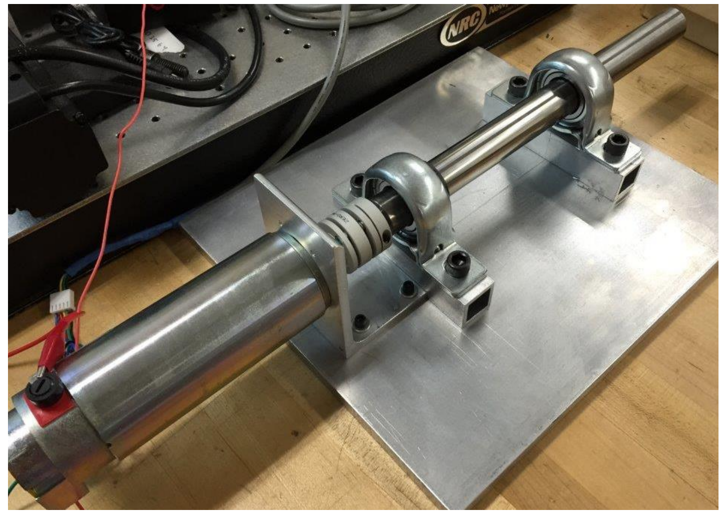

Figure 1 – DC Motor with Inertia

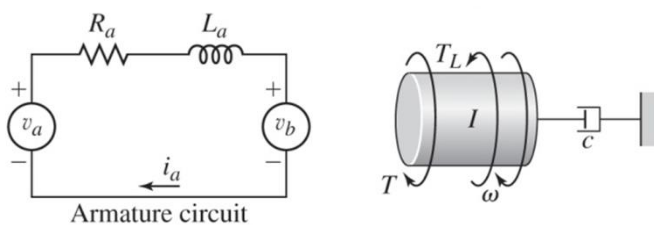

Figure 2 - Armature Controlled DC Motor Schematic

System: A Pittman Brushed DC motor is connected through a coupling to a steel shaft (ρ = 7850-kg/m^3). See attached data sheet. The shaft is supported by two standard ball bearings and the motor is driven by a standard DC power supply.

Considerations: For <u>both</u> the first and second order models use the specifications provided by the motor manufacture. First analyze the motor only data set (inertia disconnected). How well does the reported specification match the result? Can you modify any parameters to get a better fit? Why? Second, analyze the system when connected to the shaft. For this case the inertia and damping will have to be estimated. Use a 2D parameter sweep with a cost function utilizing motor speed only and again using both speed and current. (*Note*: you will need a weight factor to scale the two measurements $J=e^Te+e^TWe$.) Redo both cases using Matlab's "*fminsearch*" command. Document all optimizations and discuss the differences. Make sure to have quantifiable measures of the model fits (RMS, etc.). Is there another model form that is better? Simulate the identified models versus the validation data sets using the measured motor command voltage as the input. How does the model fit (RMS) compare versus the validation data sets? Lastly, determine a first-order plus dead-time (FOPDT) model (τ, K, θ) from a <u>single</u> step change in the data. How does this simplified model match the full modeling data set? The validation sets? The full physics-based model?

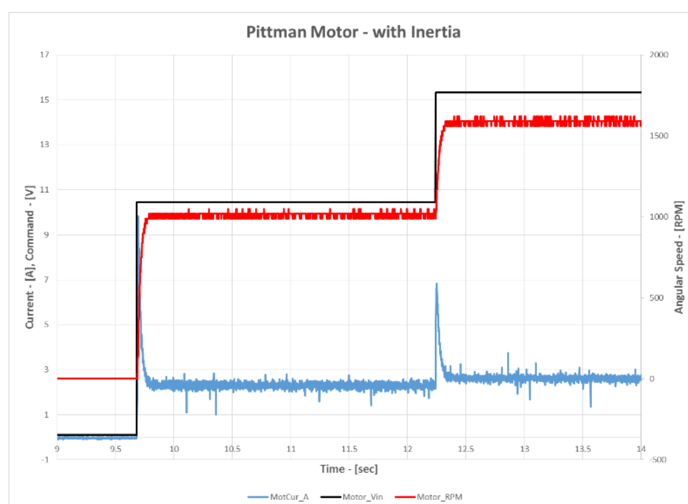

Figure 3 - Angular Velocity, Armature Current, & Voltage Command vs. Time

Deliverable: A concise <u>three</u> page (max.) report on the modeling approach with full derivation of all equations from first principles (i.e. F=ma) through final model. A discussion of the final results related to quality of the model fit of the data is critical including a quantification of the error (RMS, etc.). The number of plots should be kept to a minimum but be of high quality and description (legends, captions). A portion of the grade is reserved for the quality of the written report. Please submit all of your Matlab/Simulink code <u>separately</u> and consolidate it to as few pages as possible.

Due Date: Two weeks after the assigned date.

14207S008

Lo-Cog® DC Servo Motor

Assembly Data	Symbol	Units	Value	
Reference Voltage	E	V	24	
No-Load Speed	S_{NL}	rpm (rad/s)	3,211	(336)
Continuous Torque (Max.)[1]	T_C	oz-in (N-m)	50	(3.5E-01)
Peak Torque (Stall)[2]	T_{PK}	oz-in (N-m)	410	(2.9E+00)
Weight	W_M	oz (g)	58	(1630)
Motor Data				
Torque Constant	K_T	oz-in/A (N-m/A)	10.0	(7.06E-02)
Back-EMF Constant	K_E	V/krpm (V/rad/s)	7.39	(7.06E-02)
Resistance	R_T	Ω	0.59	
Inductance	L	mH	0.87	
No-Load Current	I_{NL}	A	0.30	
Peak Current (Stall)[2]	I_P	A	40.4	
Motor Constant	K_M	oz-in/√W (N-m/√W)	13.1	(9.25E-02)
Friction Torque	T_F	oz-in (N-m)	2.2	(1.6E-02)
Rotor Inertia	J_M	oz-in-s^2 (kg-m^2)	6.7E-03	(4.7E-05)
Electrical Time Constant	τ_E	ms	1.50	
Mechanical Time Constant	τ_M	ms	5.5	
Viscous Damping	D	oz-in/krpm (N-m-s)	0.25	(1.7E-05)
Damping Constant	K_D	oz-in/krpm (N-m-s)	127	(8.6E-03)
Maximum Winding Temperature	θ_{MAX}	ºF (ºC)	311	(155)
Thermal Impedance	R_{TH}	ºF/watt (ºC/watt)	41.0	(4.98)
Thermal Time Constant	τ_{TH}	min	32.3	
Gearbox Data				
Encoder Data				
Channels			3	
Resolution		CPR	500	

1 - Specified at max. winding temperature at 25ºC ambient without heat sink. 2 - Theoretical values supplied for reference only.

Included Features

2-Pole Stator
Ceramic Magnets
Heavy-Guage Steel Housing
11-Slot Armature
Silicon Steel Laminations
Stainless Steel Shaft
Copper-Graphite Brushes
Diamond Turned Commutator
Motor Ball Bearings

Customization Options

Alternate Winding
Sleeve or Ball Bearings
Modified Output Shaft
Custom Cable Assembly
Special Brushes
EMI/RFI Suppression
Spur or Planetary Gearbox
Special Lubricant
Optional Encoder
Fail-Safe Brake