MECE-606 Systems Modeling

Computer Project #2: *Single Mass Pendulum*

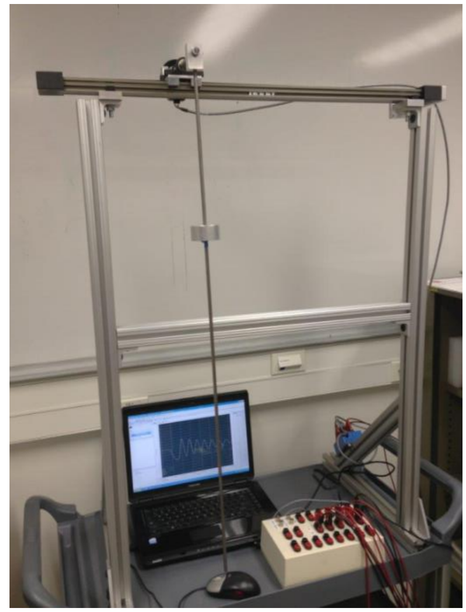


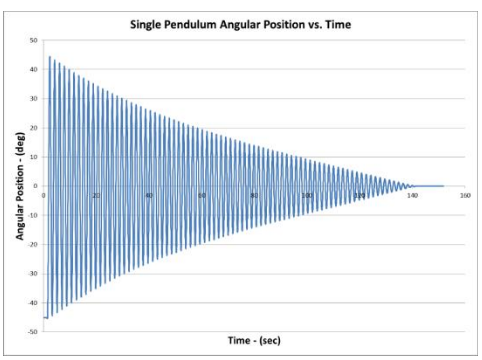
Figure 1 - Single Pendulum System

Goal: Develop a dynamic model of the single pendulum and estimate the moment of inertia, location (X) of the point mass, and the damping coefficient. First, assume a point mass and neglect the rod, and then account for the rod inertia as well as the mass. Apply the developed linear and nonlinear models to the validation data sets.

Measurement: Angular position from rotary encoder (2500 CPR quadrature U.S. Digital encoder).

System: A 138.9 gram mass is connected to a 92.7-cm steel rod (diameter = 0.635-cm, density ρ = 7850-kg/m^3) an unknown distance "X" from the rotation point. The pendulum rotates on an aluminum shaft through two pillow block ball bearings. The modeling data set initial condition is $\theta = +45^o$ and the validation data sets are $\theta = +30^o$ and $\theta = +90^o$.

Considerations: Model and simulate 4 different scenarios: (i) assume small angles and viscous friction (linear model); (ii) do not assume small angles and use viscous friction; (iii) do not assume small angles and use the turbulent flow friction model; (iv) do not assume small angles and use the combined Coulomb/viscous friction model. For the turbulent flow model use the following functional form for the damping force $F_d = sgn(\dot{\theta}) b\dot{\theta}^2$ and for the case where there is a combined Coulomb and viscous friction use $F_d = sgn(\dot{\theta})[K_g|\dot{\theta}| + K_o]$ where K_o is the Coulomb friction value and K_g is the coefficient of viscous friction.



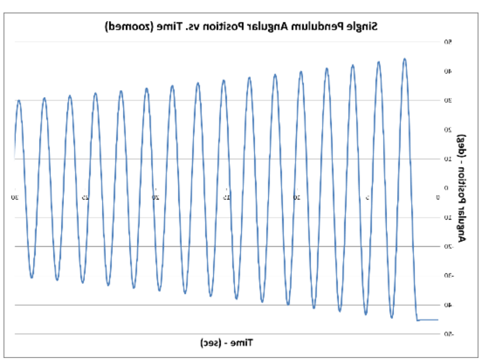


Figure 2 - Angular Position vs. Time

For the linear model case (i) use the concept of logarithmic decrement and the natural frequency to identify the model parameters. From the estimated inertia (*J*) determine the location of the mass (*1*) assuming a point mass, and (*2*) accounting for the mass of the rod. (*Hint*: $s^2 + 2\xi\omega_n s + \omega_n^2 = 0$) For each of the next three cases (ii-iv) you will need to identify the damping coefficient (*b*). Set up a 1D parameter sweep based on a range of possible damping coefficients. Simulate the model for each and compare to the data by setting up a cost function. Plot the cost function versus damping to identify the optimum. Simulate this optimum versus the data for your final model. For the combined Coulomb/viscous damping case you will have to set up a 2D parameter sweep. For every case, how does the model fit compare versus the validation data sets?

Discuss how close the simulations are. Can inertia of the rod/mass assembly be treated as a point mass? How accurate is the linear damping representation? Are the nonlinear models better? Etc.

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.