MECE-606 Systems Modeling

Computer Project #5: *Hydraulic Two-Tank Fluid Modeling*

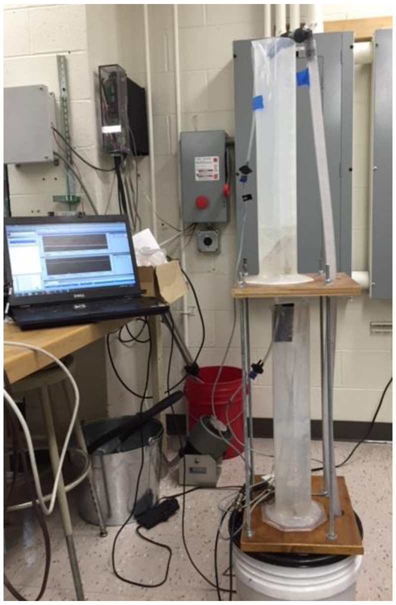

Figure 1: Two Tank Leveling Systems

Goal: To develop a model of the fluid dynamics of a two tank system subject to three different orifice flow models. The model parameters are estimated based on the filling and draining of each vessel. Use tank hydrostatic pressure data to estimate the pump gain (flow/volts) and the orifice model coefficients. Apply the developed models to two validation data sets.

Measurement: Pressure data is collected using a National Instruments USB-6261 DAQ with a Motorola Mpx5015dp pressure transducer.

System: Two graduated cylinders are placed in a column arrangement, each with a threaded orifice at the bottom. (**Figure 1**) The orifices are tapped so that nozzles of various diameters are able to be screwing into the tank to restrict the exit flow of water. The top cylinder drains to atmosphere and then into the bottom cylinder which then empties into a bucket. Inside the bucket is a common DC voltage driven bilge pump that then pumps the water back to the top cylinder. Changing the voltage command varies the flow of water to top. Each cylinder is equipped with a submerged pressure transducer that measures hydrostatic pressure. From this pressure, and knowing the density of water and diameter (*d=8cm*) of the cylinder, a measurement of water height in the cylinder is obtained. The objective of this project is to develop three dynamic models from first principals using the continuity equation (conservation of mass) and various representations of orifice flow.

Considerations: The orifice flow models are as follows:

1. $q = \frac{1}{R}\Delta P$ Laminar
2. $q = C_d A_o \sqrt{\frac{2\Delta P}{\rho}}$ Bernoulli
3. $q = k(\Delta P)^m$ Empirical

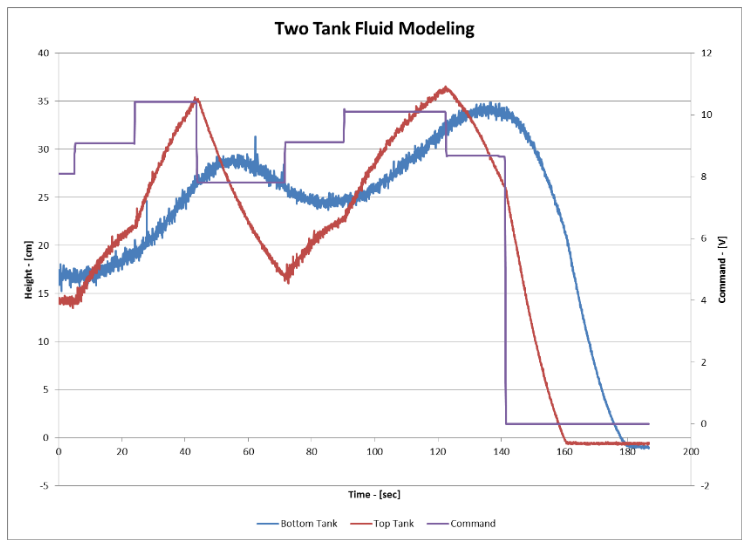

Figure 2: Tank Fluid Height vs. Pump Voltage Command

where q is volumetric flow rate, ΔP is the pressure drop across the orifice, R is the laminar flow resistance, C_d is the discharge coefficient, A_o is the orifice area, and k and m are empirically determined coefficients. Develop **three** 2nd order models of the two tank system assuming orifice flow at the discharge and the heights of top tank (H_T) and the bottom tank (H_B) as states with the input to the system being flow rate (q_{in}) to the top tank. Assume that there are no pump dynamics rather a static gain (K) converting voltage command to pump flow. To determine the static gain, the data set (TT_PumpCal_5) showing the filling of the top tank is used. For this experiment the orifice in the top tank is plugged and several different command voltages are applied and the tank is allowed to fill. Develop the theoretical static model that calculates flow rate as a function of water height and voltage. Use a linear curve fit, including zero volts equals zero flow, with the slope being the static gain. Next, use the two tank draining data files (TT_TopTankDrain_0.295in_3, TT_BottomTankDrain_10mm_4) to determine the orifice flow parameters for all three model above for both orifices. The top tank orifice is d_o=*0.295in* and the bottom tank orifice is d_o=*10mm*. For the first orifice model use the time constant method to determine the linear flow resistance (R), for the second model use the parameter sweep optimization technique based on changing the discharge coefficient (C_d), and finally for the last orifice model use the Matlab command 'fminsearch' to find the values of k and m. (example fminsearch code will be provided). Once the pump calibration and orifice flow models are determined, apply each full dynamic model to the two validation data sets. (TT_DynamicValidationData_1, 2). Present all results and parameters identified clearly. Which model is the best? Can any parameters be adjusted to fit the dynamic data better? Feel free to do this and compare versus the targeted test.

Notes:

- There is a voltage at which the pump is commanded to overcome head pressure and is 6.9 volts. That bias should be removed from the data files to ensure zero volts equals zero flow.
- All data files require the generation of a time vector (Δt=0.05sec), column 1 is the height of the top tank (H_1), column 2 is the height of the bottom tank (H_2), and column 3 is the voltage command to the pump.

Deliverable: A concise three page (max.) report on the modeling approach with full derivation of all equations from first principles (i.e. F=ma) through final model including control volume depictions. 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 separately and consolidate it to as few pages as possible.

Due Date: Two weeks after the assigned date.