AE 443 Servo Modeling

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I. Procedure

I.1. Bump Test Experiment

The bump test experiment aims to assess a system's response to sudden shocks, impacts or in this case a step input, providing insights into its dynamic behavior. By subjecting the system to controlled impulses one can evaluate its stability or performance under different conditions.

To perform the bump test experiment, several steps are followed:

1. Set up the MATLAB environment using the provided function, preparing the simulation environment, and initializing necessary parameters.
2. Configure the Signal Generator block in Simulink to produce a square wave with an Amplitude of 1, and Frequency of 0.4 in hertz.
3. Set the spd src block to 2 and Amplitude slider gain to 1.5 V, as well as Offset to 2
4. View the shaft speed and input voltage scopes
5. Set the run time for 5 seconds. And start the Simulation by clicking on “Monitor & Tune”
6. Plot shaft speed data
7. Save the data into a .mat
8. Measure the steady state gain and time constant

I.2. Model Validation

The goal of a model validation experiment is to refine and adjust the parameters of a model so that it accurately reflects the behavior of the real-world system it represents. Comparing the simulated response with experimental data to minimize discrepancies and improve accuracy thus reliability.

To perform model validation:

1. Set the Signal Generator to produce a square wave with an Amplitude of 1 and Frequency of 0.4
2. Set Amplitude slider gain to 1 and Offset to 1.5
3. View the shaft speed and input voltage scopes
4. Start the Simulation by clicking on “Monitor & Tune” (Default Settings: K = 1, $\tau = 0.1$)
5. Set K = 2
6. Start the Simulation and Observe any changes
7. Set $\tau = 0.0.06$
8. Start the Simulation and Observe any changes
9. Plot the data in MATLAB
10. Set K = 1.25
11. Start the Simulation and Observe any changes
12. Set $\tau = 0.0.2$
13. Start the Simulation and Observe any changes
14. Plot the data in MATLAB
15. Set K = 1.53 and $\tau = 0.0253$ and examine how the graphs change

II. Results

$$J_m = J_{tach} + J_{m,rotor} = 4.06 \times 10^{-7} kg \cdot m^2 \quad (1)$$

$$J_{disc} = \frac{mr^2}{2} \quad (2)$$

$$J_g = J_{24} + 2J_{72} + J_{120} = 5.28 \times 10^{-5}\ kg \cdot m^2 \quad (3)$$

$$J_l = J_g + J_{l,ext} = 1.03 \times 10^{-4}\ kg \cdot m^2 \quad (4)$$

$$J_{eq} = \eta_g K_g^2 J_m + J_l = 0.002\ kg \cdot m^2 \quad (5)$$

$$B_{eq} = \eta_g K_g^2 B_m + B_l = 0.015\ \frac{N \cdot m}{s} \quad (6)$$

$$B_{eq,v} = \frac{\eta_g K_g^2 \eta_m k_t k_m + B_{eq} R_m}{R_m} = 0.084\ \frac{N \cdot m \cdot s}{rad} \quad (7)$$

$$A_m = \frac{\eta_g K_g \eta_m k_t}{R_m} = 0.129\ \frac{N \cdot m}{V} \quad (8)$$

$$\tau = \frac{J_{eq}}{B_{eq,v}} = 0.0253\ s \quad (9)$$

$$K = \frac{A_m}{B_{eq,v}} = 1.53\ \frac{rad}{V \cdot s} \quad (10)$$

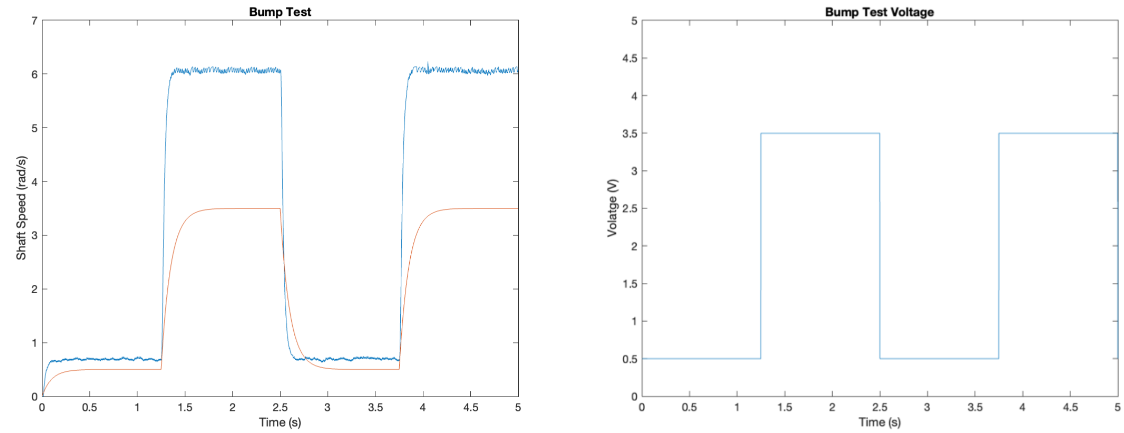

Figure 1: Bump Test Experiment Shaft Speed and Voltage

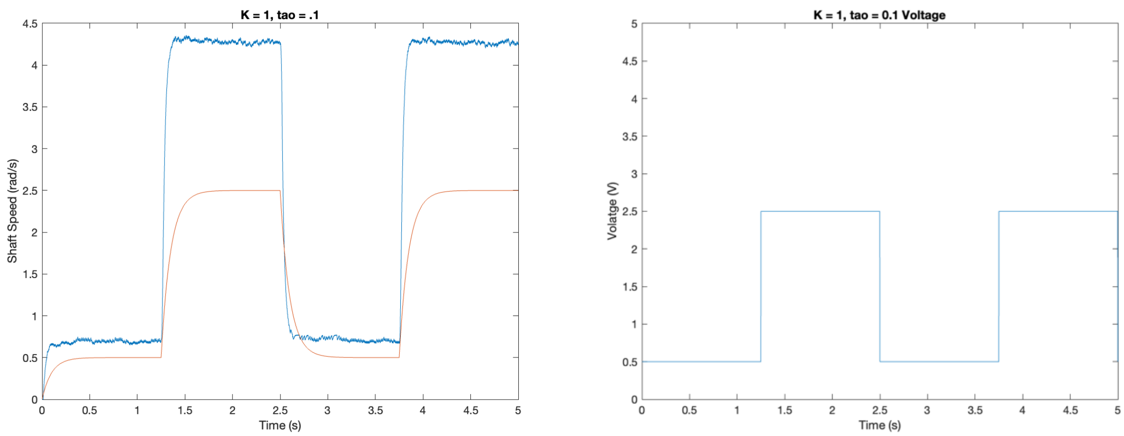

Figure 2: Model Validation with $K = 1$, $\tau = 0.1$

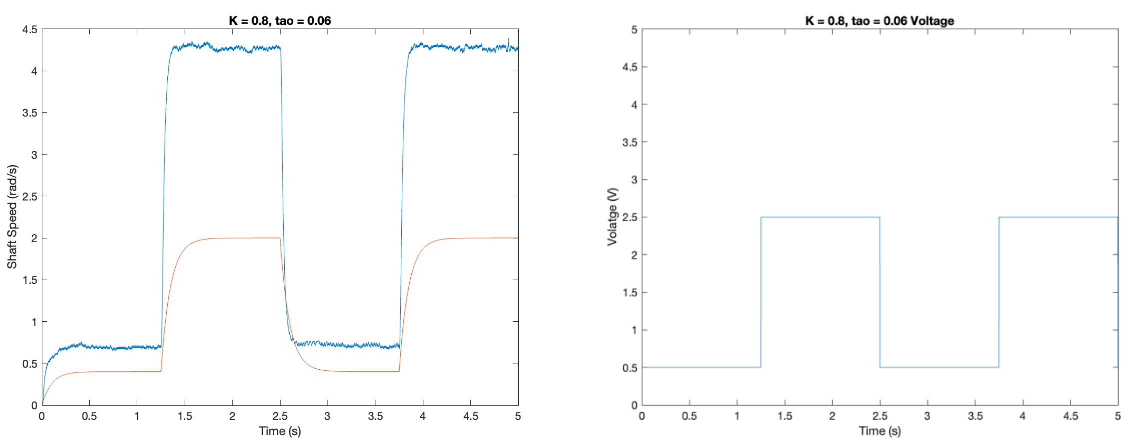

Figure 3: Model Validation with $K = 0.8$, $\tau = 0.06$

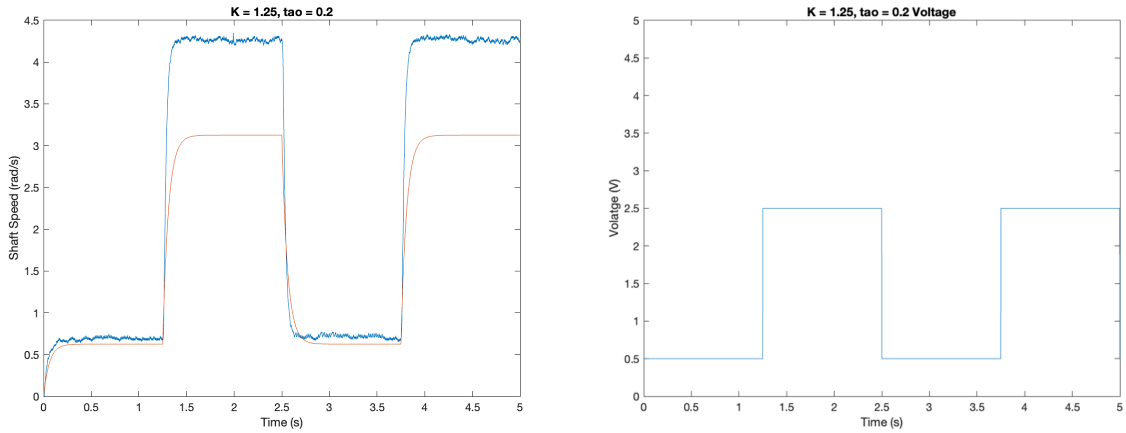

Figure 4: Model Validation with $K = 1.25$, $\tau = 0.2$

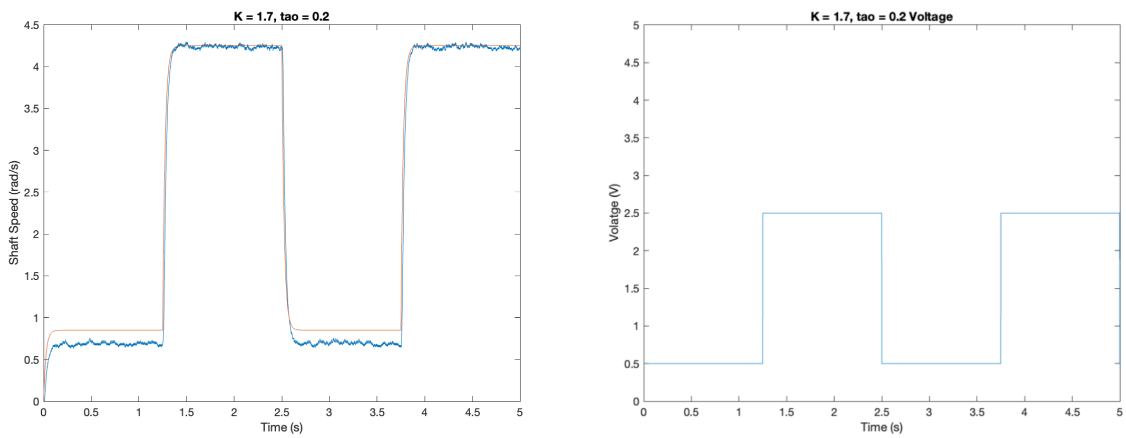

Figure 5: Model Validation with $K = 1.7$, $\tau = 0.2$

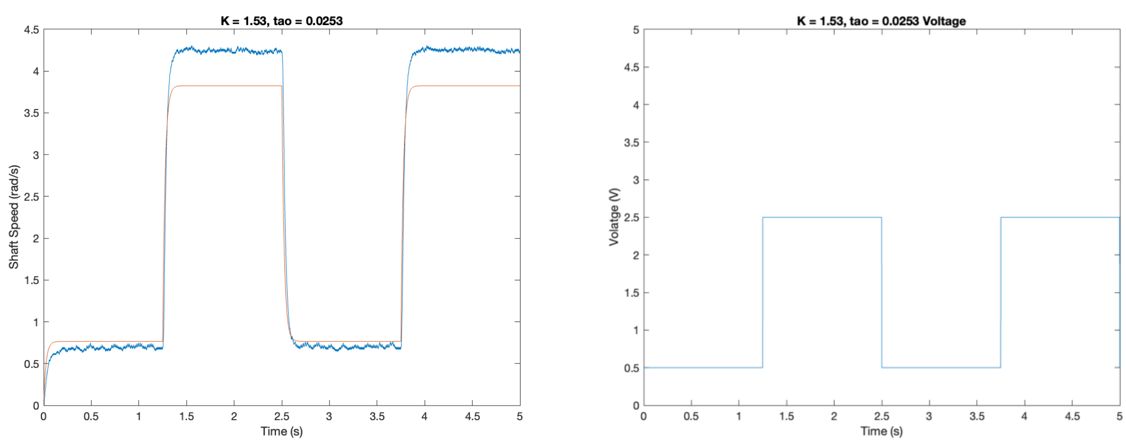

Figure 2: Nominal Values of $K = 1.53$, $\tau = 0.0253$

Nominal Open-Loop	K = 1.53 $\tau = 0.0253\ sec$
Bump Test Open-Loop	K = 1.911 $\tau = 0.316\ sec$
Model Validation Open-Loop	K = 1.7 $\tau = 0.0253$ sec

III. Analysis

III.1 Bump Test Experiment

The gain of system was asked to be found; this was done by using the equation given that the change of y (shaft speed) divided by the change of u (voltage) is equivalent to the gain. From the data the max value of shaft speed was found and then the steady state value was subtracted from it, this was done to the voltage as well. Once those were found then the two were just left to be divided to find the gain. Time constant is approximately 63.2% of the steady state value, so once this number was achieved in the previous step all that was needed to be to multiply the two.

III.2 Model Validation

Looking at Figure 3, decreasing the gain (K) from 1.0 to 0.8 decreased the amplitude of the output by nearly 0.5 rad/s, lowering the time constant lessened the curve towards the steady state signaling that the system reacted to how it should.

In Figure 4, both the gain and time constant were increased. Comparing the orange line between Figures 2,3 and 4 it can be seen that Figure 4 has the highest amplitude due to the highest gain value. However, a higher time constant indicates a slower system response time.

The nominal values do accurately represent the system due to the nominal values representing an ideal system. The motor could have unideal factors such as friction, gear box issues, inertia, etc.

The nominal values of the SRV02 system do not exactly match that of real life, however, it does give a good estimation for what the system response will look like. The bump test matches much better due to being based off experimental data

IV. Conclusions

From this lab, I gained the better knowledge of how the gain of a system amplifies the system input, the higher the gain the higher the amplification, typically decreasing steady-state error. However, too high of a gain can lead to instability of the system. Time constant changes the response time of the system, the lower the time constant the quicker the reaction of the system.

I also learned that to accurately model a system multiple steps need to be done, such as making the model of the system and then validating that model with real data to refine a more accurate and reliable model.