<u>SRV02 MODELING: Lab 1 and Lab 2 Report</u>

Course: ENG 4550

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Lab#: 3

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Procedure:

Frequency Response Experiment

Steady-state Gain

The main goal of this portion of the lab was to find the steady state gain $K_{e,f}$, and time constant, $\tau_{e,f,}$ at varying frequencies of the SRV02 using sine waves of varying frequencies. The steady-state gain was found by supplying a constant 2V input and measuring the peak of the speed of the load shaft (in rad/s); steady state gain is equal to the peak of the output divided by the amplitude of the input. Since the angular frequency, ω, of a constant signal is 0, the steady state gain, $K_{e,f}$, is equal to $|G_{wl,v}(0)|$.

$$\left|G_{wl,v}(\omega)\right| = \frac{Ke,f}{\sqrt{1+\tau e,f^2\omega^2}} \tag{1.01}$$

$$\left|G_{wl,v}(0)\right| = K_{e,f} \tag{1.02}$$

Gain At Varying Frequencies

The gain of system at varying frequencies was found by applying sinusoidal V_m input, with constant amplitude (2V), with varying frequencies to the system, and recording the peak of the speed of the load shaft (in rad/s). The gain, $\left|G_{wl,v}(f)\right|$, was found by dividing the peak of the speed by the amplitude of the V_m wave (2V). The time constant, $\tau_{e,f}$, was found using the bode plot; it is the inverse of the angular frequency, at which the gain is -3dB of the steady state.

Bump Test Experiment

The goal of the experiment was to find the steady state gain $K_{e,b}$, and time constant $\tau_{e,b}$ of the SRV02 using a periodic square wave. The steady state gain was found by dividing the change of the output by the change in the input. The mean of the maximum and minimum were used instead of using the absolute maximum and minimum due to noise.

$$K_{e,b} = \frac{\Delta y}{\Delta u} = \frac{yss - yo}{umax - umin} \tag{1.03}$$

The time constant, $\tau_{e,b}$ was found by finding the point on the bode diagram where gain was 0.632 of the steady state plus the minimum value of the input.

$$y(t_1) = 0.632y_{ss} + y_0 \tag{1.04}$$

The time it takes to get from the initial value to 0.632 of the steady state is the time constant, τ .

$$\tau_{e,b} = t_1 - t_0 \tag{1.05}$$

Model Validation Experiment

The goal of the portion of the lab was to match the simulated response of the system to the actual response of the system by varying the K and Tau values. The K and Tau values taken from this experiment would be the ones that matches the simulation model to the actual model the best. The final values for K and Tau that is taken has a slight discrepancy compared to the nominal values. The discrepancy can be due to noise, or residual conditions due to previous tests(has initial condition).

Results:

Frequency Response Experiment

F (Hz)	**Amplitude (V)**	**Maximum Load Speed (rad/s)**	**Gain:|G(ω)| (rad/s/V)**	**Gain:|G(ω)| (rad/s/V, dB)**
0.0	2.0	3.7181	1.8591($K_{e,f}$)	5.3858
1.0	2.0	3.5555	1.7778	4.9974
2.0	2.0	3.3605	1.6803	4.5075
3.0	2.0	3.1218	1.5609	3.8675
4.0	2.0	2.8156	1.4078	2.9708
5.0	2.0	2.6056	1.3028	2.2976
6.0	2.0	2.3950	1.1975	1.5655
7.0	2.0	2.1960	1.0980	0.8120
8.0	2.0	2.0228	1.0114	0.0985

Table 1.1: Lists the gain of the transfer function for sine waves with different frequencies.

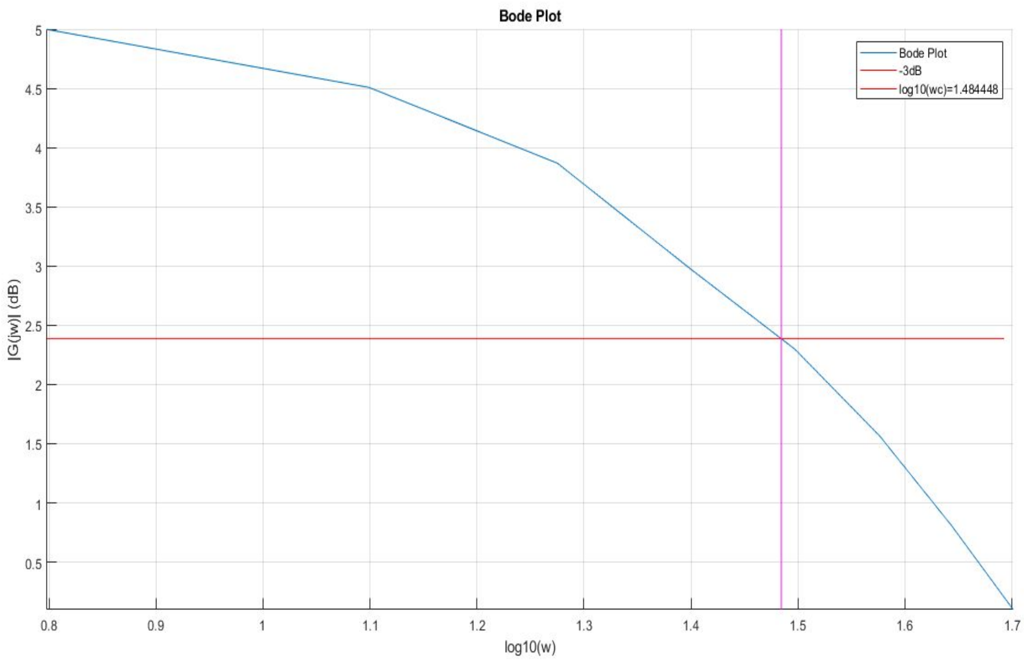

Figure 1: Bode Plot for frequency response of SRV02. log(wc) was determined to be 1.484.

Bump Test Experiment

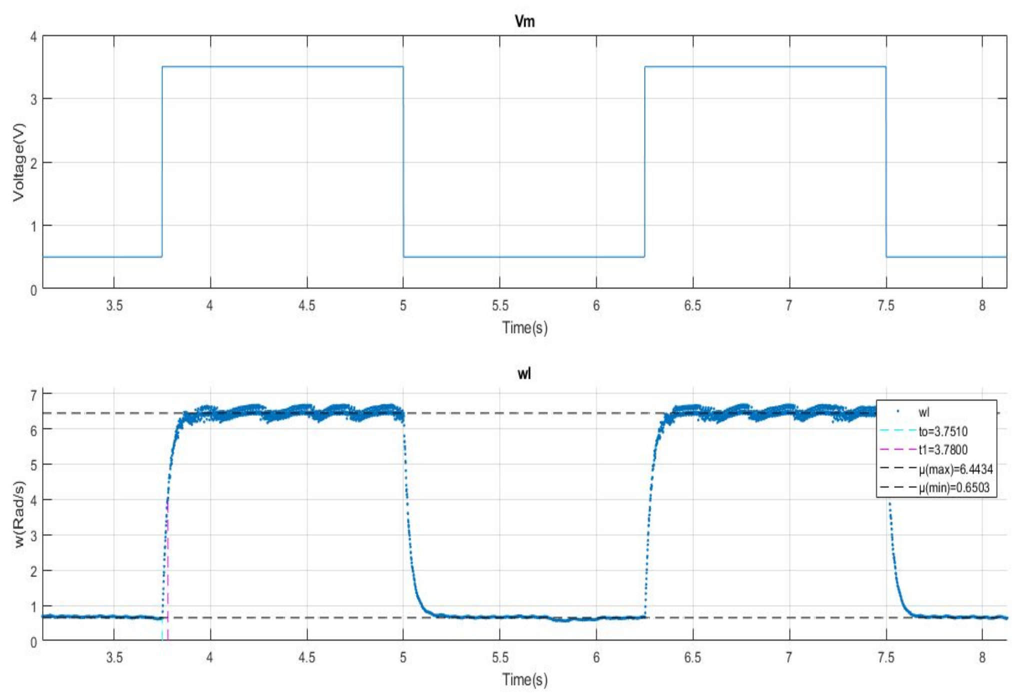

Figure 2: The system response for a periodic square wave with duty cycle 50%. The average value of the peak is 6.4434(rad/s). The average value of the minimum is 0.6503(rad/s). t_0 is 3.7510, and t_1 is 3.7800.

Model Validation Experiment

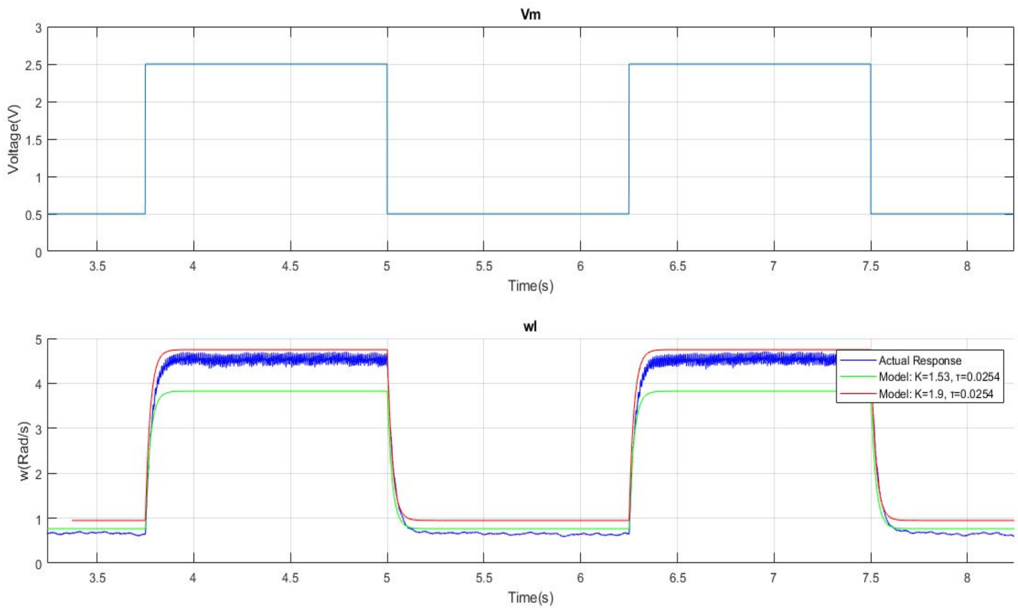

Figure 3: Shows the simulation model using $K_{e,v}$ =1.53 and $\tau_{e,v}$=0.0254, and $K_{e,v}$=1.9 and $\tau_{e,v}$=0.0254 for model validation experiment.

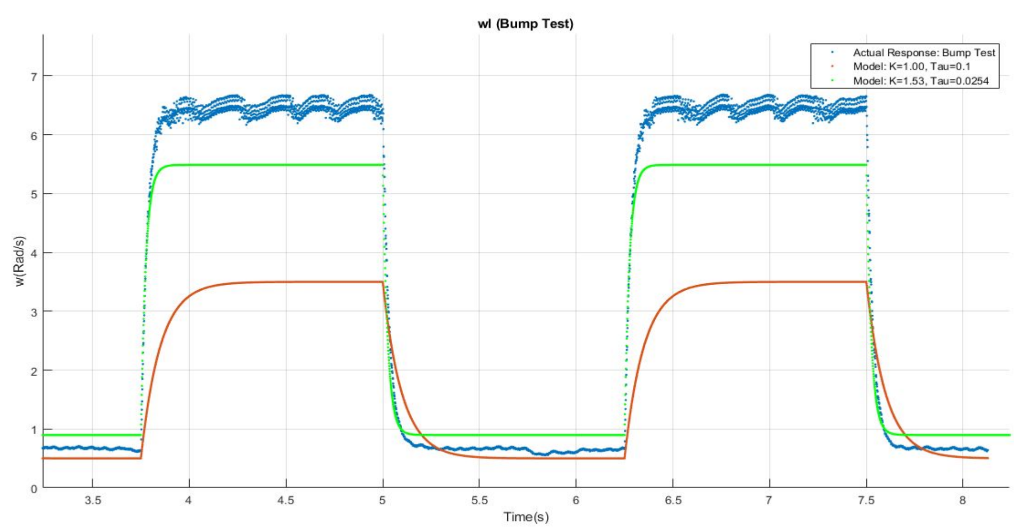

Figure 4: Shows the model validation for Bump Test. $K_{e,b}$ =1.53 and $\tau_{e,b}$=0.0254

Section	Description	Symbol	Value	Unit
1.3.1	**Frequency Response Exp.** Open-Loop Steady-State Gain Open-Loop Time Constant	$K_{e,f}$ $\tau_{e.f}$	1.8591 0.0328	rad/s/V s
1.3.2	**Bump Test Exp.** Open-Loop Steady-State Gain Open-Loop Time Constant	$K_{e,b}$ $\tau_{e.b}$	1.9310 0.0290	rad/s/V s
1.3.3	**Model Validation** Open-Loop Steady-State Gain Open-Loop Time Constant	$K_{e,v}$ $\tau_{e,v}$	1.5300 0.0254	rad/s/V s

Table 1.2: The gain K, and time constant τ using the different methods.

Analysis:

Frequency Response Experiment

Steady-state Gain

Given that the amplitude of the angular velocity of the shaft load (From Figure 1) from a constant 2V input is 3.7181 (rad/s), the gain can be calculated by dividing the amplitude of the angular velocity by the amplitude of the input voltage.

$$Ke,f = \frac{amp.\ of\ wl}{amp.\ of\ V m} = \frac{3.7181}{2} = \mathbf{1.85905\ rad/s/V} \text{ or } \mathbf{5.5315dB} \quad (1.06)$$

Gain at Varying Frequencies

Given the bode plot (Figure 1), the time constant, $\tau_{e,f}$ can be found by locating on the bode plot at which log(w) results in a -3dB gain. Given that the steady state gain is 5.3858dB, the -3 dB gain is 2.3858dB. The log(w) that results in a 2.3858dB gain is 1.484448. The resulting angular velocity is 30.510 rad/s (or 4.8559 Hz), and the time constant $\tau_{e,f}$, is the inverse of the angular velocity.

$$\tau_{e,f} = \frac{1}{|wc|} = \frac{1}{30.510} = \mathbf{0.0328\ s} \quad (1.07)$$

Bump Test Experiment

Given the plot of the step response of a periodic square wave (Figure 2), the mean of the maximum and the minimum were found using the *mean* function in Matlab; mean of maximum and minimum were 6.4434 and 0.6503 respectively. The mean was used instead of using the absolute maximum and minimum in order to get rid of the variation in the two states(might be due to noise or initial condition).

Using eq. (1.03), $K_{e,b}$= $\frac{\Delta y}{\Delta u} = \frac{yss-yo}{umax-umin}$ = $\frac{6.4434-0.6503}{3.5-0.5}$ =**1.9310 rad/s/V** or **5.7156dB**

Using the plot, t_0(time before rise), and t_1(time of 0.632 gain)can be found; t_0 and t_1 are 3.7510(s), and 3.8000(s) respectively. Using eq. (1.05), $\tau_{e,b}$ = $t_1 - t_0$=3.7800-3.7510=**0.029 s**

Conclusion:

Model Validation Experiment

The simulation model was attempted to be matched to the actual response by modifying the K and Tau values.

K affects the steady state gain experienced by the output given an input. Tau affects how quickly the response reaches 0.632 of the steady state gain. By varying the values of K and tau, the simulation model and the experimental model could be matched and the nominal values. $K_{e,v}$ was found to be **1.5300 rad/s/v**, and the $\tau_{e,v}$ is **0.0254 s.**

Three reasons why the nominal model might not match the actual response might be due to noise, the persistence of initial conditions or backlash of gears. The noise might be due to vibrations on the table from outside sources that affected the tachometer ability to reliably measure the rotational speed of the shaft load. The noise could be from thermal noise added to the input voltage; the thermal noise is amplified in the response. The noise can be reduced by performing the experiment in an isolated system(not affected by outside forces such as vibrations), and in a cooler environment to reduce thermal noise.

Since the test was done multiple times on the same SRV02 unit using a periodic square wave, initial conditions might have persisted from previous tests that affected future values. Knowing that a motor can be represented with a resistor and an inductor, and an inductor resists the change of current, a residual current might have existed from previous tests. To remove such residual current, time between experiments can increase so that the inductor is discharged.

The noise could be caused the backlash of gears. Initially, when input gear is providing force to the output gear, the input gear could be moved without applying any appreciable force or motion to the output gear. This is caused by the clearance between two gears. It is unavoidable because the clearance is designed to preventing jamming between gears.

The frequency response model and the bump test model reflects the SRV02 well. The gain values K, and time constants τ , are close to the nominal values K=1.53 and τ =0.0254; K is within 0.4 rad/s/V and τ is within 0.01s. The discrepancies can be accounted for noise as well as persistence of previous conditions.

Reference

Apkarian, J., Lévis, M., & Gurocak, H. (Eds.). (n.d.). *SRV02 Base Unit Experiment For Matlab/ Simulink*. Retrieved October 20, 2018.