ECEN 4638: Lab X.1PI

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1 Description

This lab will further explore the Torsional Disc System. The system setup will be similar to what was used in labX.1P; only the bottom disc of the TDS will used and the four weights will be set at a radius of 6.5cm.

2 System Model

2.1 Calculated Parameters

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4 Experimental Analysis

After conducting the matlab analysis in section 3 experimental data was collected from two different torsion disc systems. Data was collected from two systems in order to examine the robustness of the PI controller and make any necessary adjustments.

4.1 Setup

The first step in collecting experimental data was to select a rise time (t_r) and overshoot (M_p) for the system. As an initial starting point values of $t_r = 0.5$ sec and $M_p = 5\%$ were selected. Using these values the damping ζ and natural frequency ω_n were calculated using equations 1 and 2

$$\zeta = \frac{|\ln(0.05)|}{\sqrt{\pi^2 + [ln(0.05)]^2}} = 0.69 \tag{1}$$

$$\omega_n = \frac{1.8}{0.5} = 3.6 \tag{2}$$

These values were used as an initial starting point and adjustments were made based on the response calculated in matlab and the corresponding response on the TDS. In cases where the overshoot became too high the damping was increased. It also became necessary to increase the bandwidth of the system in order to reduce the noise on the live system. Table 1 shows the various calculated values based on necessary changes. For each iteration the value in bold was adjusted to improve the response. The adjustments were determined based on the response of the system to a step input as outlined in section 4.2 and to a ramp disturbance in section 4.3.

Test	M_p	t_r	ζ	ω_n	K_p	K_I	BW
test1	**5.00**	**0.50**	0.69	3.60	0.1548	0.4611	6.55
test2	19.58	0.090	0.69	**10**	0.469	3.558	19.55
test3	16.23	0.085	**0.80**	10	0.5472	3.558	20.948
test4	14.67	0.039	**0.90**	**20**	1.258	14.23	45.59
test5	13.63	0.038	**0.95**	20	1.329	14.23	47.00
test6	13.92	0.025	0.95	**30**	2.006	32.018	71.08

Table 1: System Response

4.2 Time Domain - Step Response

The values shown in table 1 were calculated from the closed loop transfer function of the system model. The ideal step response from matlab was then compared to experimental data from the TDS. This experimental data was collected by adjusting the K_p and K_I values in Labview and saving the response data to a text file. Data was collected for TDS machine 1 and TDS machine 4.

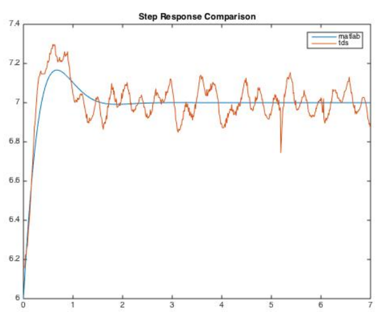

Figure 1: Step Response m1t1

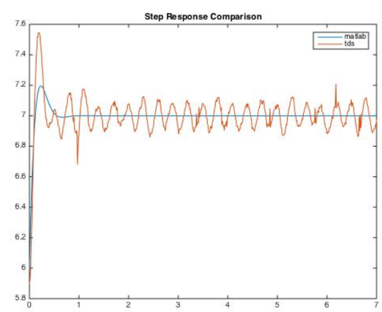

Figure 2: Step Response m1t2

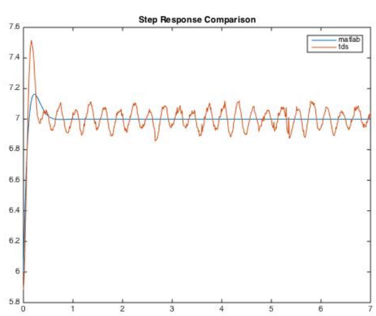

Figure 3: Step Response m1t3

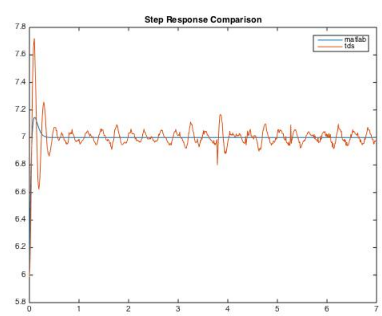

Figure 4: Step Response m1t4

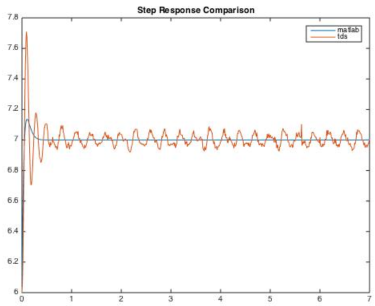

Figure 5: Step Response m1t5

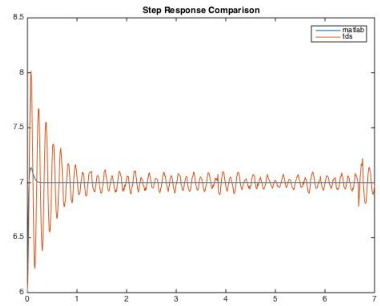

Figure 6: Step Response m1t6

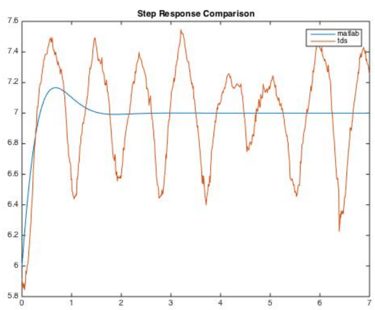

Figure 7: Step Response m4t1

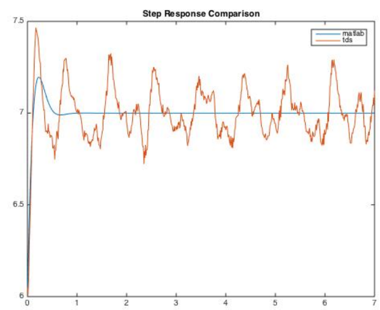

Figure 8: Step Response m4t2

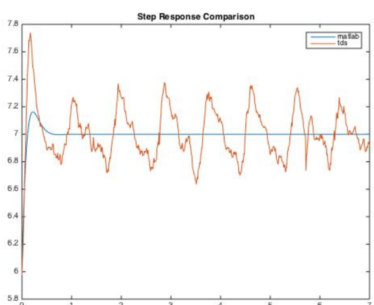

Figure 9: Step Response m4t3

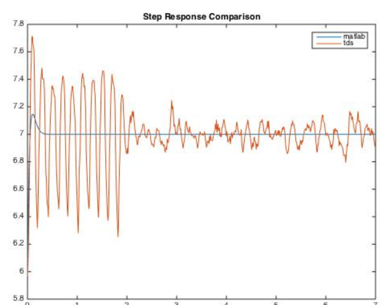

Figure 10: Step Response m4t4

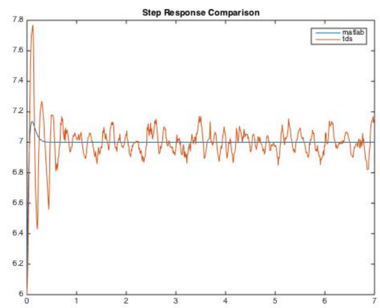

Figure 11: Step Response m4t5

Figures 1 through 6 show the plots of the matlab data and the collected experimental data for machine 1. Figures 7 to 11 show the data comparisons for machine 4. From this information it is possible to calculate the actual rise time and overshoot of the system for different K_I and K_p values. Table 2 shows the calculated t_r and M_p values.

matlab t_r	mach1 t_r	mach4 t_r	matlab M_p	mach1 M_p	mach4 M_p
0.275	0.09	0.19	16.646	29.78	54.66
0.09	0.05	0.05	19.58	54.58	46.45
0.085	0.05	0.03	16.23	51.71	73.95
0.039	0.03	0.03	14.67	71.97	71.37
0.038	0.03	0.03	13.63	70.93	77.01
0.025	0.02	n/a	3.916	101.66	n/a

Table 2: t_r and M_p Comparison

The overshoot amounts for the proportional integral controller quickly become large. Even with maximum damping it was not possible to reduce the overshoot by the desired amount. This large overshoot was partly due to increasing the natural frequency to reduce the steady state noise. With more iterations and experiments it would be possible to get a slightly better response.

4.3 Time Domain - Disturbance

Another important aspect of of designing the PI controller was viewing the response of the system to a ramp disturbance. As shown from the transfer functions and calculations in section 2.2 there should be a constant steady state error to a ramp disturbance. As seen in figures 12 and 13 there is a constant error to a ramp disturbance on the physical system as expected. In the plots the response with no disturbance is shown in blue and the response to the ramp disturbance is shown in orange.

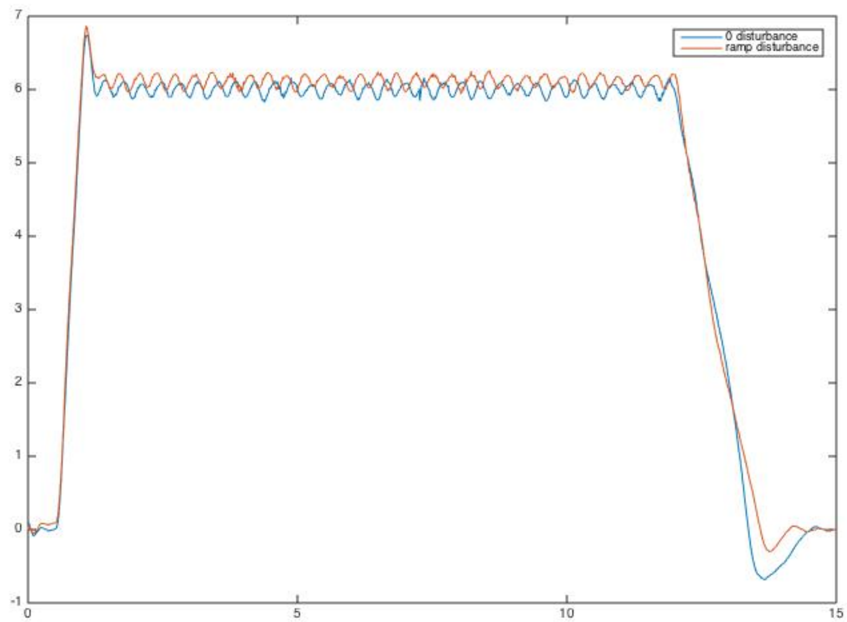

Figure 12: Ramp Distrubance m1

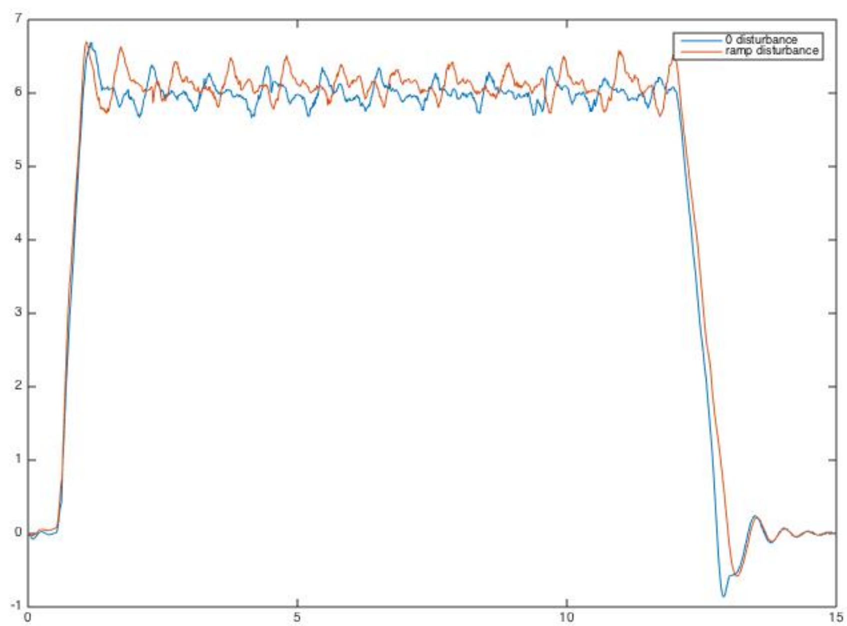

Figure 13: Ramp Distrubance m4

5 PI Controller Design Summary

Designing a PI controller is a complex and iterative process as outlined in the above sections. Analyzing a model of they system using matlab is a starting point that can provide some useful information. For example, viewing the various transfer functions helps to provide a baseline for the expected response to different inputs and disturbances. Calculated system parameters such as overshoot, rise time, natural frequency, and damping provide initial K_p and K_I values. On the actual TDS the response varies from the simulation due to variables that are not present in the ideal model. Iteratively updating system values gradually improves the system response but a PI controller is not sufficient to eliminate all undesirable characteristics. Further labs will explore more complex controllers which will continue to improve the response characteristics.