Torsion Experiment

Figure 1 shows the Torsion Experiment consists of two (Model 205) or three (Model 205a) disks supported by a torsionally flexible shaft that is suspended vertically on anti-friction ball bearings. The shaft is driven by a brushless servo motor connected via a rigid belt (negligible tensile flexibility) and pulley system with a 3:1 speed reduction ratio. An encoder located on the base of the shaft measures the angular displacement, θ_1 of the first disk, J_1. The second disk is connected to its encoder by a rigid belt / pulley with a 1:1 speed ratio. The Model 205 torsional mechanism represents many physical plants including rigid bodies; flexibility in drive shafts, gearing and belts; and coupled discrete vibration with actuator at the drive input and sensor collocated or at flexibly coupled output (noncollocated).

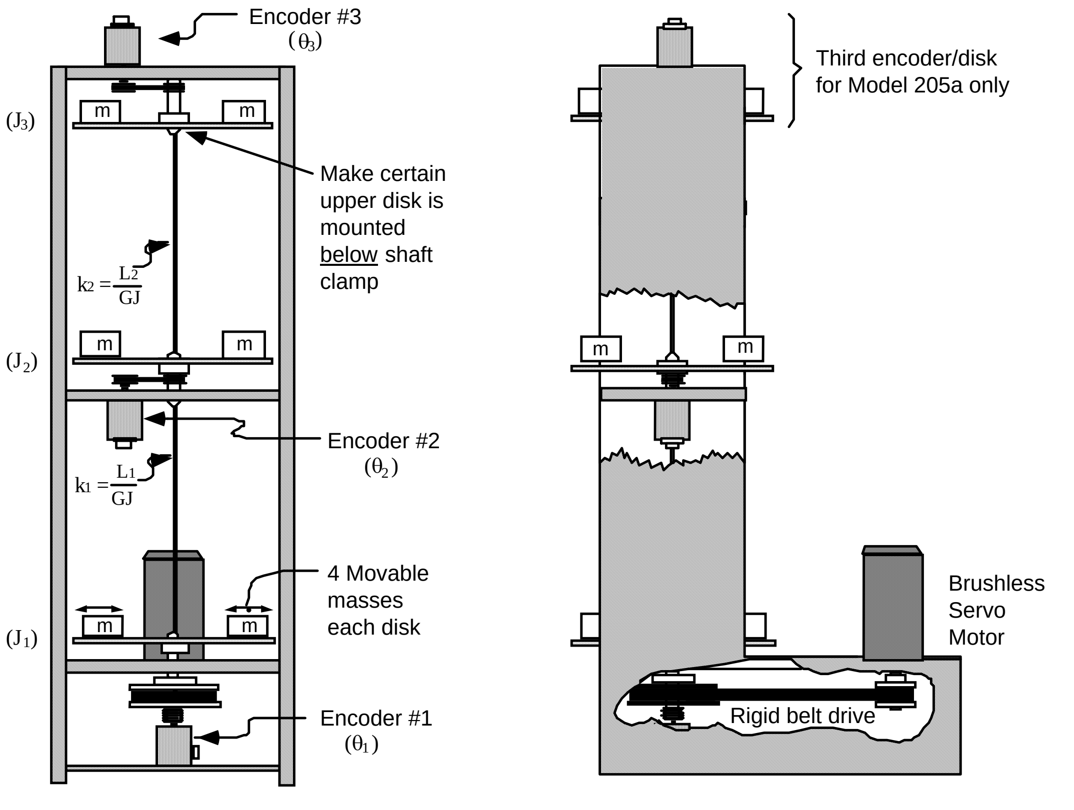

Figure 1: ECP Torsion Experiment

Checkout Procedure

Step 1: Enter the ECP program by double clicking on its icon. You should see the Background Screen. Gently rotate the drive or load disk by hand. You should observe some following errors and changes in encoder counts. The

Control Loop Status should indicate "OPEN" and the Controller Status should indicate “OK”.

Step 2: Make sure that you can rotate the disks freely. Now press the black "ON" button to turn on the power to the Control Box. You should notice the green power indicator LED lit, but the motor should remain in a disabled state. Do not touch the disks whenever power is applied to the Control Box since there is a potential for uncontrolled motion of the disks unless the controller has been safety checked.

Introduction Exercises

A. Read the safety information for the Torsion Experiment in Chapter 2 of the equipment manual (See also Appendix B on the course website).

B. Identify the control elements and signals in the Torsion Experiment*.

Sensor:	Actuator:
Controller:	Reference Input:
Actuator Output:	System Output:

*Refer to the Introduction Literature.

Experiment 6.1: System Identification

Follow the instructions in Experiment 6.1 (System Identification) in the ECP Manual. Note 1: Since only 4 masses are available you will have to perform the experiments for the first disk then place the weights on the second disk and continue. Note 2: The concentric circles on the inertia disks are at increments of 1 cm; the manual specifies the masses should be placed at a radius of 9 cm which is not possible. Place the masses at the widest position possible (approximately 8 cm). Include all plots generated in the procedure.

The following quantities should be found experimentally from the System Identification procedure:

Disk 3 Trial 1 Natural Frequency, ω_{nd31} = _______________ (rad/s)
Disk 3 Trial 2 Natural Frequency, ω_{nd32} = _______________ (rad/s)
Disk 3 Trial 2 Damping Coefficient, ζ_{d32} = _______________
Disk 1 Trial 1 Natural Frequency, ω_{nd11} = _______________ (rad/s)
Disk 1 Trial 2 Natural Frequency, ω_{nd12} = _______________ (rad/s)
Disk 1 Trial 2 Damping Coefficient, ζ_{d12} = _______________

Do Exercise A and find the following quantities:

Inertia of the 4 Masses, J_m = _______________ (kg-m^2)
Inertia of Disk 1, J_{d1} = _______________ (kg-m^2)
Inertia of Disk 3, J_{d3} = _______________(kg-m^2)

Damping Constant on Disk 3, c_{d3} = ______________ (N-m/rad/s)
Damping Constant on Disk 1, c_{d1} = ______________ (N-m/rad/s)
Spring Constant on Disk 3, k_{d3} = _______________ (N-m/rad)
Spring Constant on Disk 1, k_{d1} = _______________ (N-m/rad)

Note: $J_{d2} = J_{d3}$ and k_{hw} = 17.4 N-m/rad

Plot of Disk 3 Trial 1 is on pg.______.
Plot of Disk 3 Trial 2 is on pg.______.
Plot of Disk 1 Trial 1 is on pg.______.
Plot of Disk 1 Trial 2 is on pg.______.

Experiment 6.2: Rigid Body PD and PID Control

Follow the instructions in Experiment 6.2.

The following values should be determined when following the procedure:

Step 3: k_p = _____________
Step 7: w_n = _____________ (Hz)
Step 8: k_d = ______________
Step 11: k_p = ______________
(under-damped) k_d = _______________
(critically damped) k_d = _______________
(over-damped) k_d = ______________

Provide all the curves requested in the procedure.

Plot of Encoder #1 using k_p = ___________ is on pg._____.
Plot of Encoder #1 using $2k_p$ = ____________is on pg._____.
Plot of Under-Damped Step Response is on pg._____.
Plot of Critically Damped Step Response is on pg._____.
Plot of Over-Damped Step Response is on pg._____.
Plot of Under-Damped Frequency Response (logarithmic axes) is on pg._____.
Plot of Critically Damped Frequency Response (logarithmic axes) is on pg._____.
Plot of Over-Over Damped Frequency Response (logarithmic axes) is on pg._____.

Discuss the effects of increasing/decreasing k_d? How might this be used for control purposes?

Graphically determine the resonance frequency and the high and low frequency gain slopes? Use a colored pen on your curves to indicate the frequency and slopes.

Do the experimental Bode plots match those that would be generated theoretically? Discuss any discrepancies and cite possible reasons for these discrepancies?

What are the effects of adding integral action to the controller? How does increasing/decreasing k_i affect the system response?