DESIGN OF A PD CONTROLLER FOR A HARMONIC DRIVE

Department of Electronics & Communication Engineering,

Institute of Technical Education and Research

CONTROL SYSTEMS

(EET3071)

PROJECT REPORT

SUBMITTED BY

NAME:	**TANIYA BARAL**
REGISTRATION NO.:	**2141002154**
BRANCH – SECTION:	**ECE-A**
SEMESTER:	**6th**

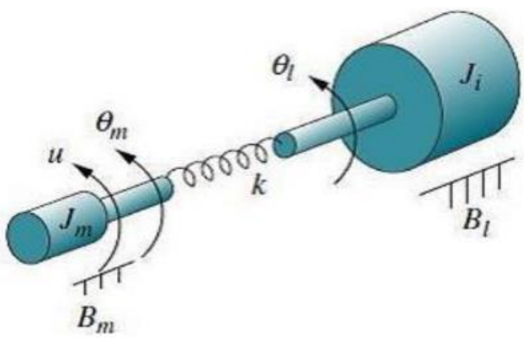
There are eleven student outcomes (A-K) for the B. Tech programme in Electronics and Communication Engineering.

Abet Outcomes	Description of Outcome
A	Ability to apply mathematics, science and engineering principles.
B	Ability to design and conduct experiments, analyse and interpret data.
C	Ability to design a system, component, or process to meet desired needs.
D	Ability to function on multidisciplinary teams.
E	Ability to identify, formulate and solve engineering problems.
F	Understanding of professional and ethical responsibility.
G	Ability to communicate effectively.
H	The broad education necessary to understand the impact of engineering solutions in a global and societal context.
I	Recognition of the need for and an ability to engage in life-long learning.
J	Knowledge of contemporary issues.
K	Ability to use the techniques, skills and modern engineering tools necessary for engineering practice

The students will able to satisfy ABET outcomes A, E, B, C, G and K in this subject. They will satisfy outcome A, E through mid-semester, end semester, Quizzes and assignments, where as they will satisfy B, C, G and K through lab tests, projects, reports and viva-voce.

1 Problem Statement

Harmonic drives are very popular for use in robotic manipulators due to their low back-lash, high torque transmission, and compact size. The problem of joint flexibility is sometimes a limiting factor in achieving good performance. Consider that the idealized model representing joint flexibility in Figure. The input to the drive is from an actuator and is applied at θ_m.The output is connected to a load at θ_l. The spring represents the joint flexibility while B_m and B_l represent the viscous damping of the actuator and load, respectively. Use a PD controller to improve the transient performance of the system. Design the controller such that the maximum transient error will be approximately 5%. System Parameters are: J_m = 2, B_m= 0.5, J_l= 10; B_l =1, k =100.



2 Background Theory

Here the system will have two principal nodes. The nodal equivalent diagram for the given harmonic drive system is shown below in fig.1.

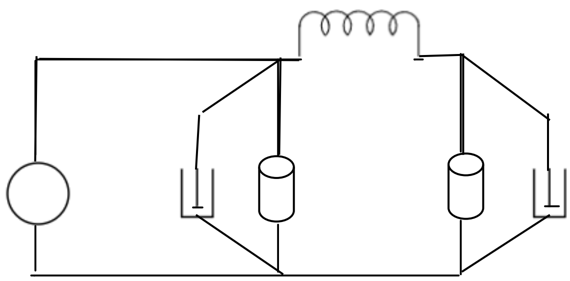


fig.1 Nodal equivalent diagram for the given harmonic drive system

$At\ \theta_m$

$$u(t) = J_m \frac{d^2\theta_m}{dt^2} + B_m \frac{d\theta_m}{dt} + K(\theta_m - \theta_l) \quad \dots\dots\dots\dots (1)$$

$At\ \theta_l$

$$K(\theta_m - \theta_l) = J_l \frac{d^2\theta_l}{dt^2} + B_l \frac{d\theta_l}{dt} \qquad \dots\dots\dots\dots(2)$$

3 Mathematical Modelling

Equation derived from (1) and (2)

$$\frac{d^2\theta_m}{dt^2} = \frac{1}{J_m}\left[u(t) - B_m \frac{d\theta_m}{dt} - K(\theta_m - \theta_l)\right] \qquad \dots\dots\dots\dots(3)$$

$$\frac{d^2\theta_l}{dt^2} = \frac{1}{J_l}\left[K(\theta_m - \theta_l) - B_l \frac{d\theta_l}{dt}\right] \qquad \dots\dots\dots\dots(4)$$

Using eq.(3) and(4), the mathematical model was created in Simulink as shown in fig.(2).

4 Implementation and verification in Matlab/Simulink

Subsystem

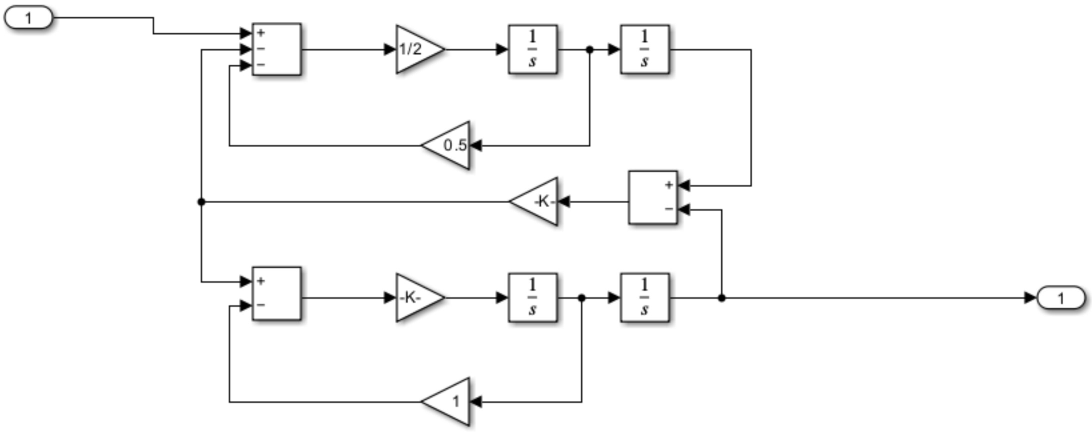


fig.2 Mathematical model for the given harmonic drive system

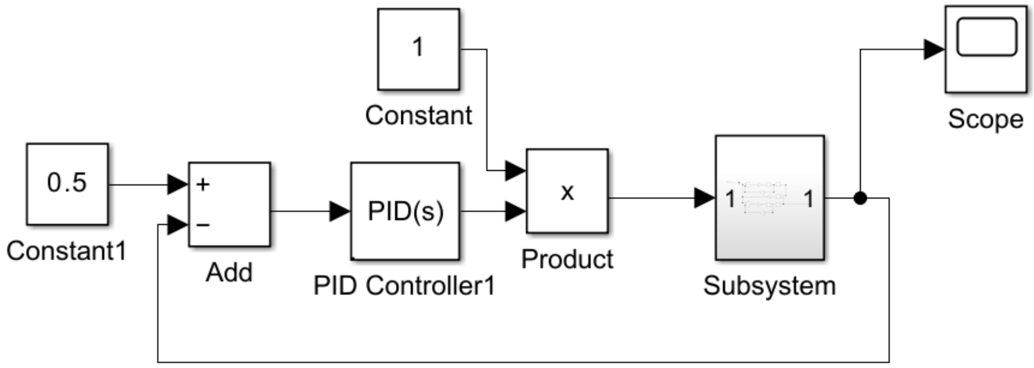


fig.3 Closed loop model with PD controller for the given harmonic drive system

5 Result and analysis

Show

Controller Parameters

	Tuned	Block
P	0.63863	1
I	0.018293	0
D	4.9339	0
N	1.5412	100

Performance and Robustness

	Tuned	Block
Rise time	3.56 seconds	4.24 seconds
Settling time	55.9 seconds	58.9 seconds
Overshoot	4.97 %	49.9 %
Peak	1.05	1.5
Gain margin	20.1 dB @ 7.24 rad/s	44.4 dB @ 4.63 rad/s
Phase margin	74.7 deg @ 0.423 rad/s	24.3 deg @ 0.276 rad/s
Closed-loop stability	Stable	Stable

Fig.4 Tuning results showing Overshoot approximately 5%

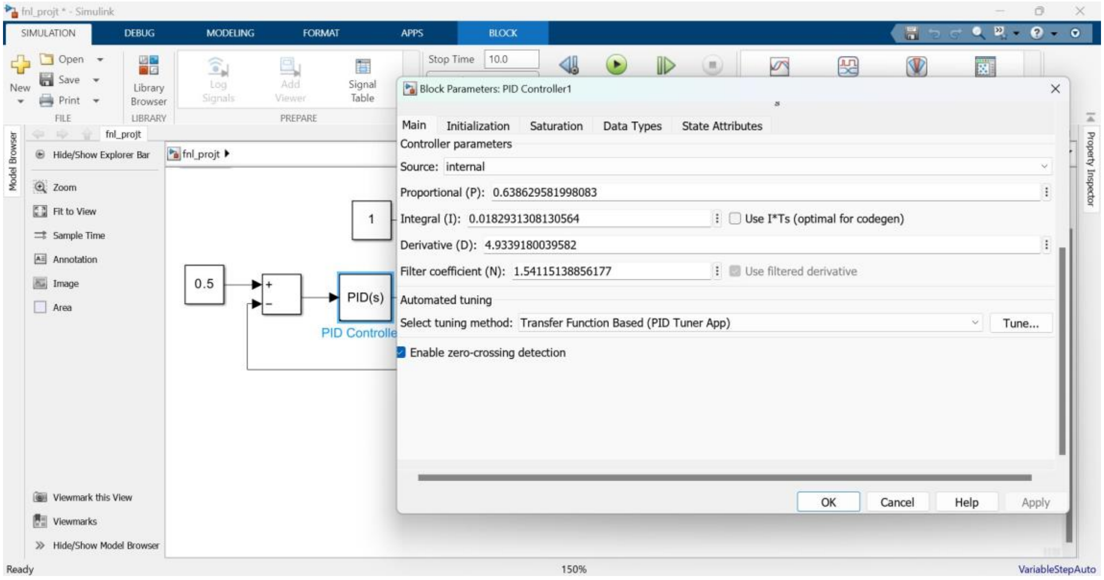


Fig.5 Controller gains after tuning to get the transient error approximately 5%

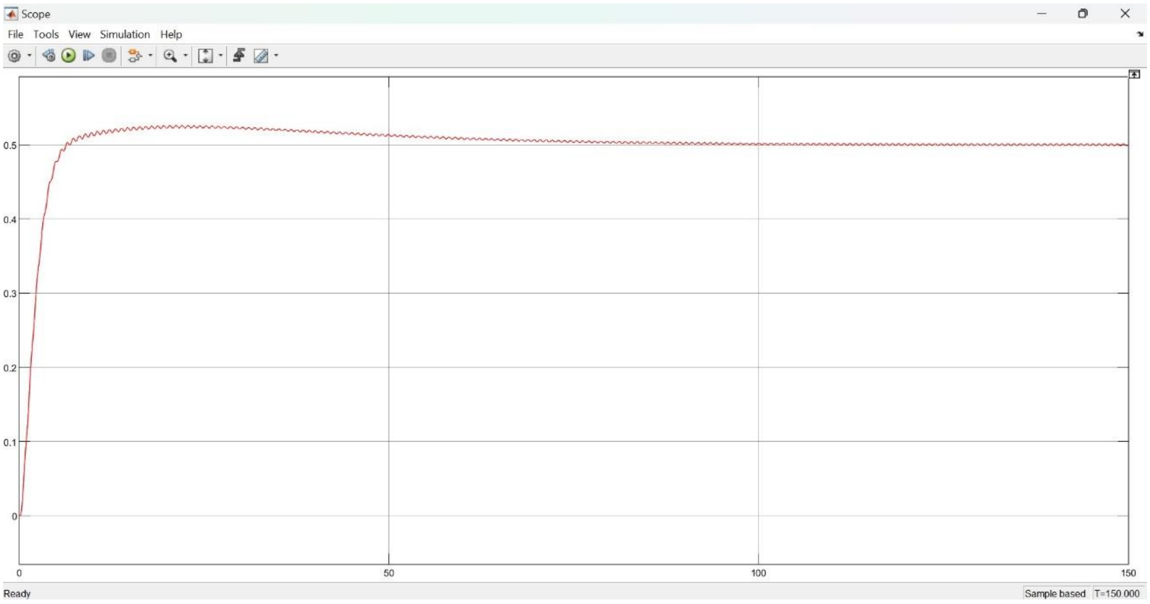


Fig.6 Response when the transient error is approximately 5%

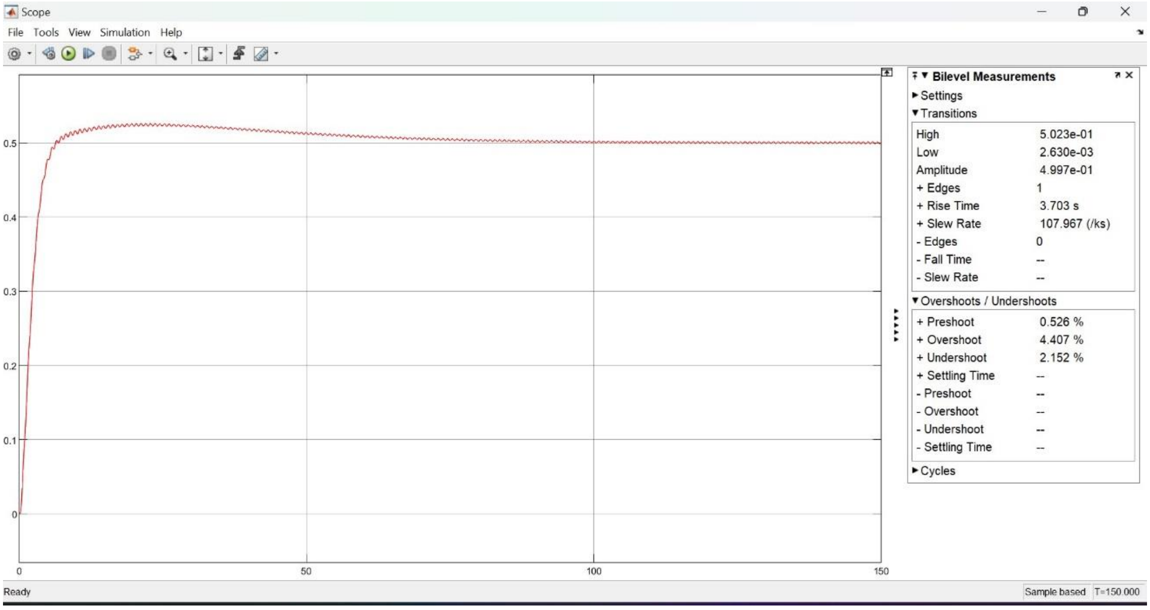


Fig.7 Response when the transient error is approximately 5%

Analysis

Here we have taken the reference load displacement(θ_l)in degree to be 0.5 and torque input as 1N.m. By tuning the response time and transient behaviour we got the overshoot from the bi-level measurements as 4.407% but in the PID tuner we have tuned till the transient error is 4.97%. And the controller parameters were set as P=0.6386, I=0.01829 and D=4.9339 for the PD controller.

6 Conclusion

In this project I have learnt how to design and use a PD controller for a mechanical harmonic drive to reduce its transient error to approximately 5% by tuning it at an overshoot of 4.97% and generating its response.

7 References

[1] Norman S. Nise, Control System Engineering ,6th Edition, WILEY Publications, 2016.

[2] A. Anand Kumar, Control Systems, 2nd Edition, PHI Learning, 2014.