Actuator Performance Analyzer

Measured PID response of a two-degree-of-freedom torsional system

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Abstract

This project evaluates how integral gain changed the measured response of a PID-controlled rotary system. Ten positive step responses were extracted from five laboratory tests. Increasing Ki reduced steady-state error, but increased overshoot and sensitivity to the controller's initial state.

1. Experimental setup

The data were recorded on a torsional apparatus with two rotary disks, 16,000-count-per-revolution encoders, and a 10 V motor amplifier. Kp was held at 0.204 and Kd at 0.014 while Ki was varied from 0.001 to 0.3. Each run contained two positive 1,000-count commands sampled at approximately 1 kHz.

2. Analysis method

The original MATLAB files were exported to CSV without altering the source data. Each positive step was isolated, encoder counts were converted to radians, and the response was evaluated using overshoot, 2% settling time, RMS tracking error, control effort, and steady-state error.

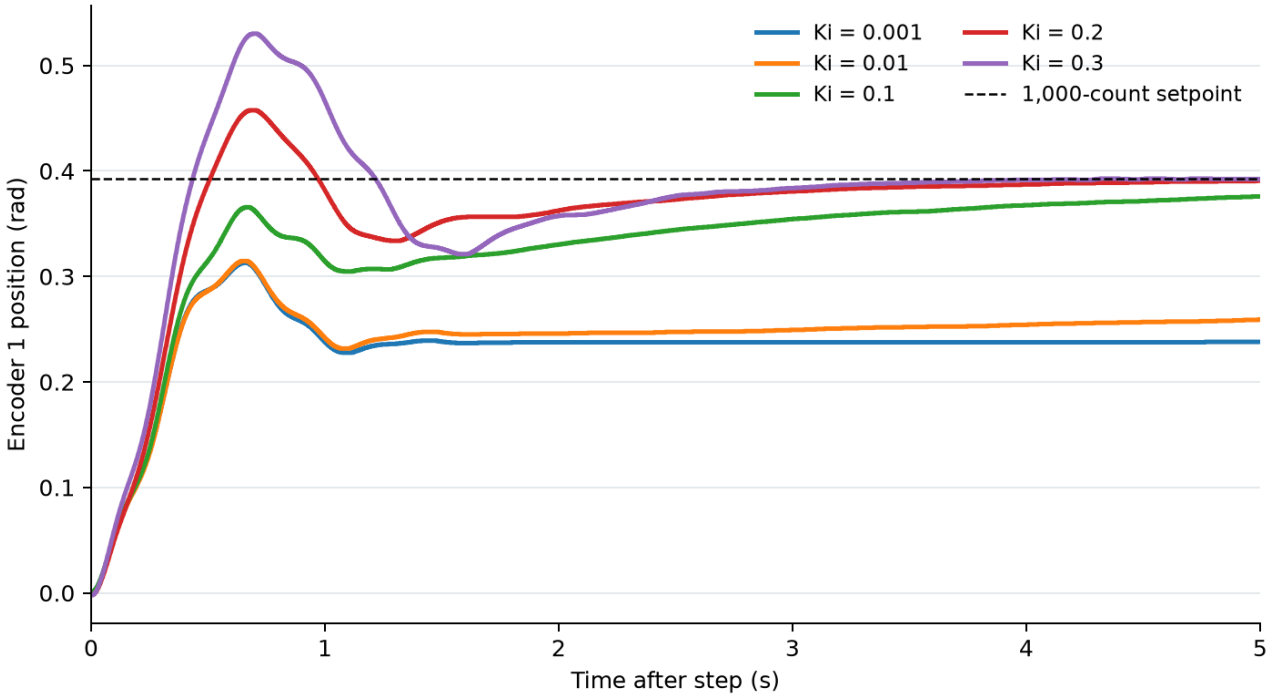

Figure 1. First positive step from each measured integral-gain trial.

At low Ki, the output remained below the command. Higher Ki improved tracking but produced a larger initial peak. Ki=0.1 was the only fixed-Kd setting that averaged less than 25% overshoot and less than 5% steady-state error, although it did not settle within the 2% band during the five-second window.

3. Results

Table 1 reports the mean of the two positive steps in each test. 'Not within 5 s' means the response did not enter and remain inside the 2% settling band during the available step window.

Ki	Mean overshoot	Mean 2% settling time	Mean steady-state error
0.001	0.0%	Not within 5 s	38.4%
0.010	4.4%	Not within 5 s	29.9%
0.100	17.1%	Not within 5 s	3.7%
0.200	46.1%	3.92 s	1.1%
0.300	61.1%	3.35 s	0.2%

Table 1. Measured response metrics averaged across two positive steps.

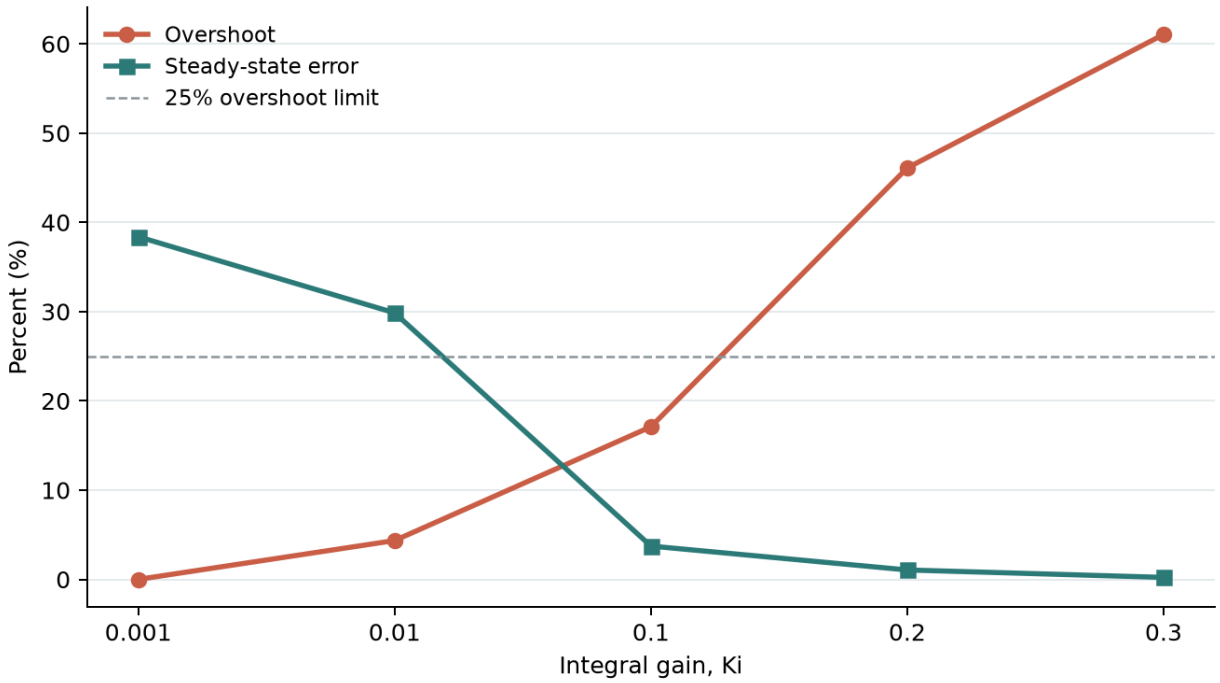

Figure 2. Effect of integral gain on overshoot and steady-state error.

4. Discussion

Integral action improved low-frequency tracking but reduced damping. The two repetitions also diverged at higher Ki. At Ki=0.2, overshoot increased from 16.5% on the first step to 75.7% on the second, which is consistent with accumulated integral state and different initial conditions between cycles.

5. Final controller

Kp	Ki	Kd	Overshoot	2% settling time	Steady-state error
0.2	0.2	0.019	20.8%	1.40 s	0.1%

The final controller increased Kd above the fixed-Kd sweep, adding damping and bringing overshoot below the 25% requirement. These final values come from the original course report because the uploaded MAT files contain the Ki sweep, not the final Kd=0.019 trial.