Executive Summary

In this experiment, a DC brush motor under test (MUT) is coupled with a back-driving motor to determine the system parameters under step input and disturbance loading conditions. The system was also subjected to three types of power op-amp control systems: proportional control, Integral control, and proportional-integral control. Motors were controlled by voltage. The objective of the control systems was to maintain motor speed regardless of the load placed on the motor. Motor speed was measured by a tachometer and the output tachometer voltage was recorded.

The velocity constant, , was calculated to be by linearly fitting the velocity data (calculated from tachometer output) to the MUT’s voltage output. The MUT’s back-EMF constant, , was found to be using the assumption that in British units. These two values are within the range listed in the motor’s specification sheet.

The MUT’s step response time constant, , and motor gain, , were calculated to be and , respectively. Multiply the motor gain with the tachometer gain, , the overall system gain was found to be . The parameters calculated from the experimental data were: , . The two gains were close in value, but when used to calculate the mass-moment of inertia and damping coefficient of the motor, the small gain difference resulted in very large system parameter differences. Since the MUT was still connected to the back-drive motor the moment of inertia and damping coefficient were expected to be double the values listed in the specification sheet at and . However, the difference in the system gains resulted in a damping coefficient of . Using the experimental damping coefficient and time constant, the moment of inertia was found to be . If the expected damping coefficient was used instead, the moment inertia would be . The smaller gain is likely due to the motor being worn out, friction being neglected, and potentially additional damping from other factors such as the connecting coupler. Additionally, the setting time is found using four times the time constant: . The response time constant to a disturbance load of is found to be , which is about two third of the the motor’s system time constant, suggesting the motor responds to disturbance loads faster than step input.

Closed-loop motor response to a voltage step input and disturbance torque was recorded with a tachometer in the same way as the open-loop response. The power op-amps were controlled by a 741 op-amp – proportional, integral, and proportional-integral control were implemented and analyzed. The time constants of the step response for the P, I, and PI controller were found to be 5.4 ms, 20 ms, 10.8 ms respectively. The P controller has the fastest response, although it is the only controller that halves the voltage output. Also, it has the highest steady state error in response to disturbance at 18.9%. The I controller has less error with 7%, and the PI is the most effective at reducing error to .0007%. In a purpose-built closed-loop system the magnitude of each control element (P,I,D) is modified such that it has a larger or smaller role to fit the individual needs of the system. Generic control parameters were used for this experiment (non-optimized).