New ACT-PACK Motor Characterization

Dynamic Test

Setup for the Dynamic Test:

Two ACT-PACK motors are connected on opposite ends of a Futek torque sensor using a shaft and flexible couplers, with the entire assembly securely mounted on a test bed. The Futek sensor communicates with a Raspberry Pi via I2C for data logging, while the motors are connected through c-type cables and controlled using the Open Source Leg (OSL) libraries.

Figure 1. Setup of the Dynamic test

Methodology

The motor on the left was operated in current control mode and the motor on the right in voltage control mode, with commanded currents from -10 A to $+10$ A and voltages up to 10 V. Data was collected using the OpenSourceLeg (OSL) logging function, recording timestamp, torque (Futek sensor calibrated readings), motor current, motor voltage, motor position, motor velocity, battery current, and battery voltage, and saved to CSV. After collection, the following regression model was fit: $\tau_a = \tau_m - \tau_f(\dot{\theta}_a, I_q) - B_a\dot{\theta}_a - J_a\ddot{\theta}_a$, where τ_a is the actual joint torque, τ_m is motor torque, B_a is viscous damping, and J_a is rotor inertia. Friction was modeled as $\tau_f(\dot{\theta}_a, I_q) = \text{sgn}(\dot{\theta}_a)(f_c + f_g|I_q|)$, with f_c as Coulomb friction and f_g as gear friction. From this, all model parameters were identified.

Results

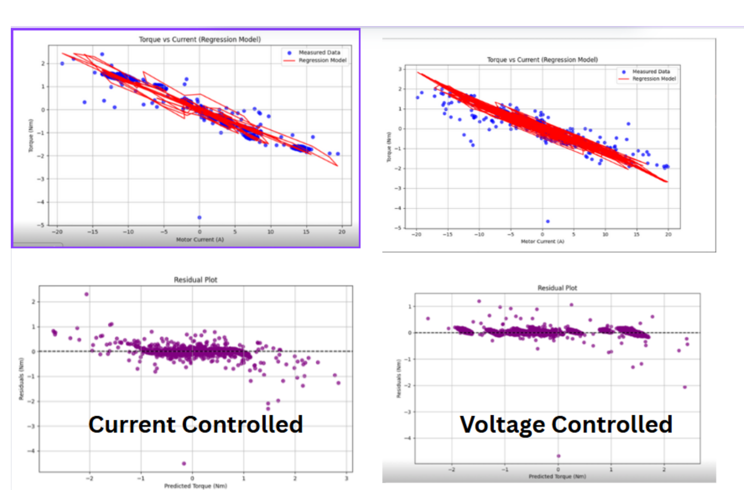

Figure 2. Comparison of results for current-controlled and voltage-controlled motors, where both yielded similar outcomes.

- The torque constant was identified as -0.145 Nm/A.
- Coulomb friction f_c was identified as 0.00787 Nm.
- Gear friction f_g was identified as 0.0211 Nm/A.
- Damping coefficient B_a was identified as -9.1×10^{-5} Nm.s/rad.
- Moment of inertia J_a was identified as 8.1×10^{-5} Nm.s^2/rad.
- The model captured 99.1% of the variance.
- The RMS residual was 0.067 Nm (1.43% of peak torque).

Static Test

Setup for the Static test

One ACT-PACK motor is connected to a Futek torque sensor using a shaft and flexible couplers, while the opposite end of the sensor is rigidly mounted to a fixed plate. The entire assembly is securely mounted on a test bed. The Futek sensor communicates with a Raspberry Pi via I2C for data logging, and the motor is connected through a c-type cable and controlled using the Open Source Leg (OSL) libraries.

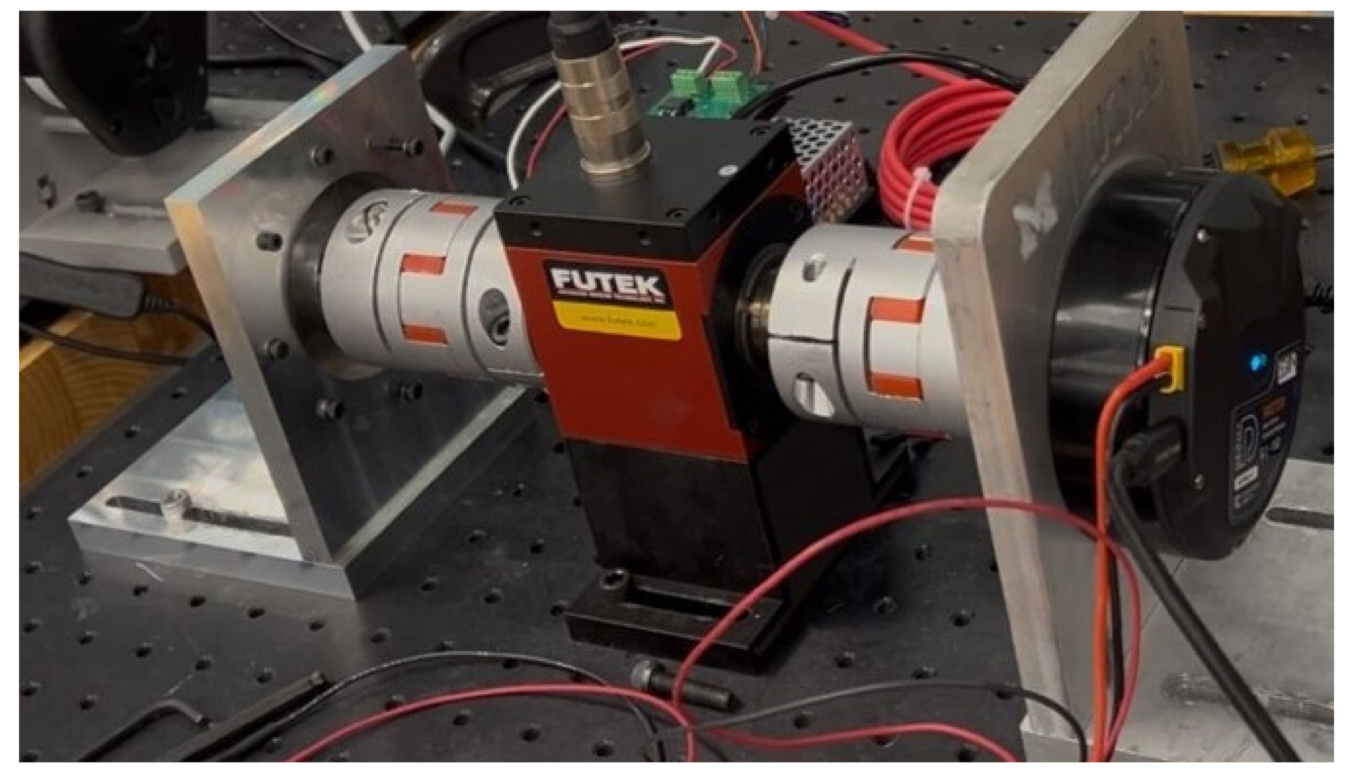

Figure 3. Setup of the Static test

Methodology

For the static tests, the motor operated in current control mode with a trapezoidal waveform: ramping to maximum in 1 second, holding for 2 seconds, ramping to negative maximum in 2 seconds, holding again for 2 seconds, then returning to zero and holding for 2 seconds. Peak current increased from 2.5 A to 20 A in 2.5 A steps. Data was logged just like the dynamic test and saved to CSV. Friction terms f_c and f_g from Dynamic tests were used to adjust torque as $\tau_{\text{adjusted}} = \tau_{\text{measured}} - (f_g \times I_q) + f_c$. The static model was identified by fitting $\tau_{\text{adjusted}} = K_t \times I_q$.

Results

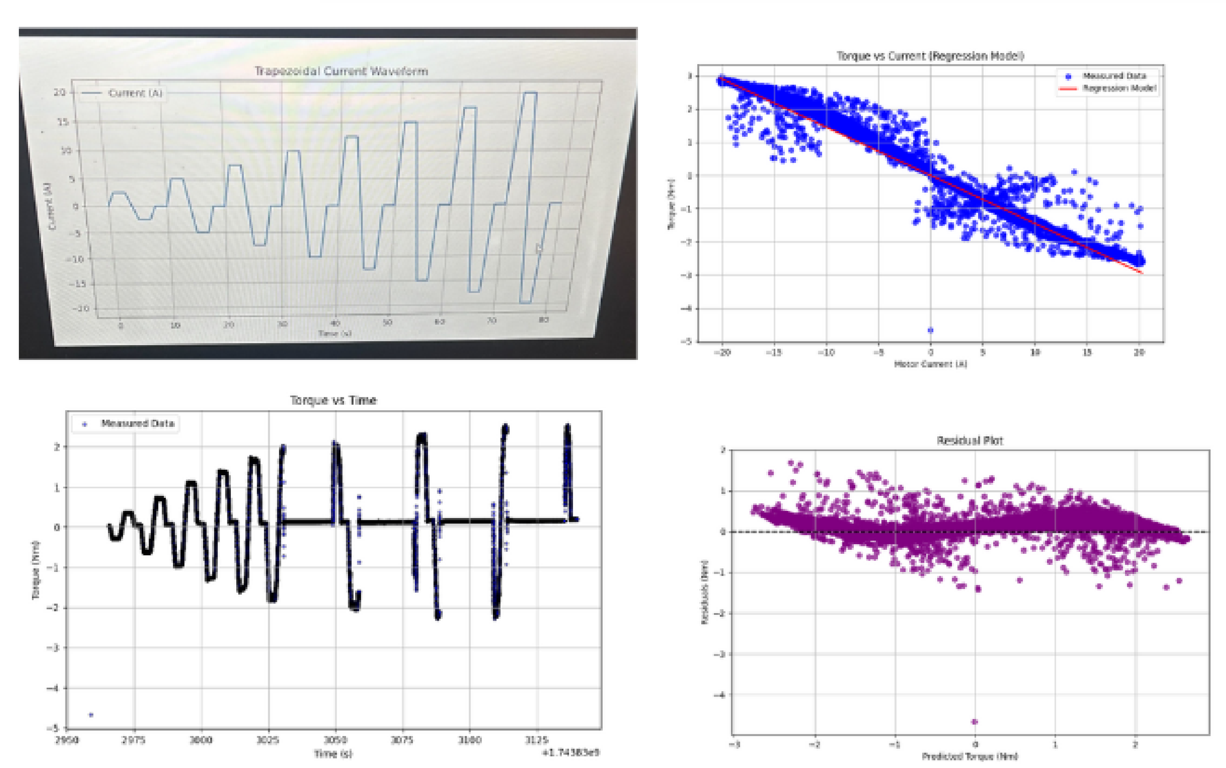

Figure 4. The figure presents the current profile, torque profile, and the resulting regression model, yielding $K_t = 0.145\,\text{Nm/A}$.

Drill Test

Setup for the Drill test

For the drill test, an oscilloscope, one ACT-PACK motor, and a handheld drill were used to actuate the motor.

Methodology

The drill test involves actuating the ACT-PACK motor at low speed using a handheld drill connected via a shaft. The motor leads are connected to an oscilloscope, which records the voltage over time. From the recorded waveform, the torque constant K_t is estimated using the equation:

$$K_t = \frac{V_{\text{pk-pk}}/2}{\sqrt{2/3} \cdot f \cdot \frac{2\pi}{\text{pole pairs}}}$$

Given the motor is delta-wound and has 21 pole pairs, this method provides an estimate of the motor's torque constant based on the back-EMF profile.

Result

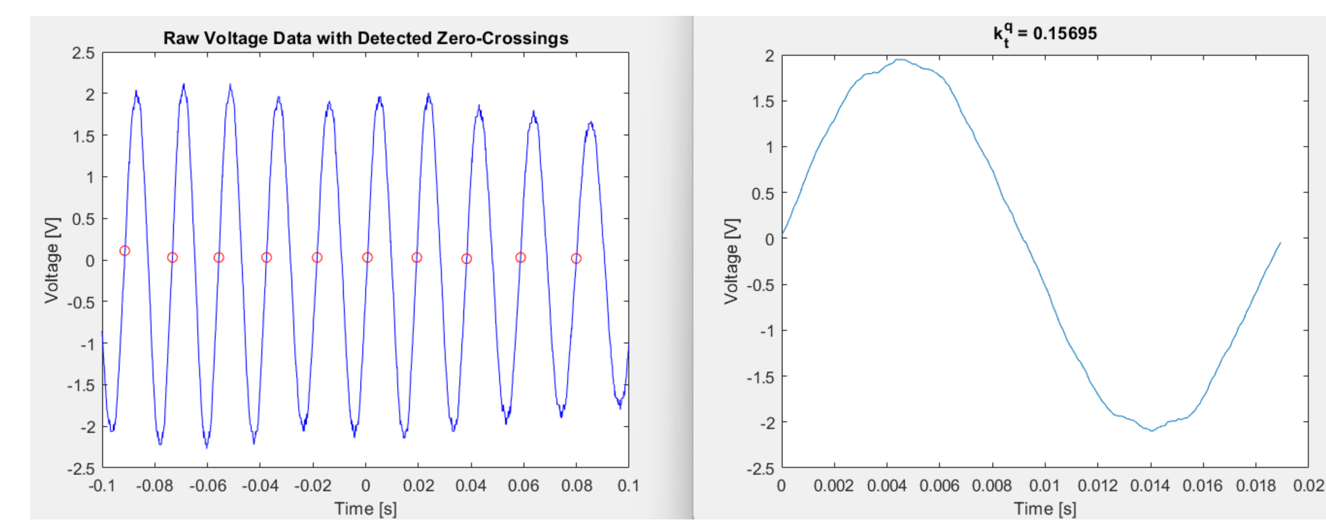

Figure 5. Results of the Drill Test showing the voltage vs. time plot and the estimated torque constant K_t.

The estimated torque constant K_t from the Drill Test (based on Back-EMF measurements) was found to be 0.156 Nm/A.

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