1 Friction Torque Measurement

The torque required to initiate rotation in either wheel will be measured statically. A rope attached to the wheel circumference will be used to add small weights to generate a vertical downward force. Weights will be added until imminent motion is detected. The friction torque is simply the radius of the rope attachment point multiplied by the force created by the proof masses.

1. The bicycle has been securely mounted on two supports (bike trainers). You must still be careful when handling the bicycle to avoid toppling it down or pulling on instrumentation wires.

2. Attach the rope to the wheel with tape or with a knot so that it can hang vertically and tangentially to the wheel. Weigh the scale plate and attach it to the rope. Measure the radius from the attachment point to the center of the wheel.

3. Add the supplied small calibrated weights until the wheel begins to rotate. You may need to try several times to avoid using more weight than necessary. Take 10 readings.

4. Repeat the process for the opposite direction of rotation.

2 Spin-Down Tests

The objective of this section is to obtain the moment of inertia of the wheel assemblies. A Hall-effect sensor is installed for each wheel. The sensor works by detecting the passage of a ferromagnetic bolt or a magnet in front of the sensor. The front wheel uses one magnet, while the rear wheel has 6 equally-spaced bolts. Each time the magnet or a bolt pass in front of the stationary sensor, a pulse is created. A Win-Con real-time interface has been prepared to record and display the incoming pulse stream. The instantaneous speed at time \( t \) is found by determining the number of pulses per second near the desired time \( t \). The interface only records the pulses as a function of time. You will need to process them offline into speed vs. time data.

2.1 Front Wheel

The front wheel sensor has been provisionally installed. Due to small misalignments, pulses can be skipped at high speed. Please run the test at low speeds.
An oscilloscope capture will be used instead of the WinCon interface for better sampling speed.

1. The front wheel has only one magnet, so there will be one pulse per revolution.

2. Set the oscilloscope timebase to 1 second per division. The pulses are recorded in batches of 10 seconds, which are over-written (screen is cleared every 10 seconds)

3. Use the throttle to accelerate the wheel so that the speedometer reads about 10 mph. Wait until a new screen cycle begins. As soon as it begins, turn the controller switch off to cut all power to the motor. Stop the oscilloscope capture right before the screen cycle ends.

4. Call the instructor to verify and save the data.

2.2 Rear Wheel

1. The rear wheel has 6 ferrous bolts, so there will be six pulses per revolution.

2. Start the WinCon capture. The pulses are recorded in batches of 10 seconds, which are over-written (screen is cleared every 10 seconds)

3. Use the pedals to accelerate the wheel to a high speed. Wait until a new screen cycle begins. As soon as it begins, freeze the pedals so that the wheel spins freely. Stop the WinCon capture right before the screen cycle ends.

4. Call the instructor to verify and save the data.

Once the speed decay curves are obtained,

3 Gear Ratio Measurements

This section is being repeated due to the new sensor installation.

A basic computer control interface has been prepared by the instructor to change the gear ratio of the continuously-variable transmission (CVT). The potentiometer sensor currently installed has a range of rotation of 10 turns, allowing the use of the whole CVT range. It is coupled to the CVT actuator through gears such that the potentiometer rotates 4 turns when the actuator rotates 3 turns. The rotation range of the actuator is 4 turns, which results in 6 turns of the potentiometer. However, to avoid hitting the limits of the CVT and damaging the sensor/motor, the WinCon interface leaves a 1/4-turn margin for the CVT at either end. Correspondingly, the computer control interface has been set to limit the potentiometer voltage between 0.75 and 3.75 volts. The objective of this section is to relate this voltage to gear ratio from the pedals to the rear wheel.

1. The instructor will explain how to operate the WinCon real-time PI control interface and point its limitations.

2. Set the pot voltage setpoint to 0.75 volts. Compile and run, allowing the actuator to settle at the corresponding gear ratio. Turn the pedals, count the turns of pedals and rear wheel. Write down these values.
3. Repeat for pot voltages every 0.25 until 3.75 is reached.

4. Enter the raw data as a Matlab matrix (first column: pot voltage, second column: #turns of pedals, third column: #turns of rear wheel). Call the instructor for verification and saving of the data in Matlab format.

5. Calculate the CVT ratios (from sprocket to wheel) using chainring/sprocket teeth number data.

6. Plot CVT ratio vs. pot voltage for visual inspection (linear or nonlinear?). Perform a curve fit.

4 Master Bond Graph

Construct a bondgraph for the bicycle including the following:

1. Overall weight

2. Variable gear ratio from pedals to rear wheel

3. Rear wheel inertia and hub friction as an external source of torque

4. Front wheel motor: combine the front wheel inertia and motor inertia into one. Include friction as an external source of torque. Consider motor resistance, but not inductance.

5. Road elevation and rolling resistance: as done in the second midterm.

6. Batteries: Model as a capacitor in series with a resistance (consult course webpage: electric vehicle case study).

It is up to the student to generate the model equations in 20-sim or by hand. The instructor needs to approve the bond graph prior to Simulink model construction.