

MCE 403/503: Modeling and Simulation of Mechatronic Systems  
Final Project - Fall 2010  
-Modeling and Experimental Parameter Estimation of Hybrid-Electric  
Bicycle-  
Lab Session 3

## 1 Alternative Spin-Down Test: Front Wheel

The hub motor's permanent magnets make it difficult to obtain an accurate friction torque reading by the static method used in the previous session. Preliminary analysis of the spin-down data confirms a fairly linear speed decay trace. An alternative to the static method is to allow the wheel to reach zero speed from a high initial speed and use a stopwatch to determine the time required. The initial speed is read with a laser tachometer. Also, the moment of inertia and friction torque can be determined simultaneously by performing 2 spin-down tests: one with the wheel inertia  $J_f$  and a second one with a known, added inertia  $J_a$ , so that the total is  $J_a + J_f$ . The extra inertia has been created by attaching concentrated masses to the rim, approximately symmetrical to maintain balance. Two 200g and two 100g masses have been attached.

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. Use extra caution when sitting on the saddle.**
2. Attach reflective tape to the tire so speed can be measured reliably with the laser tachometer.
3. Measure the mean radius to the concentrated 200g masses and 100g masses.
4. Spin the wheel to maximum speed using the throttle. Measure the initial speed in rpm.
5. Start the stopwatch and cut the power *simultaneously*. Stop the stopwatch just as the wheel comes to rest. Write down the initial speed and time.
6. Remove the extra masses and repeat the previous 2 steps.
7. Develop the system of 2 equations and 2 unknowns to calculate the friction torque and the wheel inertia from the two deceleration ( $\text{rad/s}^2$ ) values. You will compare these values with the static test results (front wheel only).

## 2 Gear Ratio Measurements

The shifter mechanism has been removed, leaving only the actuator shaft. You will measure only the maximum and minimum ratios.

1. Turn the actuator shaft fully clockwise with a set of pliers.
2. Turn the pedals one revolution and count the number of revolutions of the rear wheel. Use the spokes as a protractor for better estimation accuracy.
3. Turn the actuator shaft fully counter-clockwise with a set of pliers.
4. Turn the pedals one revolution and count the number of revolutions of the rear wheel. Use the spokes as a protractor for better estimation accuracy.
5. Write down the two ratio values.

### 3 Bicycle Weight and Rolling Resistance

The overall weight will be obtained by placing the load cell under the wheels, one at a time. The rolling resistance coefficient is defined by the force required to move the bicycle at constant velocity divided by the total weight (rider + bike). This coefficient does not include air resistance and has the same value at all speeds.

1. The rear stand has been already removed.
2. Place the load cell under the rear wheel and read the voltage.
3. Install the rear stand and remove the front stand.
4. Place the load cell under the front wheel and read the voltage.
5. Call the instructor and re-assemble and adjust the rear and front brakes. Carefully remove the front stand and detach all instrumentation wires except the multimeter used for current. Secure it to the center of the handle bar with tape.
6. Weigh a rider and have him/her ride the bicycle along the hallway at slow, constant speed, observing the speedometer and the current reading. Take 2 speeds per rider (current should be approximately the same once speed is constant). Try 5 riders of different weights.
7. Enter the data as a Matlab matrix aided by the instructor.

### 4 Battery Capacity

The batteries are unlabeled, so their capacity (total charge in Amp-hours) needs to be measured. This test may take a long time, so it will be run by the instructor outside class time. Note the procedure:

1. The total charge drawn from the batteries is the time integral of the current. For practical purposes, the batteries will be regarded as discharged when the current drops below the current required to overcome friction torque, rolling resistance (no rider) and idle controller current. Alternatively, a low battery voltage condition can be used to determine that the batteries are practically discharged.

2. A WinCon interface has been prepared to record current and battery voltage simultaneously with a long time interval (1 minute).
3. The throttle is stuck at maximum and recording starts. The interface detects the absence of velocity pulses from the Hall effect sensor to determine that the wheel has stopped rotating. It then terminates data capture.
4. The data will be analyzed to determine practical battery capacity and an empty-battery condition criterion.