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Testing a Rear Wheel Drive xEV on a 2 Wheel and 4 Wheel Dynamometer

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Vehicle Braking

Braking On-Road versus on a Chassis Dynamometer

- Braking energy is of no consequence for conventional vehicles, but could affect the net energy usage for hybrids, PHEVs and BEVs (xEVs), which recuperate braking energy.
- Braking distribution between axles generally favours the front-axle with most of the braking force.
- On a 2-Wheel Dyno 100% of braking is on driven axle
- Obviously, for front wheel drive (FWD) vehicles this is somewhat representative of on-road driving.
- But what about rear-wheel drive (RWD) vehicles? 100% of braking is on the rear axle! Not so realistic.

What's in the Code of Federal Regulations?

- RWD xEVs are routinely tested on 2-wheel chassis dynamometers for compliance testing purposes
- Currently, the U.S. EPA CFR Title 40, Part 86 does not explicitly require RWD xEVs to be tested on 4-wheel chassis dynamometers.
- Argonne National Laboratory conducted a study comparing FWD vs. AWD chassis dynamometer tests and found no statistically significant differences in regenerative braking energy or fuel consumption (SAE 2005-01-0685).

Test Setup - Hypothesis

- This mini-study intends to evaluate (primarily) regenerative braking energy and CO_2 emission differences between a 2-wheel dynamometer, a 4-wheel dynamometer and empirically determined rear-axle braking forces applied the same test conditions on a 2-wheel dynamometer.
- We expect to see the highest regenerative braking energy and lowest CO_2 emissions in the 2-wheel dyno tests since it places 100% of the braking load on the rear axle.

Test Setup - Vehicle

- 2013 Hybrid
- ~ 3000 kg
- 6L engine
- ~ 300 hp
- Rear-Drive
- Gasoline
- NiMH battery

Test Setup – Procedure

- Drive Cycles: 1) NYCC 2) NYCC with empirical braking forces 3) Track decelerations
- Temperatures: 25°C only
- Test Conditions: Rear-Only (2 drive wheels engaged), 4-wheel dynamometer and on-road braking distribution determination.
- Vehicle: Put into certification mode to allow for the normal operation of the ICE and hybrid system (while 2 wheels were driven and the other two remained stationary).
- Augmented braking: Disabled on the dyno controller.
- Preconditioning: Vehicle was preconditioned the day before on the cycle to be driven.
- Warm-up: First test of the day or after a soak > 30min was used as a warm-up .

Test Setup – Sampling

- CO, THC, NO_x, CO_2; (g/mile)
- Fuel consumption calculated on a carbon balance basis
- Battery terminal amperage and voltage measured by a HIOKI Power Analyser. Used to estimate regenerative braking energy.
- Dynamometer speed and torque sensor (along with inherent physical properties of dynamometer) are used to determine total braking energy and total exertion energy used to propel vehicle

Progress to Date

- 20 NYCC tests conducted on the 2-wheel dynamometer.
- 4-wheel dynamometer rear-driven-front-following program in development.
- Transport Canada is procuring 4 wheel torque sensors.

Results

2-Wheel Dyno

- Fuel Consumption (L/100km): 27.27 ± 0.53
- CO_2 Emission Rate (g/km): 1023 ± 21
- Regenerative Braking (Wh): 259 ± 55
- Total Braking at Wheels (Wh): 454 ± 5
- Total Charging (Wh): 310 ± 50
- Engine Assist (Wh): 281 ± 55

4-Wheel Dyno

- TBD

2-Wheel Dyno – Empirical Braking Forces

- TBD

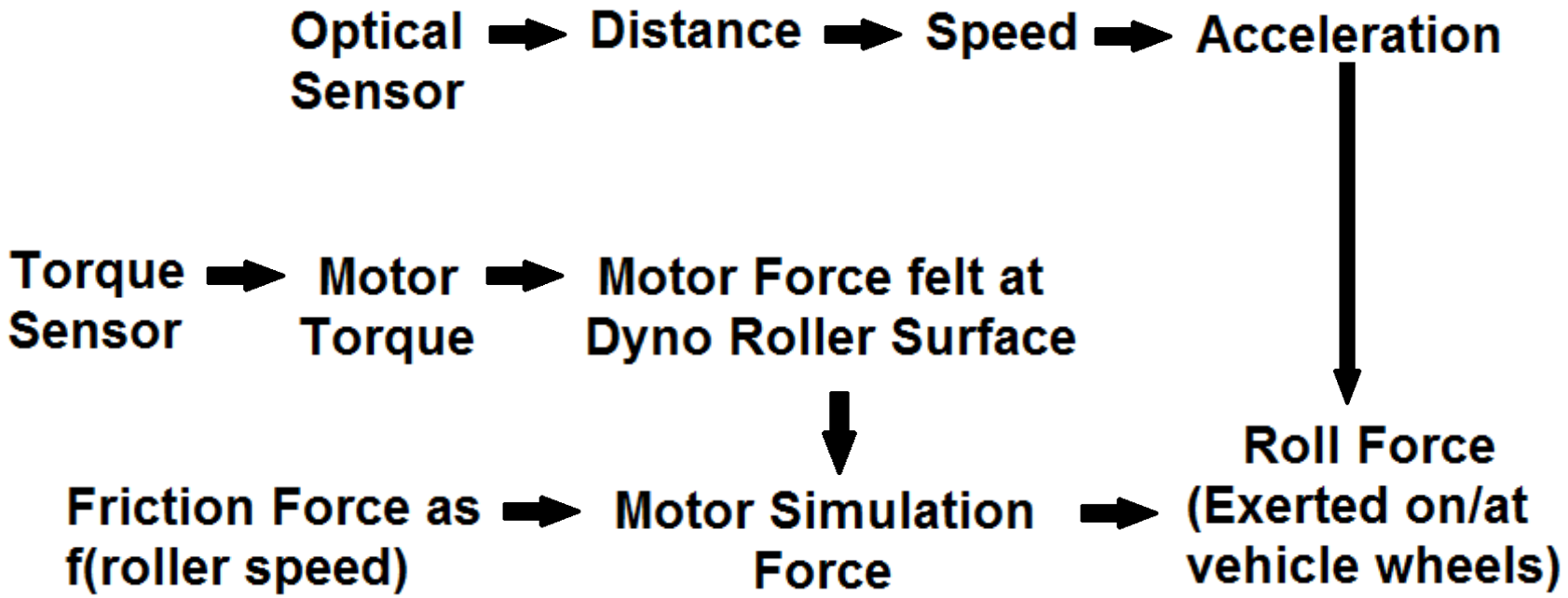
Future Work

- ERMS will conduct track deceleration tests in FY2014-2015 to determine braking force front-rear distribution for various deceleration rates.
- The rear braking force as a percent of total braking effort will be applied to the NYCC braking events.
- The 4-wheel dyno rear-driven-front-following program needs to be completed. Positive dyno loading is complete. Accurate brake loading is being pursued.

Questions?

Data Collected from Dynamometer

- Depending on project, sometimes less or special parameters are calculated/monitored
- Typically, the following information is captured:



Regenerative Braking Estimation

- Two estimates are made:
  - Conservative: $E_{bat} < 0$, $v_4 < v_3$ (i.e. Only when acc < 0)
  - Non-conservative: $E_{bat} < 0$, $a_2 < a_1$ (Including +'ve but decreasing acc events)