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Future HD GHG Test Procedure Considerations

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Outline

- Background
- Overview of Procedures Under Consideration
- Full Simulation
- Controller-in-Loop
- Powertrain-in-Loop
  - Vehicle dependant method
  - Vehicle independent methods
- Test programs to support our investigations

Background

- In 2011 EPA and NHTSA finalized our first ever heavy-duty (HD) greenhouse gas emissions (GHG) and fuel economy standards.
  - HD vehicles are certified with full vehicle simulation
  - HD engines were given a CO_2 standard on the FTP and SET.
  - Hybrids that included a transmission could generate credits with an A to B chassis or powertrain test.
  - Hybrids that didn't include a transmission could generate credits against the engine standard.
- In the HD GHG 1 rule we also spoke about how future regulations will look at how to more completely capture the complex interaction of the complete vehicle.

Overview of Procedures Being Considered for Both Hybrid and Conventional HDV

- Full vehicle simulation with inputs for engine, transmission, accessories, etc.
- Controller in loop
- Engine in loop
- Powertrain in loop

Powertrain in Loop

Vehicle Dependant Powertrain Procedure Under Consideration

Inputs into the model

- Coastdown data (A, B, C and inertia)
- Final drive ratio
- Tire radius
- Accessory loads

Cycles

- Vehicle speed and grade vs. time
- Could be application specific

Vehicle Dependant Powertrain Procedure

$$V_i = \left(\frac{T \cdot k_d}{r} - \left(A + B \cdot V_{i-1} + C \cdot V_{i-1}^2 \right) - F_{brake,i-1} \right) \cdot \frac{t_i - t_{i-1}}{m} + V_{i-1}$$

$$f_n = \frac{V \cdot k_d}{2 \cdot \pi \cdot r}$$

m: vehicle mass

a: acceleration

V: velocity

T: torque at trans. output shaft

f_n: rotational speed of trans. output shaft

F: force

k_d: final drive ratio

r: tire radius

t: time

A, B, C: coastdown coefficients

Vehicle Independent Powertrain Procedure Option 1

Inputs into the model

- Vehicle mass (function of maximum powertrain power)
- Representative final drive ratio and tire radius used to represent a group of vehicles the powertrain would go into.

Cycle

- Vehicle speed and power vs. time.
- Power cycle created from powertrain torque curve and is equivalent to conventional engine test power vs. time.

Vehicle Independent Powertrain Procedure Option 1

$$P_{powertrain} = P_{engine} = m \cdot a_{cycle} \cdot V_{cycle} + P_{residual} + P_{acc.} + P_{trans.losses}$$

$$V_i = \left(\frac{T \cdot k_d}{r} - \frac{P_{residual}}{2 \cdot \pi \cdot f_{n,i-1}} - F_{brake,i-1} \right) \cdot \frac{t_i - t_{i-1}}{m} + V_{i-1}$$

$$f_n = \frac{V \cdot k_d}{2 \cdot \pi \cdot r}$$

m: vehicle mass

a: acceleration

V: velocity

T: torque at trans. output shaft

f_n: rotational speed of trans. output shaft

F: force

k_d: final drive ratio

r: tire radius

t: time

Vehicle Independent Powertrain Procedure Option 2

- No vehicle model.
- Normalized cycle like engine testing.
- Vehicle speed cycle will define the speed setpoint.
- Torque will be defined so that power vs. time schedule will be equivalent to engine cycle.
- Cycle denormalized using powertrain torque.

Overview of HDV Test Programs

- Chassis, over the road and powertrain testing at contractor lab.
- Powertrain testing of hybrid powertrain at EPA using the vehicle dependant and independent procedures.
- Chassis testing of hybrid and conventional vehicles at EC.
- Powertrain testing at Oakridge National Laboratory in the planning stages to look at vehicle dependant and independent procedures.

EPA-SwRI Phase 1 Project Overview

- Program objectives
  - Provide comprehensive data sets for GEM validations
  - Evaluate different driving cycle impacts on CO2 emissions
  - Provide baseline data for powertrain system evaluations

- Vehicle Chassis Tests
  - One class 6 box truck - completed
  - One class 4 flat bed truck - completed
  - One Class 8 with AMT is being procured
  - One transit city bus will be procured in 2013
  - One garbage truck may be tested in 2013

EPA-SwRI Phase 2 Project Overview

- Additional chassis tests at SwRI
  - 6 additional sets of vehicle variants per vehicle (“a” and “c” coefficients, weights, optimized road load coefficient , etc.)
  - A total of 108 vehicle tests covering from Class 4-6 and 8
- Drive cycle evaluations
  - Three EPA certification cycles: 55 mph and 65 mph and transient cycles
  - Three additional cycles: delivery, parcel, and world harmonize test cycle
  - A city cycle will be selected for city transit bus test
- Over-the-road vehicle tests with a class 8 truck
  - One of critical routes to validate GEM with grade measurement

EPA-SwRI Project Overview
Powertrain Test

- Program objectives
  - Evaluate powertrain concept as one of certification options
  - Validate full vehicle simulation tool – GEM
  - Quantify alignment of CO2 and criteria emissions

- Medium duty powertrain with ISB 300hp rating engine and Allison transmission
  - Analysis of test-to-test data variation between chassis and powertrain tests
  - Identification of test-system differences and potential solutions to minimize correlation differences between chassis and powertrain-based tests
- The same driving cycles as vehicle will be evaluated
- It is planned to evaluate engine FTP based cycles

Conclusions

- EPA is looking at a wide spectrum of test procedures for a possible future regulation.
- Vehicle independent powertrain options are very similar to the procedures the HDH group is considering.
- EPA is involve in a number of test programs that have started or that are being planed to address the accuracy, representativeness, and feasibility of the different options.
- A vehicle independent powertrain option could work well to harmonize the US and HDH procedures if the US goes forward with a vehicle independent powertrain procedure.