Vehicle Mass Impact on Vehicle Losses and Fuel Economy

PI: Jim Francfort
Presenter: Richard “Barney” Carlson
Energy Storage & Transportation Systems
Idaho National Laboratory
Advanced Vehicle Testing Activity (AVTA)

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Overview

Timeline
• FY11 – Project planning, Vehicle procurement, test plan preparation
• FY12 – Vehicle coastdown testing and data analysis; Vehicle dynamometer fuel economy and energy consumption testing and data analysis

Barriers
• A change in vehicle mass changes the energy consumption; Is this change the same for all vehicle technologies?
• Difficult to isolate mass impact from other factors (aerodynamic change from ride height change, vehicle fuel economy repeatability, etc)
• Maintaining environmental conditions repeatability during coastdown testing

Budget
• FY11 – $ 125,000
• FY12 – $ 225,000

Partners
• Idaho National Lab - lead
• ECOtality North America – coastdown testing
• Argonne National Lab – dynamometer testing
Objective / Relevance

• Determine for BEV, HEV and ICE the Impact of Vehicle Mass on:
  – Vehicle drag forces
  – Vehicle fuel economy or energy consumption (MPG and Wh/mi)
• Technology dependence of Mass Impact (HEV to ICE to BEV)
  – i.e. is mass reduction more beneficial for certain technologies?
• Share results of study with DOE, Tech Teams, OEMs, etc.
Approach

- Three vehicle tested (BEV, HEV, and ICE)
  - Nissan Leaf
  - Ford Fusion Hybrid
  - Ford Fusion V6

- Multiple test weights tested for each vehicle
  - Increase and decrease from stock weight (EPA certification weight)

- On test track, coastdown testing is conducted to determine the impact of mass change on vehicle drag forces

- Road load coefficients determined from coastdown testing are used to configure the chassis dynamometer

- Chassis dynamometer testing is conducted over standardized drive cycles to determine the impact of mass change on vehicle fuel economy and energy consumption (MPG and Wh/mi)
Approach - Coastdown Testing (ECOtality)

- For each vehicle, at each test weight
  - 14 coastdowns conducted to reduce sensitivity to external variables
    - 7 in each direction to nullify any track grade variability
    - Wind, ambient temp, and humidity limits strictly adhered to
- To reduce testing variability
  - Vehicle warmed up for 30 min. prior to testing
  - Ride height is held to a small tolerance at the various vehicle test weights
  - Temperatures monitored and recorded to ensure vehicle is functioning at steady state operating conditions
    - Transmission fluid temperature
    - Tire side wall temperature (non-contact temperature sensor)
- Consistency between coastdown and dynamometer testing
  - Same vehicle operating mode utilized
  - Same three vehicles are used for all testing

<table>
<thead>
<tr>
<th></th>
<th>Fusion ICE (V6)</th>
<th>Fusion HEV</th>
<th>Leaf BEV</th>
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<tbody>
<tr>
<td>+500 lbs</td>
<td>4250</td>
<td>4500</td>
<td>4250</td>
</tr>
<tr>
<td>+250 lbs</td>
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<tr>
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</tr>
<tr>
<td>-100 lbs</td>
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<tr>
<td>-250 lbs</td>
<td>3500</td>
<td>3750</td>
<td>3500</td>
</tr>
</tbody>
</table>
Approach - Chassis Dynamometer Testing (Argonne)

- For each vehicle, at each test weight
  - Standardized drive cycles used for dynamometer testing
    - UDDS
    - HWFET
    - US06

- To reduce testing variability
  - Vehicle warmed up per dynamometer test procedures prior to testing
  - Same dynamometer driver for all tests

  - Temperatures monitored and recorded to ensure vehicle is functioning at same steady state operating conditions as on test track
    - Transmission fluid temperature
    - Tire side wall temperature (non-contact temperature sensor)

- Consistency between coastdown and dynamometer testing
  - Same vehicle operating mode utilized
  - Same three vehicles are used for all testing
Milestones

• Aug 2011 – Project planning and test plan complete
• Nov 2011 – Vehicles acquired and break-in miles accumulated
• Jan 2012 – Coastdown testing complete
• Feb 2012 – Analysis of coastdown data complete

• April / May 2012 – Dynamometer testing in progress
Technical Accomplishments

- A change in vehicle mass has shown a change in low speed rolling drag but less significant change in high speed drag forces.
Technical Accomplishments (continued)

- The mass impact on vehicle drag appears to be independent of vehicle powertrain technology

- The change in vehicle drag shows a slightly non-linear trend
**Technical Accomplishments (continued)**

- The mass impact of the Nissan LEAF on Energy Consumption
  - Decreased Energy Consumption over UDDS and US06 cycle for decreased mass
    - 1000 lbs decrease $\rightarrow$ 15 to 20 DC Wh/mi decrease
  - Negligible change in Energy Consumption over HWFET cycle
Technical Accomplishments (continued)

- The mass impact of the Ford Fusion Hybrid fuel consumption
  - Decreased fuel consumption over UDDS and US06 cycle for decreased mass
    - 1000 lbs decrease $\rightarrow$ 0.3 to 0.5 L/100km decrease
  - Negligible change in Energy Consumption over HWFET cycle
Collaboration

• Results from testing will be shared with US DOE, Tech Teams, OEMs, and others in support of improving petroleum displacement technologies

Future Work

• Dynamometer testing at multiple vehicle test weights to determine Fuel Economy and Energy Consumption
  • Nissan Leaf (completed)
  • Ford Fusion Hybrid (completed)
  • Ford Fusion V6 (in process)
• Analysis of dynamometer testing results
• Report and present on results and findings
• Possibly investigate mass impact on other vehicle technologies
  • PHEV
  • Advanced diesel
  • Downsized gasoline engine with turbocharger
  • Advanced transmissions (CVT or Dual Clutch)
Summary

• Determination of vehicle mass impact on vehicle drag losses is complete
  – Coastdown testing is complete
  – Analysis of coastdown testing data is complete

• Determination of vehicle mass impact on vehicle fuel economy and energy consumption is in progress
  – Chassis dynamometer testing (Argonne National Lab)

• Provide results from Mass Impact on
  – Vehicle Drag Losses
    • A slightly non linear trend of decreasing vehicle mass results in decreased vehicle drag
    • Shows no dependency on powertrain technology
  – Vehicle Fuel Economy or Energy Consumption
    • Results will be provided after testing and analysis are completed