Advanced Vehicle Test Procedure Development: Hybrid System Power Rating


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Argonne National Laboratory
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Project ID # VSS143
Test Procedure Development

Timeline

- SAE Committee leadership positions since 2006
  - Official Utility Factor 2009 (J2841)
  - HEV/PHEV test procedure 2010 (J1711)
  - Dyno quality metrics 2011 (J2951)
  - BEV test procedure in 2012 (J1634)

- Hybrid System Power Rating
  - Committee formed in 2013
  - Ran chassis dynamometer tests in 2014
  - Running hub dyno tests in 2015
  - Draft procedure in Fall of 2015

Barriers

- Risk Aversion (A): New vehicles need complete and fair information to compare to conventional vehicles
- Infrastructure (C): What equipment is needed? Goal is not to find cheap and conventional equipment for testing
- Lack of Standardized Testing Protocols (D): No standard exists anywhere in world

Budget

- $180k in FY15
  - All test procedure work is $480k
  - Second project for advanced coast down development is $300k

Partners

On SAE Committees
- Toyota USA, Honda USA, GM, Ford, Chrysler, VW, EPA

On ISO Committee
- Toyota, Honda, VW, Nissan, others

At KATRI
- UN GTR committee chair
APRF Activities are Very Applied and Thus Used Extensively by Important Stakeholders

Technology Assessment

“Provide to DOE and Partners the Best Advanced Vehicle Test Data and Analysis”

Test Procedure Standards

“Leadership in test procedure development with public and independent research and data”

Why?

2015 DOE AMR, June 9, 2015
All Quantitative Advancements in Technology Come from a TEST

New Technology Vehicles are evaluated by:

- Analysts that make decisions
- Media that make recommendations
- Consumers that make purchases

New Technology Vehicles have added dimensions in capabilities, but are often compared to conventional technology.

They will be accepted or rejected based upon proposed merits.

Merits are defined by impartial, accurate test procedures and analysis methods.

Every element in the entire DOE Research Portfolio relies upon proper test procedures.
Enormous Risk to DOE
If Any Test Method Fails to Characterize a Technology

Over Predict
- Technology promises too much
- Attention not warranted
- Funds are misdirected
- Real experience not matching expectations
- “Poisoned Well” (diesel in USA ‘80s)

Under Predict
- Technology underrated
- Attention not given
- No adoption because benefits were never predicted
- Missed opportunity by DOE
Serving as SAE J2908 Committee Chair

- J2908: “Hybrid Electric Powertrain Power Test Methods and Definitions”
- Coordination with J2907: Hybrid Motor Rating
- Past: Chair J1711, co-chair J1634, key expert in ISO ISO/TC 22/SC 21/WG 2
- Argonne staff provide open and unbiased judgement, sound recommendations
- Argonne provides unrestricted data for entire committee to analyze
  - Use past “Level 2” test vehicles from Argonne
  - Installed axle torque sensors provide data on chassis and hub dynos

General Approach:

1. In committee: Gather Ideas and Methods
2. Compile Test Options to Investigate
3. Try Methods and Report
4. Analyze Results, Make Procedure Adjustments
5. Freeze Final Method & Validate
6. Describe Procedure in SAE Document
7. Ballot

We are here
### Timing, Milestones

<table>
<thead>
<tr>
<th></th>
<th>2014</th>
<th>2015</th>
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<tbody>
<tr>
<td>Q1</td>
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<td>Q4</td>
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<tr>
<th>Task</th>
<th>Q1 (Now)</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
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<tr>
<td>Recruit committee, define scope</td>
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<td>Chair Monthly SAE J2908 meeting</td>
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<td>Meet with KATRI (Korea)</td>
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<td>Analyze Existing Data</td>
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<td>Run New Tests on Chassis Dyno</td>
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<td>Serve as member of ISO workgroup</td>
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<td>Receive rented Hub Dyno</td>
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<td>Run Tests for Hub Dyno</td>
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<td>Decide on best practices</td>
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<td>Draft document</td>
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<tr>
<td>Send J2908 to Ballot</td>
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Must Satisfy a Challenging List of Objectives

1. Describe **Hybrid System Power** in clear, unambiguous terms
2. Avoid **creative interpretation** of procedure → “horsepower wars”
3. If we use **wheel power**, what about current **Engine Flywheel power**?
   - The same “200 HP” car could rate at “162 System HP”
4. Avoid **requirement** to buy **expensive new dynamometer equipment**
5. Target the needs and perspectives of **both audiences**:
   - **Consumers**
   - **Vehicle Systems Engineers**
6. Provide a procedure **robust** enough to succeed in any powertrain configuration
   - Power-split, series, step transmission, belt CVT, mild HEV, full PHEV, (even BEV?)
Two System Power Approaches

A. Nominal System Power Rating
   – Based upon component-level power(s)
   – Similar to current engine power rating, “Catalog Rating”

B. System Power Test
   – Based upon dyno test
   – Verifiable test for engineers to communicate power levels
Additional Hybrid System Metrics in J2908

Ratings Will Provide Common Data Benchmarks

1. Electric Assist
   - How much electric power assist is given during maximum total power?
   - Provides an input needed for **Nominal System Power Rating**

2. Electric-only Drive Power (mostly for PHEVs)
   - Maximum electric traction power assist in “EV Mode”

3. Regen Power
   - Maximum electric power going to battery during braking
A. Nominal System Power Rating

- This approach parallels current engine power ratings
  - Rating look at sum of “upstream” component power
  - Powertrain losses downstream of the engine do not diminish peak power.

- Current OEM catalog ratings use this approach. However:
  - There are no rules or standards in how, or in what condition ratings are given.
  - Added components not consistent: Motor + Engine? Battery + Motor?
  - Claims can not be traced back to standard test for validation

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2015 Dodge Challenger Hellcat
Engine: 707 HP

2015 Ford Focus
Engine: 123 HP

2010 Toyota Prius
Engine: 98 HP
Motor: 80 HP
Battery: 36 HP
System Net: 134 HP
Photo: Argonne
Specs: “Toyota Prius Product Information”

2011 Sonata HEV
Engine: 166 HP
Motor: 40 HP
System Net: 206 HP
Photo: Argonne
B. System Power Test

- Only valid approach to measure net power is at wheel/hub
  - HEV configurations are too varied
  - Unique system controls regulate component powers for each configuration

- Either Chassis or Hub dyno for test
  - Many labs already own chassis dynamometer
  - **Chassis dynamometer** could limit wheel torque in some tests
  - **Hub dynamometer** allows high torque and less expensive for new installations

*Draft procedure notes for System Power Test*
Technical Accomplishments and Progress Summary

A. Found workable method for **Nominal System Rating**
   - Working with many partners worldwide (KATRI, JARI, and SAE)
   - New rating **must** rely on some **system test** data
   - SAE will harmonize with JARI-led ISO standards workgroup
   - Specific limitations are being addressed with Argonne testing

B. Now down-selecting methods for **System Power Test**
   - Many different approaches tried,
   - First on chassis dynamometer
   - Then on (rented) hub dynamometer
   - Each vehicle provided new lessons
Chassis Dyno
Using axle torque sensors to directly measure powertrain power

Hub Dyno
Using two hub dynos to directly measure powertrain power
*(very small losses in wheel bearings)*
Wide selection of Vehicles in Development and Validation Study at Argonne

- Tested on both Hub and Chassis dynos
- HEVs (power-split, step transmission, mild HEV CVT), Conventional, BEV
- All vehicle have axle torque sensors for chassis dyno testing

Sonata HEV  Prius HEV  Volt PHEV  Accord PHEV  Gen 2 Insight HEV  Fusion Conventional  Focus BEV
Important Findings Are Contributing to a Robust Test

- Peak battery power not always during peak total power
- Fixed speed test fails with step transmissions
- Peak battery power ≠ peak electric assist (lost power in engine spool-up)
- New Terminal Velocity test method invented - very promising

<table>
<thead>
<tr>
<th>Accomplishments</th>
<th>Important Findings Are Contributing to a Robust Test</th>
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<tbody>
<tr>
<td>Max Battery Power</td>
<td>Max Power Received at Dyno</td>
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<tr>
<td>Engine RPM/10</td>
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<tr>
<td>Observed peak motor power did not occur at peak powertrain power</td>
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- Peak power

Acceleration test with zero inertia and F0, F1, F2 road load adjusted to match peak power with MPH
Additional Tests for J2908 Accomplishments

Developed test cycle for finding Regen Power

Successful Fixed-Speed EV Drive Power Procedure
Progress on Defining A. Nominal Rating

Engine Power + Electric Power = Hybrid System Power

Results from B. System Power Test

Standard Engine Test Power Test

Peak Engine Power

Peak Electric Power Data
Accomplishments

Some Preliminary Results

Prius HEV

Elec = 22 kW
Wheel = 81 kW

Sonata HEV

Axle kW = 132
Elec kW = 36

Current Catalog Ratings
Engine: 98 HP (73 kW)
Batt: 27 kW
Total: 134 HP (100 kW)

A. Nominal Rating
73 + 22 = 95 kW
(engine rating + measured battery power)

B. Test Result
Total: 81 kW
(measured wheel power)

Current Catalog Ratings
Engine: 166 HP (123.7 kW)
Motor: 40 HP (30 kW)
Total: 206 HP (153.6 kW)

A. Nominal Rating
123.7 + 36 = 159.7 kW
(engine rating + measured battery power)

B. Test Result
Total: 132 kW
(measured wheel power)
Specific Collaborators on J2908

- **SAE**
  - EPA, OEMs, Suppliers, Universities

- **KATRI**
  - UN WP29 GRPE est Nov. 2014, “Determination of Powertrain Performance of Hybrid Electric Vehicles,” Germany and Korea to lead
  - WLTP: drive cycle depends upon vehicle power/weight ratio
  - Dr. Dongseok CHOI (KATRI) visited Argonne, Argonne staff visited KATRI
  - Similar to B. System Test

- **JARI (ISO)**
  - JARI-led ISO work group (TC22/SC37/WG2)
  - Similar to A. Nominal Rating
  - JARI-led delegation visited Argonne, including Shinichi Abe (General Manager Hybrid Systems at Toyota)
Future Work to Finish SAE J2908

- Finish evaluating all **candidate test methods**
  - Complete testing on all 7 test vehicles
  - Hub Dyno rental period ends June 1
  - If needed tests can be repeated on chassis dyno

- Lead J2908 **document creation**
  - Collaborate/communicate with J2907 committee

- Committee **review** document
  - Comments collected from SAE and ISO/JARI committee

- **Validate** procedures one last time
  - Argonne and others in committee

- **Ballot** SAE J2908
Future Work in Test Procedure Development

- **Revision of J1711** (Test procedures for HEVs/PHEVs)
  - Add improvements discovered in last 5 years
  - Harmonize with revised EPA and CARB procedures

- **BEVx/REx Test Procedure**
  - Unsuitable for both J1711 and J1634
  - Apply a ‘hybrid’ of J1711 and J1634 using BMW i3

- **2WD vs 4WD for xEVs**
  - Regen and thermal aspects can cause inaccurate MPG ratings in 2WD
  - Prius and Insight tested in 2004, no significant difference found
  - RWD i3 and BEVs with high regen need to be assessed

- **Coastdown Research Wrap-up**
  - Current research in advanced road load determination

- **Miscellaneous Procedure Support**
  - J3066 (MPG calc for dash), 5-Cycle method for BEVs and PHEVs, CARB support
The End