Validation Test Results at KATRI

- Power Determination of Hybrid Electric Vehicles -

Korea Transportation Safety Authority
Korea Automobile Testing and Research Institute
1. Test vehicle setup and Dynamometer

2. Validation test for system power
   - determination of vehicle speed
   - vehicle conditioning
   - system power calculation
   - test results

3. Proposal on GTR draft
## System Power Determination

Validation testing plan by country

<table>
<thead>
<tr>
<th>Country</th>
<th>Vehicle Models to be Tested</th>
<th>Laboratory Locations</th>
<th>Timelines</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada (ECCC)</td>
<td>2016 Chevrolet Volt, 2018 BMW 530e</td>
<td>River Road Facility</td>
<td>Anytime after spring 2018, with a few months notice</td>
<td>Already own Volts, 530e purchase approved and in process. Potential additional funding if warranted.</td>
</tr>
<tr>
<td>EU (JRC in Ispra/Europe with OICA)</td>
<td>To be agreed</td>
<td>JRC Dir C Energy, Transport and Climate, Ispra, Italy</td>
<td>2018 with a few months notice</td>
<td>Vehicle technology and type to be agreed in advance. Delivery of vehicles to be tested with appropriate monitoring system could be an ideal solution.</td>
</tr>
<tr>
<td>Korea (KATRI)</td>
<td>2017 Hyundai Ioniq Hybrid</td>
<td>Korea Automobile Testing and Research Institute</td>
<td>2018 (March to April)</td>
<td></td>
</tr>
<tr>
<td>U.S. (EPA)</td>
<td>2013 Malibu Hybrid, 2013 Chevrolet Volt</td>
<td>U.S. National Vehicle and Fuels Emissions Laboratory</td>
<td>Anytime after spring 2018, with a few months notice</td>
<td></td>
</tr>
<tr>
<td>Japan (JARI)</td>
<td>2015 Toyota Yaris, 2015 Honda Fit, 2016 Mitsubishi outlander PHEV</td>
<td></td>
<td></td>
<td>Already done, supporting with test report</td>
</tr>
</tbody>
</table>
Manufacturer: **Hyundai Motor Company**

<table>
<thead>
<tr>
<th>Test Vehicle</th>
<th>Items</th>
<th>Power</th>
<th>Gearbox system</th>
<th>Accumulated mileage [km]</th>
</tr>
</thead>
<tbody>
<tr>
<td>IONIQ hybrid (P2, NOVC-HEV)</td>
<td>ICE [kW/ min⁻¹]</td>
<td>E-Motor [kW/ min⁻¹]</td>
<td>REESS system [kWh]</td>
<td></td>
</tr>
<tr>
<td></td>
<td>77.3 / 5,700 (1,580cm³)</td>
<td>32 / 1800 (PMSM)</td>
<td>1.56 (240V, 6.5Ah)</td>
<td>DCT(6)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3,038</td>
</tr>
</tbody>
</table>
Hub dynamometer

- **Dynamometer spec.**
  - Max power : 290 kW @1100 ~ 3000 rpm
  - Max torque : 2500 Nm @ ~ 1100 rpm
    (40% overload : 3500 Nm)
  - Max speed : 3000 rpm
  - Supporting weight : 750 kg in each wheel
  - Inertia : 0.87 kgm²
  - Wheel base : 1.8 ~ 3.8 m
  - Thread : 1.2 ~ 2.2 m

- **Actuator for acceleration pedal**
Vehicle setup

Battery voltage
Battery current
Wheel torque
Wheel speed
Pedal actuator
Vehicle data (CAN, OBD)

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Measurement items and accuracy according to ISO 20762

<table>
<thead>
<tr>
<th>Item</th>
<th>Units</th>
<th>Accuracy</th>
<th>Remarks</th>
<th>This test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engine speed</td>
<td>min⁻¹</td>
<td>±0.5 %</td>
<td>-</td>
<td>CAN</td>
</tr>
<tr>
<td>Intake manifold pressure</td>
<td>Pa</td>
<td>±50 Pa</td>
<td>Intake manifold pressure means inlet depression in ISO 1585</td>
<td>OBD</td>
</tr>
<tr>
<td>Atmospheric pressure</td>
<td>Pa</td>
<td>±0.5 kPa, with a measurement frequency of at least 0.1 Hz</td>
<td>-</td>
<td>O.K.</td>
</tr>
<tr>
<td>Humidity</td>
<td></td>
<td></td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>Electrical voltage</td>
<td>V</td>
<td>±0.3 % FSD or ±1 % of reading</td>
<td>Whichever is greater. Resolution 0.1 V</td>
<td>O.K. CAN</td>
</tr>
<tr>
<td>Electrical current</td>
<td>A</td>
<td>±0.3 % FSD or ±1 % of reading</td>
<td>Whichever is greater. Current integration frequency 20 Hz or more. Resolution 0.1 V</td>
<td>O.K. CAN</td>
</tr>
<tr>
<td>Electrical energy</td>
<td>Wh</td>
<td>±1 %</td>
<td>Resolution 0.001 kWh. Equipment: static meter for active energy. AC watt-hour meter, Class I according to IEC 62053-21 or equivalent</td>
<td>O.K.</td>
</tr>
<tr>
<td>Room temperature</td>
<td>K</td>
<td>±1 °C, with a measurement frequency of at least 0.1 Hz</td>
<td>-</td>
<td>O.K.</td>
</tr>
<tr>
<td>Time</td>
<td>s</td>
<td>±10 ms; min. precision and resolution: 10 ms</td>
<td>-</td>
<td>O.K.</td>
</tr>
<tr>
<td>Wheel speed</td>
<td>s⁻¹</td>
<td>±0.05 s⁻¹ or ±1 %, whichever is greater</td>
<td>-</td>
<td>O.K.</td>
</tr>
<tr>
<td>Wheel torque</td>
<td>Nm</td>
<td>±6 Nm or ±0.5 % of the maximum measured total torque, whichever is greater, for the whole vehicle, with a measurement frequency of at least 10 Hz</td>
<td>-</td>
<td>O.K.</td>
</tr>
</tbody>
</table>

- Measurement frequency: 100 Hz (ISO 20762: not less than 10 Hz)
- Time for full load (Acc. 100%): ~20 s (ISO 20762: at least 10 s)
Determination of vehicle speed for the test

High torque → 114 km/h → High speed

5,650 rpm (Spec. 5,700 rpm)

Engine speed (rpm)

Vehicle speed (km/h)

1st gear
2nd gear
3rd gear
4th gear
5th gear
6th gear
Diagram for test procedure

- **VC**: Vehicle Conditioning
  - VC1: 20 min at 60 km/h (~115 min)*
  - VC2: 10 min at 70 km/h (~65 min)*
    *Testing time*

- **PT**: Power Test

- **TP**: Test Procedure
  - TP1*: Test procedure option 1
  - TP2**: Test procedure option 2
    *TP1*: Test procedure via measured REESS power and determined ICE power
    **TP2**: Test procedure via torque and speed measurement
Vehicle conditioning and REESS adjustment

Vehicle speed: 90km/h

Vehicle speed: 80km/h

Vehicle speed: 70km/h

Motor temp is nearly constant

Vehicle speed: 60km/h

REESS Adjust. 265V

SOC 94.5%

ACC 100%
System power test

VC1: 20 min at 60 km/h

Power test @ 114km/h

VC2: 10 min at 70 km/h

Moving average (2s filter)
Calculation for TP1

“Sustained power”

- **ICE power,** \( P_{ICE(corr)} : 76.5 \text{ [kW]} \)

- **Converted REESS power,** \( P_{REESS(con)} \)
  \[
  P_{REESS(con)} = \left[ U_{REESS} \times I_{REESS} / 1000 - P_{DCDC} - P_{aux} \right] \times K
  \]
  \[
  = [ 31.4 - 1.0 - 0 ] \times 0.88
  \]
  \[
  = 26.7 \text{ [kW]}
  \]

- **HEV system power,** \( P_{HEV} \)
  \[
  P_{HEV} = P_{ICE} + P_{REESS(con)}
  \]
  \[
  = 76.5 + 26.7
  \]
  \[
  = 103.2 \text{ [kW]}
  \]
Calculation for TP2

“Sustained power”

- **HEV system power at the wheels,** $P_{\text{HEW}}$ : 93.9 [kW]

- **HEV system power,** $P_{\text{HEV}}$ :

  
  \[
  P_{\text{HEV}} = \left[ \frac{P_{\text{HEW}}}{\eta_{\text{gb}}} \right]
  
  = \left[ \frac{93.9}{0.97} \right]
  
  = 96.8 \text{ [kW]}
  \]

- **ICE power,** $P_{\text{ICE}}$ :

  \[
  P_{\text{ICE}} = P_{\text{HEV}} - P_{\text{REESS (con)}}
  
  = 96.8 - 26.7
  
  = 70.1 \text{ [kW]}
  \]

- **Corrected ICE power,** $P_{\text{ICE (corr)}}$ :

  \[
  P_{\text{ICE (corr)}} = P_{\text{ICE}} \times f
  
  = 70.1 \times 0.986
  
  = 69.1 \text{ [kW]}
  \]

- **Corrected HEV system power,** $P_{\text{HEV (corr)}}$ :

  \[
  P_{\text{HEV (corr)}} = P_{\text{ICE (corr)}} + P_{\text{REESS (con)}}
  
  = 69.1 + 26.7
  
  = 95.8 \text{ [kW]}
  \]

- **Gearbox system efficiency factors,**

  $\eta_{\text{gb}} : 0.97$  
  (dual-clutch automatic)

- **ICE power correction factors,**

  $f : 0.986$
Test results (1)

Sustained Power

VC1: 20 min at 60 km/h

Power test @ 114 km/h

Peak Power

TP1: 0.19%, TP2: 1.34%
Test results (2)

**Sustained Power**

- **VC2:** 10 min at 70 km/h
- **Power test @ 114 km/h**

<table>
<thead>
<tr>
<th>Test number</th>
<th>TP1</th>
<th>TP2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>103.9</td>
<td>94.0</td>
</tr>
<tr>
<td>2</td>
<td>103.5</td>
<td>94.6</td>
</tr>
<tr>
<td>3</td>
<td>103.4</td>
<td>95.0</td>
</tr>
<tr>
<td>4</td>
<td>103.5</td>
<td>95.7</td>
</tr>
<tr>
<td>5</td>
<td>103.4</td>
<td>95.0</td>
</tr>
</tbody>
</table>

**Peak Power**

<table>
<thead>
<tr>
<th>Test number</th>
<th>TP1</th>
<th>TP2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>103.5</td>
<td>93.5</td>
</tr>
<tr>
<td>2</td>
<td>103.9</td>
<td>95.9</td>
</tr>
<tr>
<td>3</td>
<td>103.5</td>
<td>95.5</td>
</tr>
<tr>
<td>4</td>
<td>103.5</td>
<td>96.3</td>
</tr>
<tr>
<td>5</td>
<td>103.4</td>
<td>96.1</td>
</tr>
</tbody>
</table>

- **TP1:** 0.05%, **TP2:** 0.92%

EVE-28
1. To add a hub dynamometer option to the test instrumentation

4.3 Hub Dynamometer

A hub dynamometer is suitable for all testing covered in this document. Because of low rotating inertia, special care needs to be taken to avoid oscillations, overshoots, or other transient problems that may interfere with measurement or could damage the test and measurement hardware or vehicle components. A hub dynamometer connects to the vehicle’s hub (usually with the brake assembly remaining intact). Absorption mode is required for all tests (Sections 7, 8, 9, and 10), and motoring capability is required for the Peak Electric Regenerative Braking Power Test (Section 10).

Vehicles tested on a hub dynamometer shall be operated with the same vehicle control used in normal on-road driving. This may require speed synchronization of all axles and proper vehicle posture (among other vehicle testing properties).

4.4 Chassis Dynamometer

A chassis dynamometer is suitable for all testing covered in this document, provided instrumentation is added to the vehicle that accurately measures all powertrain propulsion power (torque and speed) at either the axles or the wheels. Absorption mode is required for all tests (Section 7, 8, 9, and 10); motoring capability is required for only the Peak Electric Regenerative Braking Power Test (Section 10).

4.5 Axle/Wheel Torque Sensors

When using a chassis dynamometer, total powertrain power (torque and speed) can be measured from axle torque sensors or torque sensor assemblies that measure torque between the wheel hub and the tire. Direct measurement of wheel (axle) speeds are necessary, as chassis dynamometer speed will not be accurate because of tire slip.
Korea proposal on the GTR draft

2. To exclude the 1st power test result in calculation of system power

Vehicle warm up VC

PT_1

PT_2

PT_3

PT_4

PT_5

Vehicle cool down

3. Korea prefer TP2 and Sustained power for determination of HEV system power
Thank you for the attention

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