Midsize and SUV Vehicle Simulation Results for Plug-In HEV Component Requirements

SAE 2007-01-0295
April 2007

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Sponsored by Lee Slezak

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Argonne Has Leading Role in DOE PHEV Technology Development Efforts

- Li-ion Battery Development and Testing
- Vehicle Modeling and Simulation
- Vehicle Control Strategy Development
- Vehicle Benchmarking
- Vehicle Test Procedure
- Market Penetration
- Cost Analysis
Energy Storage Requirements Include Systems-Level Testing

Component in System Context

Vehicle Simulation

Model

JCS VL41M

Testing

ABC 150

JCS VL41M
Vehicle Assumptions

Pre-transmission parallel HEV configuration

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–60mph</td>
<td>s</td>
<td>9 +/- 0.1</td>
</tr>
<tr>
<td>0–30mph</td>
<td>s</td>
<td>3</td>
</tr>
<tr>
<td>Grade at 60 mph</td>
<td>%</td>
<td>6</td>
</tr>
<tr>
<td>Maximum Speed</td>
<td>mph</td>
<td>&gt; 100</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Midsize Car</th>
<th>Midsize SUV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Curb weight</td>
<td>kg</td>
<td>889</td>
<td>1132</td>
</tr>
<tr>
<td>Frontal Area</td>
<td>m²</td>
<td>2.244</td>
<td>2.46</td>
</tr>
<tr>
<td>Drag Coefficient</td>
<td></td>
<td>0.315</td>
<td>0.41</td>
</tr>
<tr>
<td>Electrical Power</td>
<td>W</td>
<td>800</td>
<td>1200</td>
</tr>
</tbody>
</table>
Accurate Battery Modeling Crucial to Generate PHEV Battery Requirements

- Discharge requirements for long periods resulting in considerable diffusion over-voltage.
- Available data from large capacity Li-Ion SAFT cells applied to SAFT VL41 M cell.
- These data were modeled and are the basis of the impedance equations used in the PHEV vehicle simulation study.

![Diagram showing battery model and test data]
Automated Sizing Process Implemented Including Oversizing

Vehicle Assumptions

Motor Power for UDDS

Battery Power

Engine Power

Battery Energy

Convergence

No

Yes

Oversize Battery

Associated Requirements

Satisfy CARB EV Range Definition

Perfo:
IVM-60 mph
Grade:
1.5 x Safety
60 mph 6% grade

Range

30% Power, 20%
Energy to have same performance at EOL
Electric Machine Power for UDDS

![Bar chart showing the peak electric machine power for SUVs and midsize vehicles at different end of life all electric range (miles). The chart includes a FreedomCAR target line at 55 kW.]

- Y-axis: Peak Electric Machine Power (kW)
- X-axis: End of Life All Electric Range (miles)
All Electric Range (AER) Increase Leads to Small Vehicle Mass Increase...
Due to High Li-ion Specific Energy

~300 kg

~220 kg
As a Consequence, Power Requirements Remain Approximately Constant

2 sec. Battery Peak Power

<table>
<thead>
<tr>
<th>End of Life All Electric Range (miles)</th>
<th>SUV</th>
<th>Midsize</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.5</td>
<td>55</td>
<td>45</td>
</tr>
<tr>
<td>10</td>
<td>56</td>
<td>46</td>
</tr>
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<tr>
<td>60</td>
<td>61</td>
<td>51</td>
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Energy Storage Power (kW)
Energy Consumption is a Linear Function of AER

![Graph showing energy consumption as a linear function of life end range.](image-url)
Specific Power/Energy Ratio Batteries Should be Designed for Targeted Applications
At High AER, Battery Pack Voltage Increases Due to Capacity Limitation
Charging Power Calculated Based on US06 Driving Cycle

Midsize Car
40 miles AER
Conclusion

- Component power requirements are fairly independent of AER.
- Battery energy is linear function of AER as a result of the Li-Ion battery high specific energy.
- Battery pack voltage needs to be taken into consideration for high AER (above 40 mi). Higher capacities or battery packs in parallel might need to be used.
Current/Future Work

- Evaluate battery requirement uncertainties based on:
  - Drivetrain configurations (e.g., series, power split…)
  - Component sizing assumptions (e.g., other than UDDS)
  - Vehicle and component assumptions (e.g. vehicle mass, electrical accessories…)

This study was funded by Lee Slezak from the U.S.DOE
Special thanks to Tien Duong and Dave Howell for their technical support and guidance