Modeling and thermal simulation of a PHEV battery module with cylindrical LFP cells

Paolo Cicconi, Michele Germani, Daniele Landi
Università Politecnica delle Marche, Ancona, Italy
Outline

- Research context
- Research objectives
- Methodological approach
- Experimental tests
- Thermal model for one cell
- Battery model (test case)
- Simulation
- Conclusion
Research Context

Hybrid and Electric Vehicles

- feasible solutions for sustainable urban transportation
- business opportunity for industry
- development of customized product (SMEs)

Li-ion Battery

- Many advantages: high energy density, capacity, etc.
- Some disadvantages: cost, weight, aging effect due to temperature, safety use, electrochemical heat generation, cooling system necessity.

Thermal Dissipation

Electrochemical Heat (inside)

Temp. increasing
Research objectives

The research aims to analyze a design methodology to support the engineer on evaluating the thermal behavior and the cooling performance of a Li-ion battery pack for customized EV/PHEV.

HOW

Using the Virtual Prototyping tools and methods integrating with an analytical thermal approach for modeling the reaction heats.

- Li-ion cell testing
- analytical thermal model
- cell thermal simulation
- battery pack CFD analysis
Methodological approach

- Battery Pack Specification
  - Input: Electric layout, Cell datasheet

- Tests Configuration
- Cell Electrical Test
  - HD Tools

- First Analytical Thermal Analysis
- Cell FEM Thermal Analysis
  - VP tools

- Pack Layout Configuration
- Pack FEM Thermal Analysis
  - Simplified battery model and cooling analysis

- Test Models
- Layout Models
- CAD System
- DB
- KBE
- VP tools

Organized by: [Organizational Logos]
Hosted by: [Host Logos]
In collaboration with: [Collaboration Logos]
Supported by: [Support Logos]
Organized by Hosted by In collaboration with Supported by

Experimental Tests

Cell characterization

- OCV tests (0.33 C)

- Charge, Discharge tests (1C, 2C, 3C)

Output:
- OCV $\rightarrow$ (SOC)
- $V \rightarrow f(SOC, I)$
- $T_{cell}$ trend

LiFePO4 10Ah

IR camera

Cycler Test Bench

Host PC
Experimental Tests

NEDC test profile

Evaluated current rate on one cell

Test output:
- V values
- T trend
Thermal Model for one cell

Tests

\[ \dot{Q} = I(V - E_0) - IT \frac{\partial E_0}{\partial T} \]

Real and Simulated Temperature values

Heat produced during NEDC cycle

Cell simulation
Battery Model

- Battery for PHEV prototype (customized vehicle): 25 kW drive electric motor, 7.55 kW Li-ion battery pack, and 1.2 L ICE (max speed 50 km/h if electric powered)
- 236 cells in 4 module of 59 elements (test case)

- Parametrical layout
- Battery model

<table>
<thead>
<tr>
<th>Chemistry</th>
<th>LFP (LiFePO4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal Voltage</td>
<td>3.2 V</td>
</tr>
<tr>
<td>Geometry</td>
<td>Cylinder</td>
</tr>
<tr>
<td>Nominal Capacity</td>
<td>10 Ah</td>
</tr>
<tr>
<td>Max Discharge</td>
<td>3C (30 Ah)</td>
</tr>
<tr>
<td>Max Charge</td>
<td>2C (20 Ah)</td>
</tr>
</tbody>
</table>
Simulation

Simulation concerns CFD analysis regarding thermal behavior of battery pack during NEDC cycle (780 s)
Conclusion & Development

• A methodology has been proposed to integrate the experimental data of one Li-Ion cell in a virtual analysis
• Virtual simulation solves thermal model through an analytical calculation of heat source
• A CFD simulation has been proposed to evaluate cooling performance in a prototype battery pack during a NEDC cycle

Future works:
• evaluate BMS effect in thermal simulation
• extend proposed approach to different cell type and battery layout
Thank you for your attention!

*Paolo Cicconi, Ph.D.*
*Research Fellow*
*Università Politecnica delle Marche*
p.cicconi@univpm.it