Implementation of an Active Fluid Cooling Design in a 48 V High-Power Battery Module

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Active Fluid Cooling Design in a High Power Battery Module

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- Motivation

- Ground Model
  - Partially Lumped Single Cell Model
  - Battery Module

- Thermal Analysis
  - Ground Model (GM)
  - GM & Active Fluid Cooling (ACF)
  - GM & Internal Cooling Fin (ICF)
  - GM & ICF & & ACF

- Summary
Active Fluid Cooling Design in a High Power Battery Module

Motivation

Technical Data
- SAMSUNG INR18650-33G

<table>
<thead>
<tr>
<th>Cell Chemistry</th>
<th>NCA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal Capacity</td>
<td>11.4 Wh / 3300 mAh</td>
</tr>
<tr>
<td>Voltage</td>
<td>2.5 V (2.8 V) / 4.2 V</td>
</tr>
<tr>
<td>Standard/Rapid Discharging Current</td>
<td>0.3C / 1C</td>
</tr>
<tr>
<td>Pulse Peak Current</td>
<td>10 A 10 s (Rest 30 s)</td>
</tr>
<tr>
<td>AC Impedance (1kHz)</td>
<td>27 mΩ</td>
</tr>
<tr>
<td>DC Impedance</td>
<td>40 mΩ</td>
</tr>
<tr>
<td>Operating Temperature (Charge / Discharge)</td>
<td>-10 °C ~ 45 °C / -20 °C ~ 60 °C</td>
</tr>
</tbody>
</table>

Ground Model
Partially Lumped Single Cell Model

- Pole

Mandrel

Gap between + pole and active material

Active material

+ Pole
Ground Model
Battery Module
Ground Model
Battery Module
Ground Model
Battery Module

- Busbar
- Cell
- Upper spacer
- Lower spacer
Ground Model
Battery Module
Thermal Analysis
Ground Model

- Software COMSOL Multiphysics®
- Principle: Stationary FEM
- Scope: 3D, transient model
- Coupling of Non-Isothermal Flow:

  \[
  \text{Navier Stokes Equation:} \quad \rho(T)(u \cdot \nabla u) = -\nabla p + \mu(T)\Delta u + F
  \]

  \[
  \text{Heat Transport Equation:} \quad \rho C_p u \cdot \nabla T + \nabla \cdot (-k \nabla T) = Q
  \]

- Parametric sweep for module heat generation rate:

<table>
<thead>
<tr>
<th>Parameter name</th>
<th>Parameter value list</th>
<th>Parameter unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>P_30cell(Gesamtv)</td>
<td>range(10, 5, 30)</td>
<td>W</td>
</tr>
</tbody>
</table>

Temperature Field
Velocity Field
Thermal Analysis
Ground Model

Objective 1
\[ T_{\text{max}} \]

Objective 2
\[ \Delta T \]
Thermal Analysis
GM & Active Fluid Cooling (AFC)

- Fluid channel is embedded in Al cover
- Inlet at module center
- Outlet at module edge
- Temperature probes along the fluid channel to visualize the heating of cooling Water
Thermal Analysis
GM & Active Fluid Cooling (AFC)

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![Graph showing thermal analysis results for different power levels and cooling methods.]
Thermal Analysis
GM & Active Fluid Cooling (AFC)

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Thermal Analysis
GM & Active Fluid Cooling (AFC)
Thermal Analysis
GM & Internal Cooling Fin (ICF)
Thermal Analysis

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10 W 15 W 20 W 25 W 30 W

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Thermal Analysis
GM & Active Fluid Cooling (AFC)

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GM & AFC & ICF

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Active Fluid Cooling Design in a High Power Battery Module

Summary

- Simulative thermal analysis is a helpful step before conducting actual tests

- Temperature distribution in GM (no cooling concept is involved) is uneven
  - differences in cell cycle life within the same battery module
  - a shortened cycle life of the entire module

- By involving detailed measurement data of employed cells, both the complexity and the accuracy of the simulation models can be increased

- Effects of passive cooling concepts are analyzed

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<tr>
<td>Temperature uniformity</td>
<td>++</td>
<td>0</td>
</tr>
<tr>
<td>Reduction of cell temps</td>
<td>+</td>
<td>++</td>
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- Combined systems with different passive cooling principles shall be involved for large and high power battery module
非常感谢！

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Faculty of Aerospace Engineering - Energy Storage Systems

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