Experimental Analysis of Latent Heat Storages Integrated into a Liquid Cooling System for the Cooling of Power Electronics
International Refrigeration and Air Conditioning Conference

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Purdue University, July 11-14, 2016
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Motivation

- Increasing quantity of electric components in aircrafts
- New semiconductor materials
  → Power electronics with high power load/density
  → Liquid cooling system

- Latent heat storage (LHS) as buffer storage
  → How much weight can be saved?
  → Weight savings higher than weight of LHS?
Latent Heat Storage

- Phase Change Materials (e.g. ice and paraffins)
- Thermal energy stored during the melting process
- Advantages: Downsizing of cooling system and back up function
- Drawback: Low thermal conductivity
  - Supporting structures of thermally conductive materials
  - Composite Latent Heat Storage (CLHS)
Latent Heat Storage

~ 10 % volume increase of the paraffin
Test Rig

- Pump
- Heat sink (20 °C)
- Mass flow meter
- Power electronics dummy, cold plate and CLHS
- Reservoir
- Propylene Glycol Water mixture 60/40
- Paraffin: Parafo 22-95 (Sasol Germany GmbH)
Test Rig

I

Cold Plate
CLHS
Power Electronics

II

Power Electronics
Cold Plate
CLHS

III

Cold Plate
Power Electronics
CLHS

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**Comparison of Positioning**

- Junction temperature (temperature between two types of semiconductors)
- Positioning III the only one with significant lower temperature
Weight Reduction Tests

Idea:
Reduce mass flow rate
→ downsize pump/pipe
→ less weight

\[ \dot{Q} = \dot{m} \cdot h \cdot (T_{wall} - T_{fluid}) \]

\[ \dot{m} = \frac{\dot{Q}}{h \cdot (T_{wall} - T_{fluid})} \]

\[ \dot{m} \downarrow \rightarrow h \uparrow \quad dT \uparrow \quad \dot{Q} \downarrow \]
**Weight Reduction Tests**

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<tr>
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<th>40 kg/h</th>
<th>$\dot{m}_{\text{adapted}}$</th>
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<tr>
<td>direct</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>SHS</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>CLHS</td>
<td>x</td>
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- Sensible Heat Storage (SHS) made of aluminium
- 20 °C inlet temperature cold plate
- Thermal interface material (10 W/mK)
- Torque handle used (4 screws, each with 3 Nm)
Weight Reduction Tests

Comparison of direct, CLHS and SHS

- CLHS maximum temperature reduced by 14 K (SHS by 6 K)
- Effect on mass flow rate?

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Weight Reduction Tests

- Mass flow rate can be reduced from 100 kg/h to 40 kg/h
- Effect on weight?
**Weight Reduction Tests**

Exemplary estimation:

- 5 Power Electronics Modules in parallel → 500 kg/h mass flow rate needed
- 5 CLHS: 500 kg/h reduction to 200 kg/h
- Pump weight reduction from 3.8 kg to 1.6 kg
- Pipe weight reduction from 0.8 kg to 0.44 kg (l = 3 m)

Total weight reduction: \(2.56 \text{ kg} - 5 \cdot 0.382 \text{ kg} = 0.65 \text{ kg}\)

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<td><strong>CLHS</strong></td>
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<td>0.382 kg</td>
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Summary & Outlook

Summary:
• Test Rig presented
• Results:
  • Positioning III with lowest temperature
  • Mass flow rate can be reduced with CLHS
  • Weight can be reduced by 130 g per power electronics

Outlook:
• Parameter study to identify coherence of different parameter
• Cooling of batteries
Thank you for your attention!
Optical Evaluation

- No information of phase inside of CLHS
- Information used for model validation
Weight Reduction Tests

\[
\dot{m} = \frac{\dot{Q}}{h \cdot (T_{\text{wall}} - T_{\text{fluid}})}
\]

\[
T_{\text{wall}} = T_{\text{junction}} - R_{\text{th}} \cdot \dot{Q}
\]

\[
\rightarrow \dot{m} = \frac{\dot{Q}}{h \cdot (T_{\text{junction}} - R_{\text{th}} \cdot \dot{Q} - T_{\text{fluid}})}
\]
Double-Sided Cooling of Power Electronics

www.infenion.com