Overview of APEEM Thermal Control Research Projects

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DOE FreedomCAR and Vehicle Technologies Program
Advanced Power Electronics and Electric Machines Projects
FY08 Kickoff Meeting
National Transportation Research Center
Knoxville, Tennessee
November 6, 2007

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Thermal Control Research Direction

Meeting costs, specific power, power density, and efficiency targets while driving toward higher coolant temperatures:

- **Motor R&D**
  - Increasing speed (Reduce Size)
  - Innovative concepts to lower material and manufacturing costs
  - Eliminate need for boost converter
  - Reduce stress on battery during high loads

- **Power Electronics R&D**
  - Reduce size and cost of capacitor via topology and capacitor improvement
  - Increase temperature rating
  - Reduce and dissipate heat more effectively
  - Reduce parts count by integrating functionality

- **Thermal Control R&D**
  - Enable cost and power density targets through the elimination of the separate coolant loop and development of enhanced heat transfer technologies
  - Parallel paths will focus on the use of engine coolant at 105°C and the development of air cooling technologies
Technical Requirements

• Thermal control is a critical factor in PEEM performance
• Today’s HEVs: dedicated 70°C PEEM cooling system
  – Cost is estimated at $175 to consumer
• PEEM target cost is $440 for 55 kW system
• Current cooling system cost represents 40% of PEEM system cost target

Conclusion – need to reduce coolant system cost
Primary focus on 105°C coolant and air cooling
Technical Approach – 105C engine coolant ($T_c$)

Improve component/system efficiency
- Improved devices

$$Q = h A \left( T_B - T_C \right)$$

Enhance heat transfer coefficient
- jet/spray cooling
- surface enhancements

$$Q = \frac{(T_H - T_B)}{R_{solder} + R_{DBC} + R_{TIM}}$$

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Increase surface area
- fin shape optimization
- surface enhancements
- thermal spreading
- double-sided cooling

$$T_H = \dot{m} C_p \left( T_{out} - T_{in} \right)$$

Reduce Thermal Resistance
- advanced TIM materials
- low R IGBT structure

Increase maximum allowable temperature
- PE materials development
Technical Approach – Air Cooling

Improve component/system efficiency
- improved devices
  - dynamic control of coolant

\[ Q = hA(T_S - T_C) \]

Enhance heat transfer coefficient
- micro-channel forced convection
- surface enhancements

\[ Q = \frac{(T_H - T_B)}{R_{solder} + R_{DBC} + R_{TIM}} \]

Increase surface area
- fin shape optimization
- surface enhancements
- thermal spreading
- double-sided cooling

\[ Q = \dot{m}C_p(T_{out} - T_{in}) \]

Reduce Thermal Resistance
- advanced TIM materials
- low R IGBT structure

Increase maximum allowable temperature
- PE materials development
APEEM Technology Development

APEEM Thermal Control Subsystem integration, performance, requirements

Advanced Vehicle Systems

Technical Targets

DOE FreedomCAR APEEM Projects FY08 Kickoff Meeting
FY08 Thermal Control R&D Projects

1. Power Electronic Thermal System Performance and Integration
   – Kevin Bennion, NREL

2. Characterization and Development of Advanced Heat Transfer Technologies
   – Thomas Abraham, NREL

3. Research and Development of Air Cooling Technology for Power Electronics Thermal Control
   – Desikan Bharathan, NREL

4. Direct-Cooled Power Electronics Substrate
   – Randy Wiles, ORNL

5. Advanced Thermal Interface Materials for Power Electronics
   – Sreekant Narumanchi, NREL

6. Thermal Stress and Reliability for Advanced Power Electronics and Electric Machines
   – Michael O’Keefe, NREL
Questions