Evaluation of Cold Temperature Performance of PCM Base Thermal Management System

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INTRODUCTION

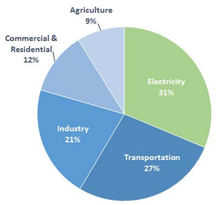

Fig. 1) 2013 USA total greenhouse gas emission.

Hybrid and Electric Vehicles

- Electric vehicles can dramatically reduce CO_2 emissions.
- Electric vehicles require cheaper long lasting thermal management systems (TMS).
- Li-ion batteries (LIBs) operate most efficiently in a temperature range between 20 – 40 °C.

Hypothesis of Phase Change Materials (PCMs)

- PCMs absorb heat to prevent thermal runaway.
- During winter, for short vehicle stops, this heat keeps the batteries warm.
- As PCM absorbs heat from discharging LIBs, there is a reduced warm up rate.

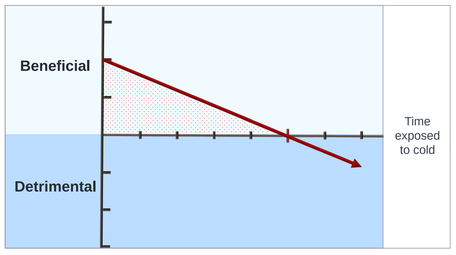

Fig. 2) Cold temperature hypothesis for experiment.

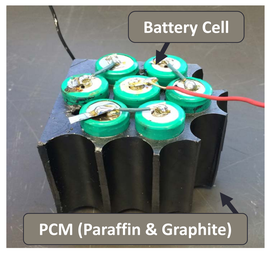

Fig. 3) LIB systems with PCM composite TMS.

METHODS

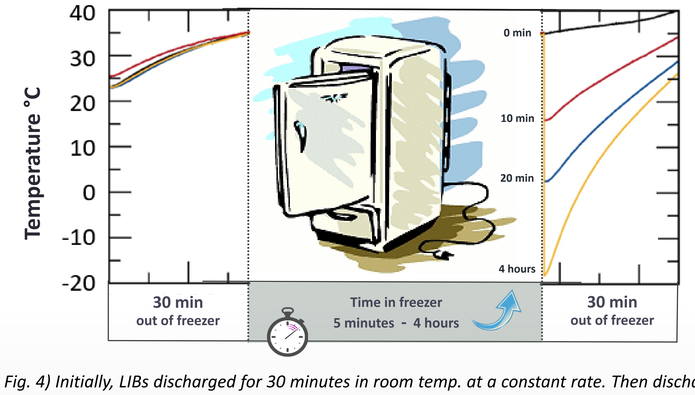

Fig. 4) Initially, LIBs discharged for 30 minutes in room temp. at a constant rate. Then discharging stopped and LIBs were placed in freezer for different time intervals. Finally, LIBs were removed from freezer and completely discharged.

- Testing was done using a battery cycler, multimeters, two thermal couples, and a freezer (to simulate cold temperature). LabView software was used to record data of the thermal management system being tested.
- Capacity, power, and time values were plotted against temperature to show residual effects of the battery cycling.

RESULTS

DIFFERENTIAL SCANNING CALORIMETRY

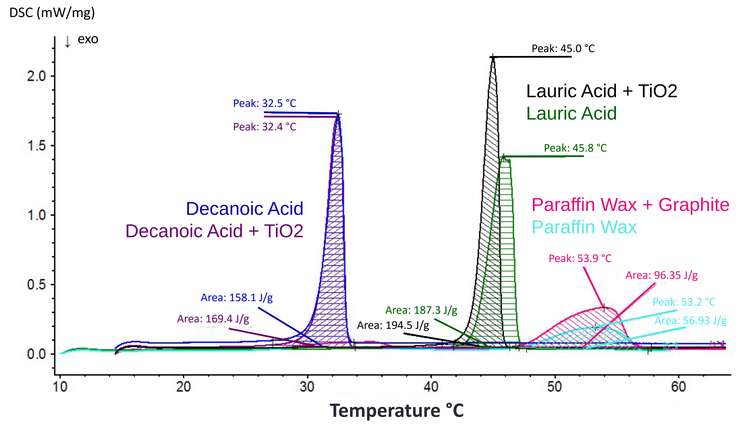

Fig. 5) Melting point and latent heat results of the top six phase change materials.

Ideal and Non-ideal PCM Thermal Management Systems

- Paraffin wax and AllCell composite had melting points exceeding 50°C. Above this temperature cell degradation and thermal run away begins to occur.
- Fatty acids melt within optimum temperature range for LIBs while maintaining high enough latent heat capabilities.

THERMAL PROPERTIES

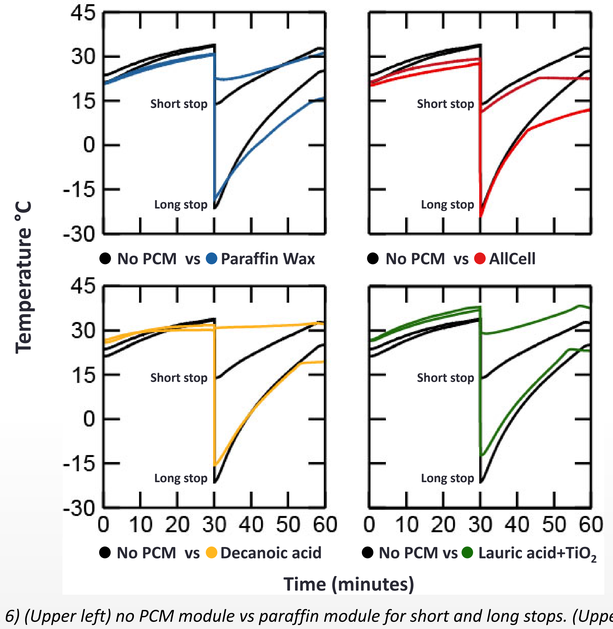

Fig. 6) (Upper left) no PCM module vs paraffin module for short and long stops. (Upper right) no PCM vs AllCell. (Lower left) no PCM vs decanoic acid. (Lower right) no PCM vs lauric acid.

Two phase change material observations

1) PCMs keep LIBs warmer over short stops.
2) PCMs delay battery warm up rate.

ANALYSIS

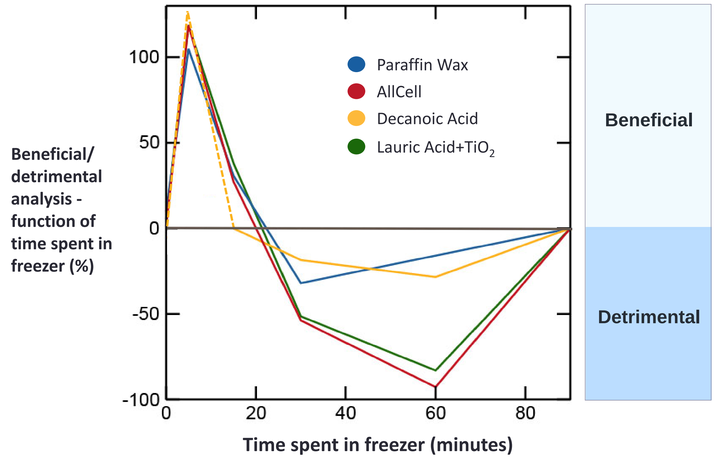

Fig. 7) Energy comparison of LIB module with no PCM in comparison to different PCM modules.

Ideal and Non-ideal PCM TMS

- Each PCM module was compared to the TMS without PCM to determine the energy improvement and disadvantage.
- We observed that our hypothesis was true.
- For each module, short times were helpful. However, after a half hour exposure to cold weather conditions the effects were detrimental.

CONCLUSION

- PCMs are normally considered to be advantageous in helping to maintain battery operating temperature.
- However, we demonstrate that when exposed to cold temperatures for prolonged periods of time, there is a point at which the PCM becomes a detrimental to the system by delaying warming time and thereby decreasing battery capacitance and power.

REFERENCES

- "Sources of Greenhouse Gas Emissions." Greenhouse Gas Emissions: Transportation Sector Emissions. US Environmental Protection Agency. 2016.
- Rao Z, Wang S. A review of power battery thermal energy management. Renewable and Sustainable Energy Reviews. 2011.

ACKNOWLEDGEMENTS

We would like to thank everyone who has been involved with this project:

- PI: Dr. Taylor D. Sparks
- Project advisor: Leila Ghadbeigi
- Paraffin module provided by: AllCell
- Sponsor: Undergraduate Research Opportunity Program