DEVELOPMENT OF AN EFFECTIVE BATTERY THERMAL MANAGEMENT SYSTEM USING EVAPORATIVE COOLING TECHNIQUE

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College ***:*** *Ramaiah University of Applied Sciences, Bengaluru*
Branch ***:*** *Department of Mechanical and Manufacturing Engineering*
Guide(s) ***:*** *Mr. Pritam Bhat*
Student(S) ***:*** *Mr. Abdul Mannan Mujawar*
Mr. Siddharth Tiwari
Ms. Thanya M E
Mr. Chethan V

Introduction:

The most potential answer for pollution problems caused by traditional internal combustion engine emissions may be Electric Vehicles (EV) and Hybrid Electric Vehicles (HEV). These technologies will be reliant on battery packs in a big way. The battery's role as a power source in an electric vehicle is critical. Lithium-ion (Li-ion) batteries have received a lot of attention as a feasible choice for increasing vehicle range and performance in electric drive vehicle applications due to their high energy density. And as for the energy storage system, lithium-ion (Li-ion) battery packs are now the largest stakeholder, accounting for 45.3 percent of the cost of an electric car. To gain a faster return on investment, the International Organisation for Standardisation (ISO) advises that a basic standard cell design should be used for all electric vehicle battery packs.

However, Lithium-ion batteries have a number of thermal constraints. Capacity/power fading, self-discharge, thermal runaway, pack electrical imbalance, and cold temperature performance are the most prevalent thermal difficulties with Lithium-ion batteries. The chemistry of the battery's positive electrode and electrolyte is claimed to affect capacity/power fading. Enthalpy changes, electrochemical polarisation, and resistive heating inside the cell all generate heat during charge and discharge. Temperature variations within the batteries might cause an uneven temperature distribution within the pack, resulting in inconsistent charge/discharge behaviour. In the worst-case scenario, when temperatures aren't effectively controlled, thermal runaway can develop in a cell, resulting in fire and explosion.

Objectives:

1. To develop a battery module and integrate it with battery management system
2. To integrate battery cooling system with the battery module
3. To study the thermal behavior of the battery module under natural convection
4. To analyse the effectiveness of forced/evaporative cooling on the performance of battery module at different discharge rates

Methodology:

Sl. No.	Objective	Method and Methodology	Resources and Materials Required
1	To develop a battery module and integrate it with battery management system	• Arranging cell according to literature survey • Develop the battery pack specifications • Spot welding nickel strip on arranged cell pattern • Connecting BMS using Soldering Machine	• Lithium-ion Battery • Nickel Strip • BMS • Electrical Wires • Soldering Machine • Spot Welding Machine
2	To integrate battery cooling system with the battery module	• Develop the design of battery cooling system using design software • Fabrication of casing by machining of Acrylic Sheet based on developed design • Placing fans and Jute in the setup to develop various configurations	• Acrylic Sheet • 4-pin CPU Fan • Plexiglass Laser Cutting Machine • Plywood • Jute Material • Catia V5
3	To study the thermal behavior of the battery module under natural convection	• Charging and Discharging batteries to conduct dry test • Analyzing performance of battery cooling at different discharge rates based on test results • Development of graphical results for better understanding	• Battery Pack integrated with BMS • H4 Blub (12V 60/55W) • Digital Thermometer • Voltmeter • Ammeter • Anemometer
4	To analyze the effectiveness of forced/evaporative cooling on the performance of battery module at different discharge rates	• Charging and Discharging batteries to conduct various test • Analyzing performance of battery cooling at different discharge rates based on test results • Development of graphical results for better understanding	• Battery Pack integrated with Cooling System • H4 Blub (12V 60/55W) • IR Thermometer • Digital Thermometer • Regulated DC Supply • Voltmeter • Ammeter • Anemometer

Conclusion:

Calorimeter tests were done to check the overall heat generation of the battery pack. Dry test was done to check the individual cell temperature. The calorimeter tests along with the dry test shows that the heat generation from the cells and temperature of individual cells is in the order of $1.5C > 1C > 0.5C$.

The various cooling configurations analysed are

- 1 Fan cooling (1 Exhaust)
- 2 Fan cooling (1 Inlet + 1 Exhaust)
- Fan cooling (1 Inlet + 2 Exhaust)
- 1 Fan evaporative cooling (Jute Inlet + 1 Exhaust)

Temperature rise of the battery pack in 3 fan cooling was $3°C$, while the temperature rise of the battery pack in 1 fan evaporative cooling was $2°C$. The effectiveness of evaporative cooling technique is more than the cooling effect of the 3 fan cooling, thereby reducing the power drawn to power the cooling system, which increases the efficiency of the battery as well as the cooling system. The evaporative cooling technique shows promising improvement in the cooling efficiency as compared to forced air convection cooling.

Scope for future work:

The simplified battery model might not be precise enough to depict Lithium-ion battery thermal behaviour. In the field of battery heat generation modelling, there is a lot of room for improvement and future development. The cooling effect and efficiency can be tested for different cell spacing and the cooling effect of the evaporative cooling can be conducted directly on a commercially available battery pack. The Heat generation test can be conducted on the battery pack by reducing the cell spacing and check to see if the heat generation is more. The design can be further improved to make it more commercial. Moreover, numerical simulations can be done to better understand the uniformity of cooling effect of each configuration using MATLAB. The cooling effect of the evaporative cooling can be evaluated by increasing the number of jute layers or by using cellulose as evaporative cooling material. And finally, the cooling system can be tested for India specific drive cycles.

Reference:

1. Kizilel, R., Lateef, A., Sabbah, R., Farid, M.M., Selman, J.R. and Al-Hallaj, S. (2008). Passive control of temperature excursion and uniformity in high-energy Li-ion battery packs at high current and ambient temperature. *Journal of Power Sources*, 183(1), pp.370–375.
2. Leng, F., Tan, C.M. and Pecht, M. (2015). Effect of Temperature on the Aging rate of Li Ion Battery Operating above Room Temperature. *Scientific Reports*, [online] 5(1).
3. Liu, H., Wei, Z., He, W. and Zhao, J. (2017). Thermal issues about Li-ion batteries and recent progress in battery thermal management systems: A review. *Energy Conversion and Management*, 150, pp.304–330.