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An Experimental Study of Battery Thermal Management using Air Cooling and PCM (Lauric Acid)

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Abstract: This report is on a Thermal management system using air and PCM (Lauric acid) as an electric vehicle cooling module. Hybrid and electric vehicles are emerging with great technology in today's world, a lot of challenges are being faced by all the manufactures, one of the main problems is the battery thermal management system. Battery thermal management system (BTMS) maintains a standard temperature for the battery to work efficiently. Cooling the battery using air and phase change material (PCM) is the latest and most efficient way of cooling the battery. This enhancement is possible by using CPU fans to direct the atmospheric air to focus and cool the width of the battery through the battery compartment's air vents. PCM cooling is achieved by using 30/70 mixture of water and Lauric acid respectively, PCM is run around both sides of the battery's length through copper tubes in which PCM is pumped using a submersible 12v DC pump. DC pump is turned ON and OFF by the Arduino Nano micro-controller and temperature sensor connected to the battery detects the temperature of the battery.
Keywords: PCM (Lauric acid), CPU fans, 12v DC pump, Arduino Nano, temperature sensor.

I. INTRODUCTION

The increasing demand for fossil fuels due to high consumption has greatly increased their prices. Furthermore, with the decrease in other available resources due to factors like urbanization and modernization, we cannot depend on fossil fuels as the primary source of fuel. This research is mainly focused on new and renewable energy sources to fulfill the energy necessary for maintainable and eco-friendly growth of the society. The only solution to this problem is to find an alternative which is Hybrid electric vehicles or Electric vehicles.

One of the biggest challenges faced by the automobile industry is the safety of the battery, the ability to design an effective cooling system for the batteries. At present, the most widely used batteries are lithium-ion batteries. Lithium-ion batteries suffer thermal runaway and cell rupture if it is overheated or overcharged, and in extreme cases, this leads to fire. When batteries charge/discharge various chemical reactions occur, the faster the battery charges/discharges the faster it tends to generate heat. These risks are related by a fail-safe circuitry system that is available in lithium-ion battery packs. This system shuts down the battery when the voltage range falls outside the safe range. Batteries are manufactured defectively or sometimes handled improperly which leads to thermal runaway resulting in overheating, safety vents also play a vital role in cooling the battery. Sometimes sealed cells explode if the vent is overwhelmed or non –functional. To work between certain temperatures many properties of the battery are coupled to these reactions, one of which is thermal properties.

Passive air cooling in this research is achieved by directing the atmospheric air into the battery through the air vents on the battery compartment and a CPU fan is used to focus the atmospheric air to the width of the battery. CPU fan is placed in a perpendicular position from the battery and at a distance of 150 mm from the battery compartment. This channel of air is directly channeled to the air vents on the battery compartment.

In this experiment, PCM (mixture of water and Lauric acid) in a mixture of 30% of water and 70% of Lauric acid runs around the battery's length through copper tubes which is pumped into the copper pipes using a 12v submersible DC pump which is submersed in a tank filled with PCM. This system basically works like a radiator in an IC engine vehicle, Lauric acid is in semi-fluid state when in cold state or in the tank. When the Lauric acid is pumped around the battery it absorbs heat from the battery and turns liquid which is then directed back to the tank or reservoir. This system works to maintain the battery below 40 ˚C for better life cycle, efficiency and working of the battery.

Temperature sensors connected to the battery detects to temperature, if the temperature is above 50 ˚C or when it reaches the cutoff voltage this sensor sends signals to the Arduino micro-controller to turn ON the DC pump to cool the battery.

II. EXISTING SYSTEM

A. Air Cooling

[1] Fan et al examined and found that the temperature rise can be lowered by reducing the gap between the cells and the temperature uniformity can be improved by increasing the flow rate with moderate spacing. [2] Yu et al examined and designed an air-flow thermal management system consisting of two independent air duct channels. One channel is to cool the batteries and the other is to minimize the heat in the middle of the battery packs.

B. Cooling using PCM (Lauric Acid)

[3] The heat generation amount of lithium ion battery upsurges with its discharge rate. Thermal management system with clean PCM cannot resourcefully manage the battery temperature, even organize with the liquid cooling. The temperature of the battery surface touched 39 ˚C. Heat transfer rate inside of the material module was at a low point owing to the low thermal conductivity. The heat generated from the battery collected close to the battery surface. It cannot be dissipated to other part of the PCM and it tops a substantial temperature increase. With the adding of copper foam, the battery surface temperature can be preserved sufficiently. The battery surface temperature was condensed 14 ˚C associate with pure PCM module. The generated heat can be efficiently moved inside the module. Thermal management module also shows exceptional temperature uniformity. In adding, the liquid cooling can contribute on battery temperature reduction.

III. PROPOSED SYSTEM

The proposed system is more updated and is made to overcome the drawbacks exhibited in the existing system. Because of the air vents the atmospheric air is channeled directly to the battery, so there is no need for spacing between the battery cells and this results in reducing the space consumed by the battery. This system also eliminated two air duct channels and combined it into air vent in the battery compartment which is cooled by CPU fans which directs the atmospheric air into the battery compartment this helps to dissipate heat from the battery more efficiently. Diluted Lauric acid showed more efficacy in cooling the battery in which the battery's temperature was maintained below 40 ˚C and the system was able to maintain the optimal battery temperature. Heat generated from the battery is absorbed by the PCM (Diluted Lauric acid) and copper pipes enhance the transfer of heat between the battery and the cooling module. DC pump is used to recirculate the PCM from the tank or reservoir to the cooling module of the battery. The model consists of a micro-controller (Arduino Nano) which senses temperature of the battery, when the battery reaches the cutoff voltage and turns ON the system to cool the battery.

IV. FINDINGS

It has been observed that the viscosity of the PCM is 6.88 cP at 50 ˚C, melting point is 43.8 ˚C [316.8k], density at 24 ˚C is 1.007 g/cm^3 and at 42 ˚C is 0.877 g/cm^3. PCM at solid state is 0.442 W/mK and at liquid state is 0.192 W/Mk

A. Formulas

$$ha * \frac{dT}{da} \quad \text{.....................................} \ (1)$$

$$\frac{\rho u D}{\mu} = Re \quad \text{.....................................} \ (2)$$

$$v = 1096.7\left(\frac{\sqrt{dp}}{d}\right) \quad \text{.....................................} \ (3)$$

$$T = t1 \quad t2 \quad \text{.....................................} \ (4)$$

$$d = \frac{1.325}{T} \quad \text{.....................................} \ (5)$$

Thermal conductivity of a Lauric acid at 293 K= 0.215 ± 0.01 W/mK
Velocity of the PCM in copper tubes= 1.1 m/s at 1.25 m (i.e. 216.53 FPM)
Heat capacity= 404.2 J/mol-k
Reynolds no.= 11.16

V. DISCUSSION AND RESULTS

The PCM application on battery thermal management system based on air and PCM cooling has been successfully performed. The figure A. shows the performance of the battery without any cooling modules which reached up to 50 ˚C starting from the room temperature 25 ˚C and figure B. shows the performance of the battery using PCM as the cooling module which showed a significant result where the battery temperature did not cross 36 ˚C. figure C. shows the performance with air and PCM as cooling module and the temperature noted was 34 ˚C.

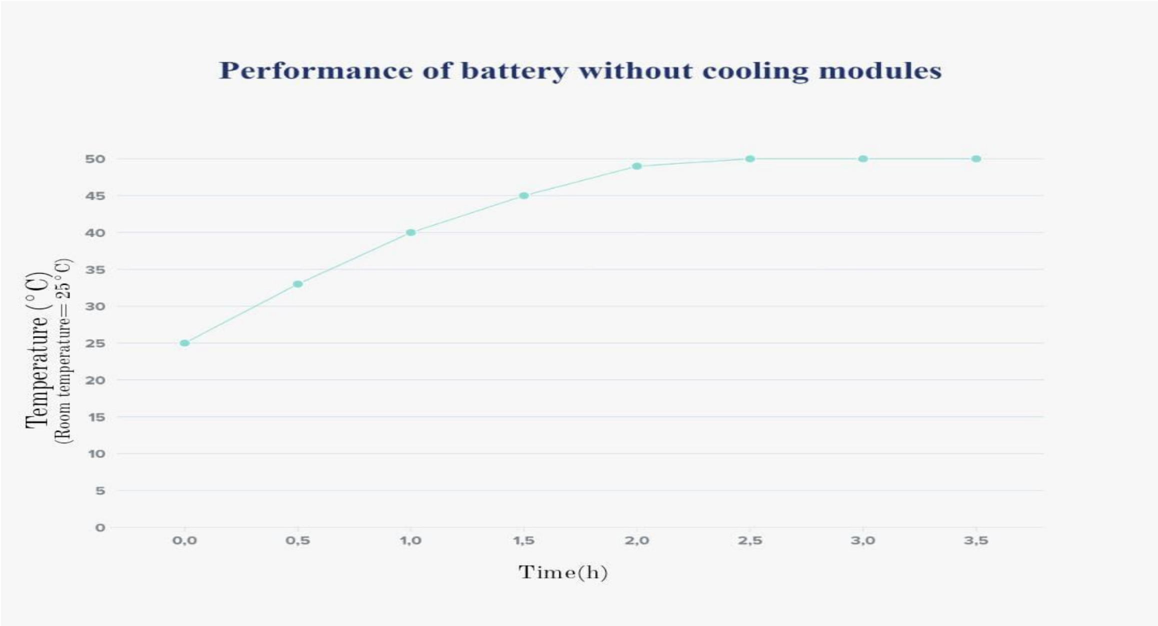

Figure 1. Performance of battery without cooling module

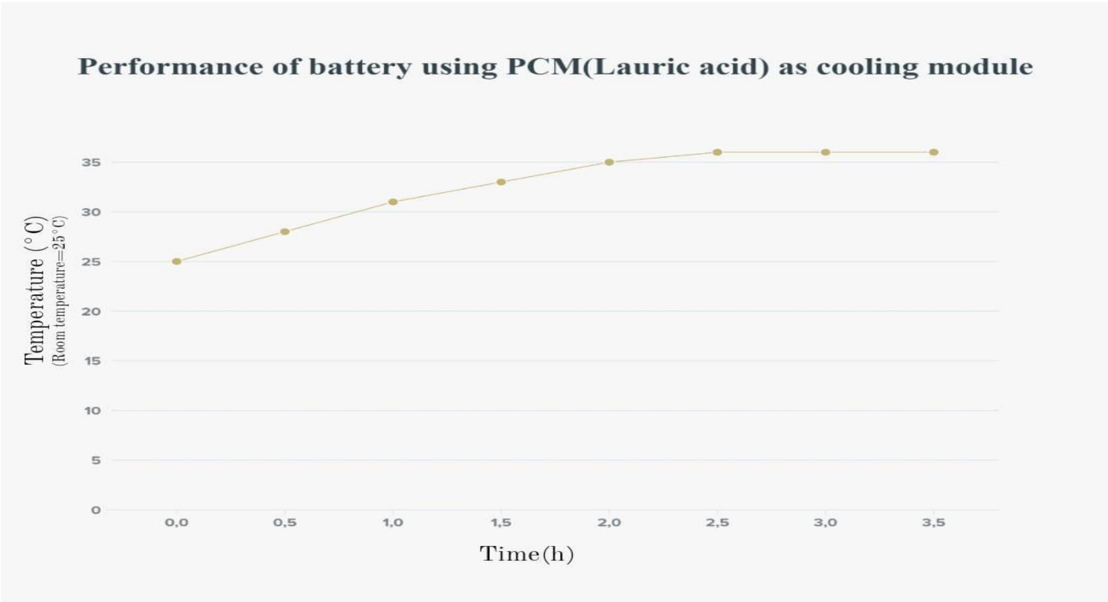

Figure 2. Performance of battery using PCM (Lauric acid) as cooling module

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Figure 3. Performance of battery using air and PCM as cooling module

VI. CONCLUSION

The thermal issues of lithium-ion batteries are significant. For the design of BTMSs, the focus must be on the cooling or heating capacity, the system complexity, energy consumption, reliability, and maintenance costs. Batteries heat generation rates are complex and closely related to their states. This plays a leading role in the BTMS design. More precise models addressing battery heat generation may be researched. Besides, excellent control strategies of BTMSs can significantly improve their performances as well. Thus, more control strategies may be offered in the future. Additionally, although numerous BTMSs have been designed in the past, their application was uneven. Also, due to the features of different BTMS strategies, ambiguous evaluation criteria cause difficulty in distinguishing good designs. Hence, the establishment of a recognized and comprehensive assessment system is eagerly awaited.

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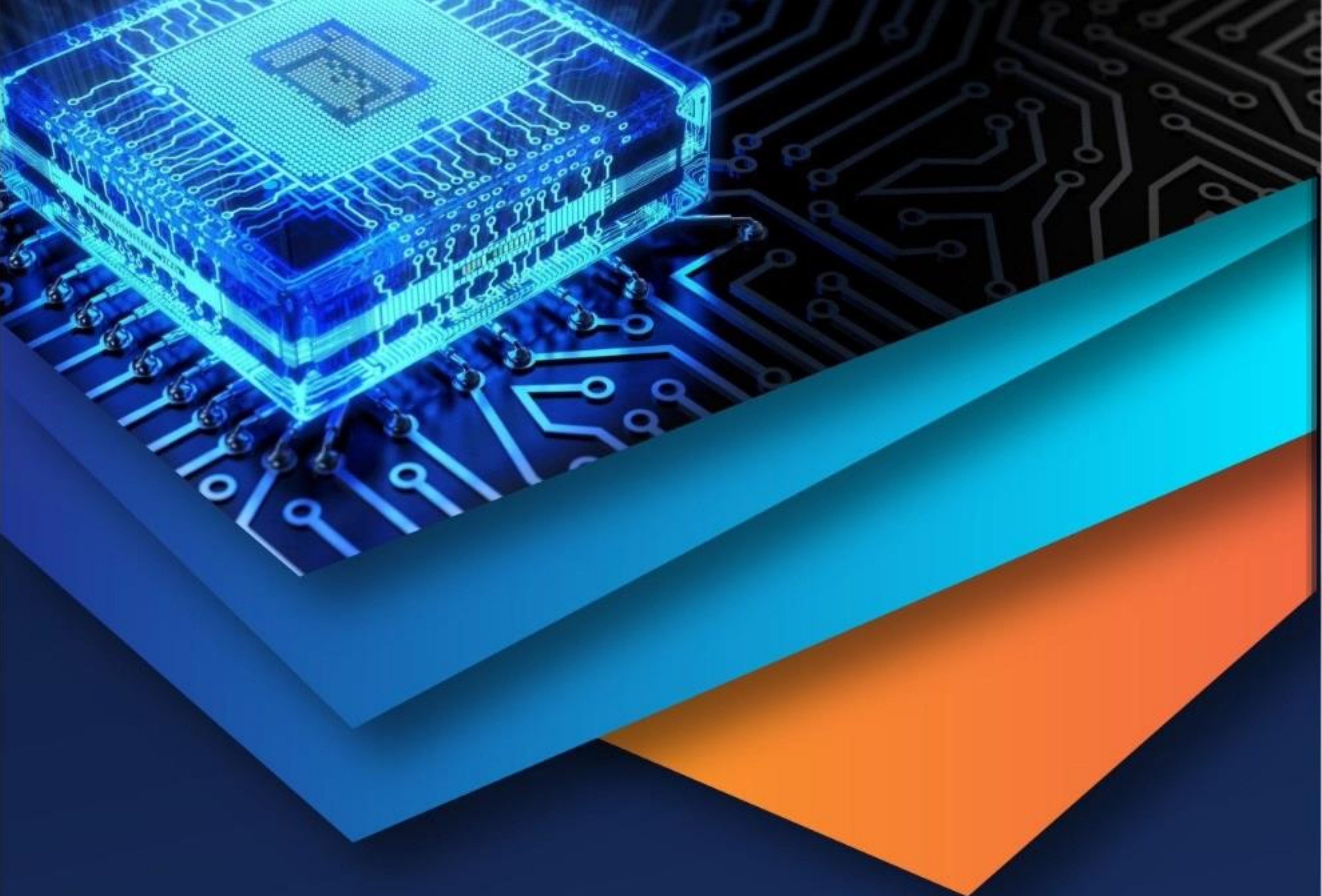

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