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Experimental Study on Battery Thermal Management System using PCM in Lithium ion Battery

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Abstract - *The Lithium ion batteries have become a popular choice for electric vehicle applications due to high energy density and long cycle life used. The battery management system for the Lithium batteries is critical to ensure longer life and better range for the vehicles. During discharging, the temperature of the battery increases and it needs cooling. and it can be allowed to cool by using one of the cooling techniques, passive cooling PCM method. It is employed to maintain a temperature at very narrow range of 25°C-40°C at ambient condition. In the current work, the effectiveness of PCM in keeping the battery temperature under check is experimentally investigated and the thermal performance of the battery can be further increased by PCM which acts as an energy storage medium in the experiment. Battery management system (BTMS) is used to manage the temperature state of charge voltage protection, cell health monitoring of huge number of cells. Experiments are to be performed to measure the temperature distributions to PCM during charging and discharging.*

***Key Words*: Lithium ion Batteries, PCM, BTMS, Electric vehicle, Temperature**

1.INTRODUCTION

Electric vehicles are entering in the world widely in order to reduce the emissions which was being produced by the conventional engines. They are better for the environment because they emit less greenhouse gases. The major benefit of electric car is the contribution that they can make towards improving air quality in towns and cities. This reduces air pollution considerably. There are many reasons to switch from internal combustion engine to electric vehicles and one of those such is it can reduce the dependency on fossil fuels and require less maintenance than most cars. One of the most significant causes of global warming is the production of carbon dioxide (CO_2) and other greenhouse gases. A portable power supply has become the lifeline of the modern technological world especially the lithium ion battery. The currently achieved number of charge and discharge cycles of a lithium ion battery is around 3000 and great minds across the globe are putting their best efforts into increasing this to 10000 cycles that means not required to replace the battery in the car for twenty-five years. Boasting feature like immediate torque, silent ride and premium performance, Electric vehicles also have lower operating and maintenance cost, Elimination of harmful pollutants such as particulates, hydrocarbons, carbon monoxide, ozone, lead and oxides of nitrogen improving public health and reducing ecological damage. The potential for a significant reduction in CO_2 emissions. Electric vehicles react quick and responsive. Although fuel costs for electric vehicles are generally lower than for similar conventional vehicles, prices can be significantly higher. Lithium ion batteries are popular because of low discharge rate and high energy density. Since Lithium ion battery contain fewer toxic metals than other types of batteries which may contain lead or cadmium. These metals can be recycled, but mining generally cheaper than recycled.

2. BATTERY THERMAL MANAGEMENT SYSTEM

BTMS is used to increase the life span of Lithium battery cells and thus it regulates and controls the temperature level and its distribution. In electric vehicles, BTMS plays a crucial role in controlling to maintain its energy storage capacity, driving range, cell longevity and system safety. Thermal management of batteries in electric vehicles is essential for effective operation in all climates. In some applications, such as electric vehicle, there is the opportunity to use the waste heat for heating the passenger compartment and most automotive systems include some form of integrating battery thermal management with the climate controls. Overheating of lithium ion batteries can be reduced with the help of Passive thermal management system. In order to increase the cycle time of power batteries and decrease the overall cost of e-vehicles. It plays a vital role in the control of thermal behavior. Some of the BTMS technologies are,

1) Air cooling system
2) Liquid cooling system
3) Direct refrigerant cooling system
4) Phase change material (PCM) cooling system
5) Thermo-electric cooling system

3. THERMAL UNIFORMITY AND RUNAWAY

It is important to maintain temperature uniformity at the cell level and pack level for optimum performance of the battery pack. Furthermore, the non-uniform temperature distribution of the battery pack can lead to a localized deterioration and internal friction. Voltage protection is another crucial job of the battery thermal management system. While charging, higher capacity cell gets charged than the other. To balance the life of a cell, it has to maintain its charging and discharging rate equal, Thus, protecting them from over and under voltage conditions. Thermal runaway happens usually during charging. The temperature quickly rises to the melting point of the lithium and causes a violent reaction. Another major reason behind thermal runaway is other microscopic metal particles come in touch with different parts of the battery (this happens all the time in the battery assembly process), resulting in short circuit. The abuse condition that include mechanical abuse, electrical abuse, and thermal abuse.

4. CRITERIA FOR PCM SELECTION

High latent heat, high specific heat and high thermal conductivity, Melting point, Small volume changes during phase transition, Stability, non-poisonous, non-flammable and non-explosive, Availability in large quantities at low cost. Based on the types, properties and selection criteria **PARAFFIN** is chosen as the PCM for this project work.

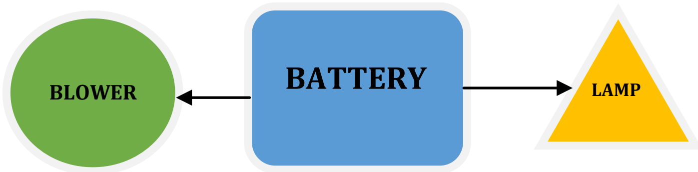
Fig -1: Paraffin in the form of powder

5. EXPERIMENTAL REQUIREMENTS

Lithium ion battery – 1 No. (with 231 cells in it), Paraffin – 7 Kg, Aluminium sheets, Loading device, Extension wires, Infrared Thermometer.

6. DESIGN

As the output power from the battery in this project work is utilized only to drive the Blower and LED lamp of the car, it decided to have one Li ion battery pack which can deliver power output of 2.4 kWh (12 V, 200 Ah). The battery stack is packed with phase change material (Paraffin) around the battery cells in such a way that the heat generated from the battery can be collected and as the latent heat for the PCM is higher it can absorb more temperature till its phase changes. Thus, it's aimed that benefit to maintain temperature uniformity among the cells of the battery stack and prevention of thermal runaway can be attained. Also, with these, concerning to the utilization part of the project work i.e., to power any of the electronic devices used in the electric vehicle.



7. RESULTS AND DISCUSSION

7.1 Battery Calibration

To understand the behaviour of the lithium ion battery pack, it is necessary to calibrate the battery. It is easier way to get the temperature-time factor which corresponds to the real time working of the battery. To infer the same, power from the battery is connected with the Car's air conditioner's blower which is 300 watts and the car headlight which is 288 watts. Hence the connections were turned to the positive side of operation, battery starts discharging the power to the load. Thus, the sum of 588 watts is the total load in which battery discharge their power to get its thermal behavior. The tabulated readings are taken in the atmospheric condition in the laboratory. Since the battery stacks are closely packed it is harder to record temperature through the thermocouple or thermometer, the infrared thermometer is found easier to record the battery's temperature. where**,**

T1- Ambient Temperature,

T2- Battery Temperature.

Battery Calibration (time vs temperature)			
S.no	**Time(min)**	**T1(ºC)**	**T2(ºC)**
1.	5	27.9	32.1
2.	10	28	33.4
3.	15	28	34.8
4.	20	28.1	35.4
5.	25	27.9	37.3
6.	30	27.8	37.4
7.	35	27.7	38.8
8.	40	27.9	39.6
9.	45	27.9	40.9
10.	50	28	42.3
11.	55	28.1	42.6
12.	60	28	42.9

Table-1: Battery Calibration

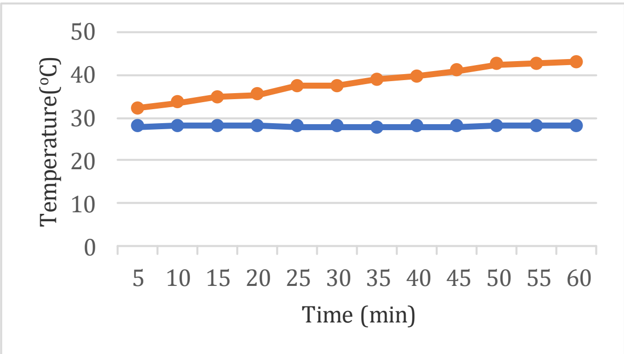


Chart -1: Calibration of the lithium ion battery

Fig -2: Measuring battery temperature using IRT

7.2 Experimental reading (with Aluminium Sheets)

Once after the battery is calibrated, its ready to be experimented. The Phase Change Material (PCM) is filled above the battery. In order to avoid the direct contact of the battery with the PCM, Aluminium sheets were introduced between them. The sheets are of with fine thickness of about 0.8 mm thickness which can promote the heat transfer in a better way. Also, the phase change of Paraffin has to be noted in this experimentation which may require further modification in the experimental set-up. As shown, the battery temperature kept increasing with respect to time and after sometime its reduced, which depicts the cooling of battery is occurring.

Aluminium Sheet reading (time vs temperature)			
S.no	**Time(min)**	**T1(ºC)**	**T2(ºC)**
2.	10	28	33.4
4.	20	28.1	35.4
6.	30	27.8	37.4
8.	40	27.9	39.6
10.	50	28	42.3
12.	60	28.2	41.9
14.	70	28.3	38.5
16.	80	28.2	36.2
18.	90	28.1	32.7
20.	100	28.1	30.2

Table-2: Battery Temperature with PCM

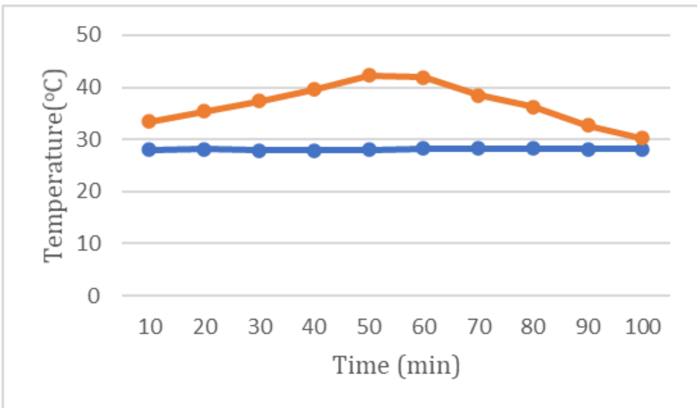


Chart -2: Aluminium Sheet in lithium ion battery (with PCM)

Fig -3: Experimental setup while testing

8. CONCLUSIONS

From the experimental results its clearly understood that cooling of electric vehicle batteries using Paraffin as the Phase Change Material has turned out to be one of the effective methods for Battery Thermal Management System. The experimental results also show that temperature is uniform throughout the cells after certain period of time which ensures the Temperature Uniformity among the cells of the battery.

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