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Battery Thermal Management System in ElectricVehicles using Phase Change Material (PCM)

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ABSTRACT

With the advancement in technology, the world is moving fast and for its fast growth, the automobile sector is also in the revolution period with the advancement in battery-driven vehicles. The Electric and Hybrid vehicles which run on the battery, face the main issue in thermal management. As there are so many electronic components inside the vehicle especially the battery, the heat dissipation is also more. Many of the researchers have proposed the Li-Ion cells as the most suitable for the battery packs in electric vehicles. And with many advantages of the Li-Ion cells, there is one major limitation of it as its heat dissipation rate. In order to get the best working performance of the battery electric vehicles, it's equally important to keep its temperature in control. The various parameters which directly influence the temperature rise of the PCM are mass of PCM, the thermal conductivity of the Paraffin material, water flow rate etc.

Keywords: Hybrid & electric vehicles, Li-Ion cells, Phase Change Materials (PCM), Paraffin.

INTRODUCTION

In the 21st century, the world is facing critical health issues due to the increase in global warming. And it is believed that the poisonous exhaust gases being released by the IC engine driven motor vehicles are contributing a major role in global warming. To reduce that, scientists worldwide are emphasizing more on the advancement of battery-driven electric vehicles. Hybrid vehicles can be proved to be the game-changer to battle global warming. And therefore, the focus and efforts are more to increase its efficiency and control

its heat dissipation rate from the batteries and the other electronic parts of the vehicle. The electric vehicles are quite similar to the IC engine vehicle from the outer structure but the circuits inside the vehicle vary a lot. Unlike IC engines, the battery electric vehicles have batteries, inverter, motor and generator. And that's why an electric vehicle is known by several names as Electric vehicle, Battery electric vehicle and hybrid electric vehicle. In a simple electric vehicle, the mode of drive mainly depends on the motor which is powered by the battery pack through an inverter.

Electric vehicles are classified into various categories as Plug-in electric vehicles and hybrid electric vehicles. Also according to the drive train, these are further categorized as

a series hybrid, parallel hybrid and combined hybrid(series and parallel). In pure electric vehicles, the IC engine is not employed but in hybrid electric vehicles, IC engines are also employed. Many researchers including Ravichandra Rangappa et al.[1] , Jiahao Cao et al. [2]etc proposed Lithium-Ion cells be used in the battery packs which has proved to be very effective in electric vehicles, Hybrid electric vehicles etc. in comparison with the other cells as of till date. But the main disadvantage of battery electric vehicles is the rate of heat removed from the large battery packs inside the vehicles. And to tackle this problem the battery thermal management system is being researched and employed inside the vehicles which are also called a battery cooling system.

This paper emphasized the modes and various types of battery thermal management system

for electric vehicles. In conventional vehicles, we generally employ air cooling or water cooling which was found to be effective for the conventional IC engine. But for the electric vehicles as referred by many researchers like Rasool Kalbasi et al. [3], Ravichandra Rangappa et al. [1], Lucia Ianniciello et al. [4] etc, proposed the use of Phase Change Material as the medium of coolant. And therefore, best efforts are made to understand the different boundary conditions, various types of PCMs and their characteristics and analyze them to come to a conclusion about the employability and effectiveness of the PCM to be used. Researchers like Ravichandra Rangappa et al. [1] highlighted that while employing phase change material cooling also there are various types of arrangements experimented, for example, Passive PCM cooling, Hybrid cooling and Pure PCM cooling. This means employing PCM material along with air cooling or water cooling, whichever suits best and

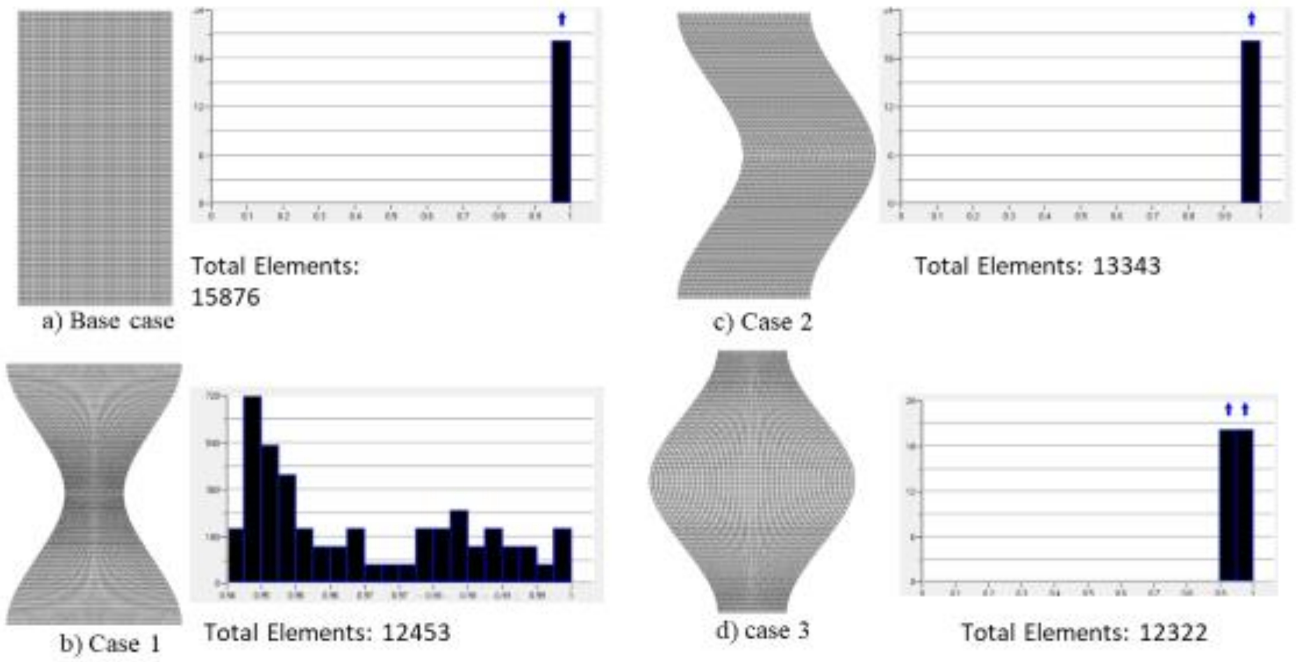
gives optimal results. Researchers like Hadi Bashir Pour-Bonab [4] talk about different types of PCM material and how they can be improved by enhancing their physical properties. Out of different types of PCM materials available in the market it is being experimented and came to the conclusion that the Paraffin PCM material is best suited to be employed inside the batteries. Also, by adding adequate additives to the PCM material, its properties can be improved and make it more effective and long-lasting. Lucia Ianniciello et al. [3] in their paper highlighted the importance of making PCM material encapsulated or in other words packaging of the PCM to make it chemically stable, non-toxic and make it resistive towards heat and electricity. Inside an electric vehicle, for the battery thermal management system, the circuit which involves different arrangements are battery pack, encapsulated PCM material, Copper tubes (for channel flow), liquid coolant, fins etc. The main aim of the paper is to identify the best arrangement for the circuit to work efficiently, to keep it less bulky and to reduce the overall size of the circuit.

METHODOLOGY

The PCM were contained in different shaped packs, which needed to be simulated. The PCM used in this case is RT50. The Meshing is done using ICEM CFD software. The simulation was completed using the Ansys Fluent software.

a) Base case b) Case 1 c) Case 2 d) Case 3

Figure:1 Geometry modelling of different shaped packs



a) Base case

c) Case 2

b) Case 1

d) case 3

Figure:2 Meshing data of different shaped packs

RESULTS AND OBSERVATIONS

Effect of average PCM temperature in different encapsulations. Four different shapes of encapsulation were considered in this case study, the first one is the base case where it will be used to compare with the other 3 cases in the sequence. It is apparent that average temperature variation is plotted for 12 hours, and the temperature is shown for the period of 12 hours.

The temperature is shown in the y axis and the time is shown in the x axis. The initial temperature of the PCM enclosure of all the cases at the start is 293 k. The change in temperature for the first three hours is 10.3 k. The enclosure of heat is in the y direction only. The temperature after 3 hours increased gradually for different cases. We have obtained the data of different temperatures for different cases. Case 3 showed the highest temperature at the eighth hour and remained constant for the next hours.

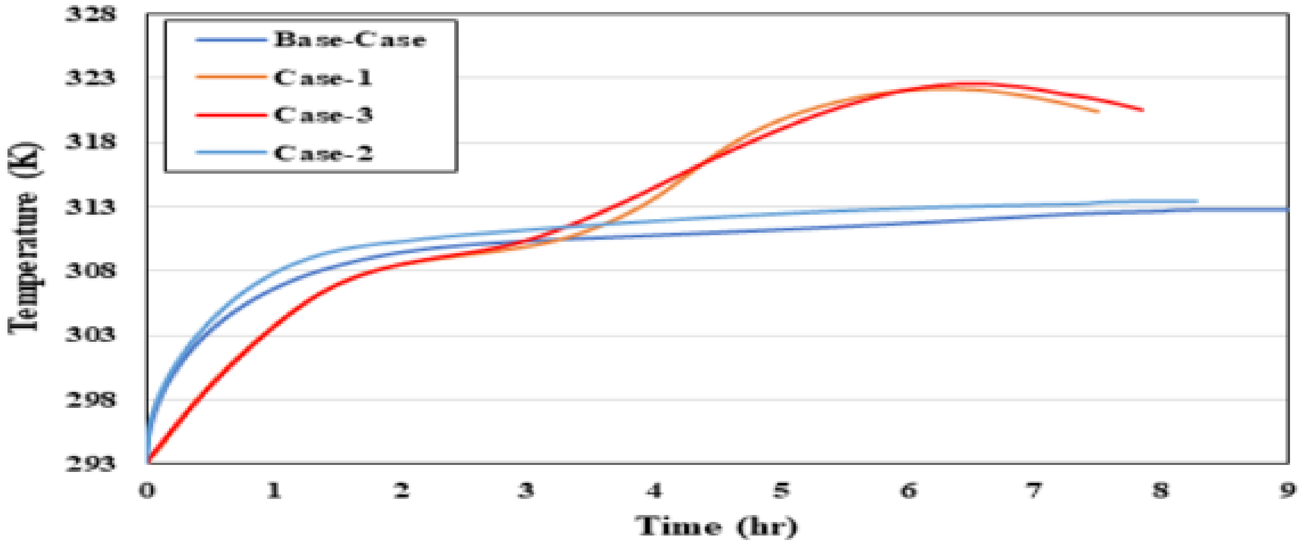


Figure:3 temperature curve for battery to discharge time

The different contours were obtained for the shapes or cases, the figures of the contours have been obtained at the end of the simulation. The contours are shown below. At the end of the simulations all the temperatures were compared with the base case temperatures obtained.

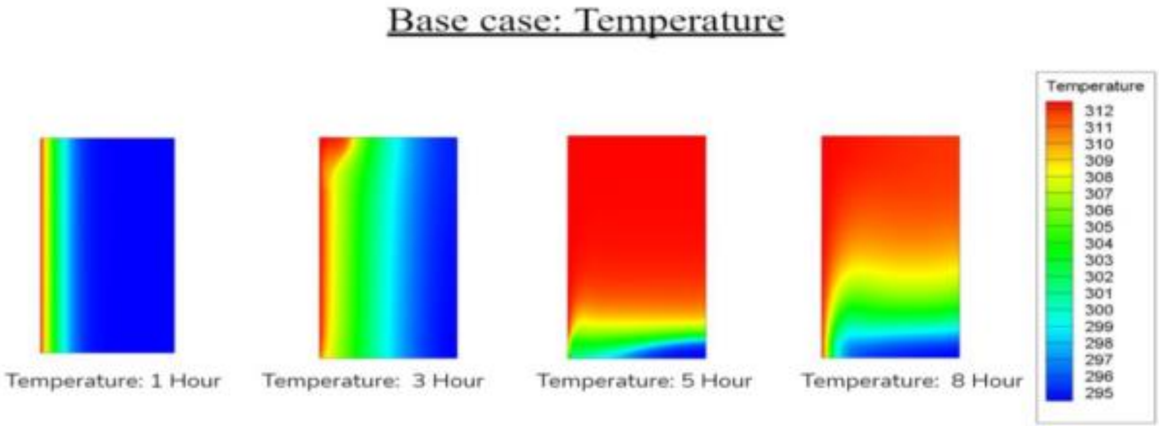


Figure:4 base case Battery temperature versus discharge time

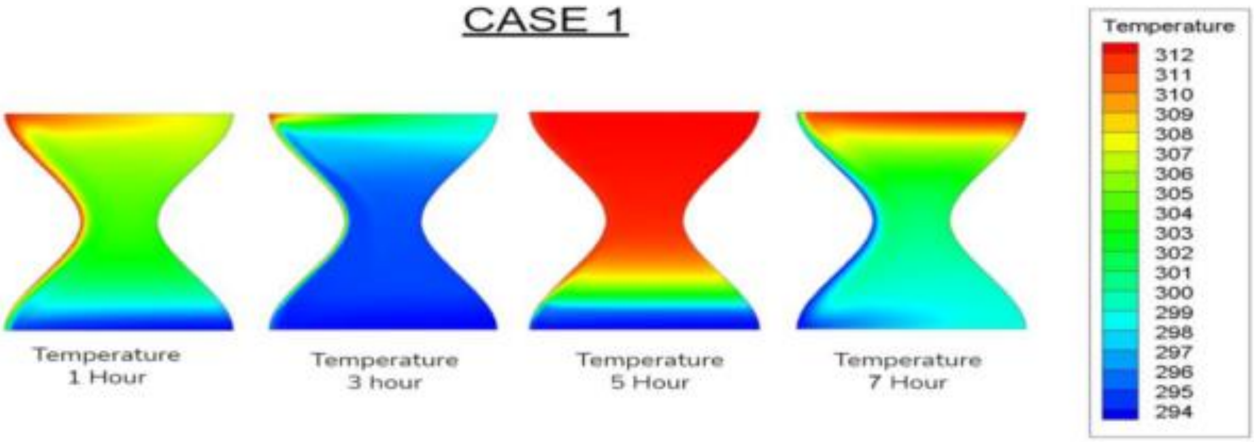


Figure:5 case-1 Battery temperature versus discharge time

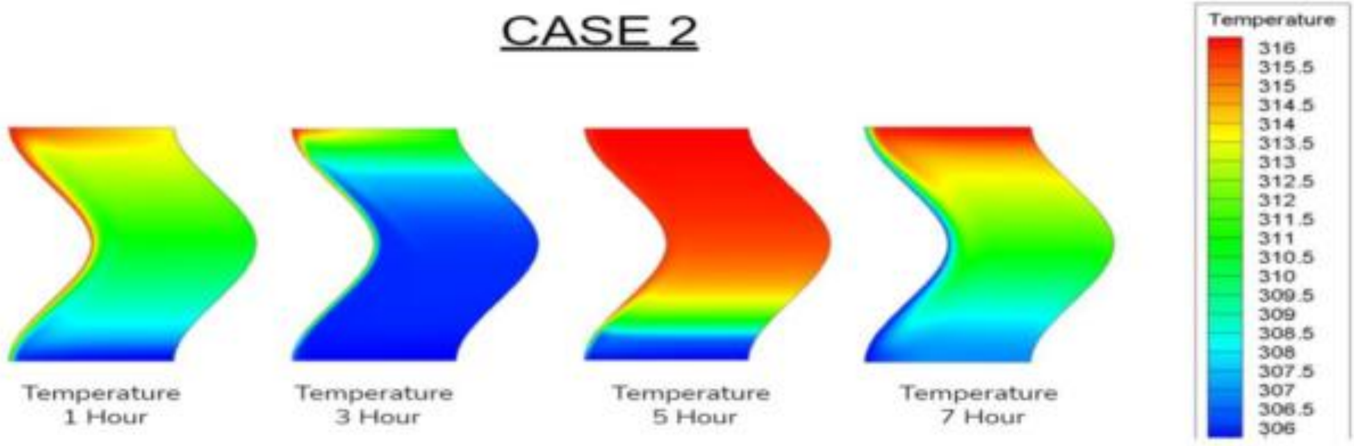


Figure:6 case-2 Battery temperature versus discharge time

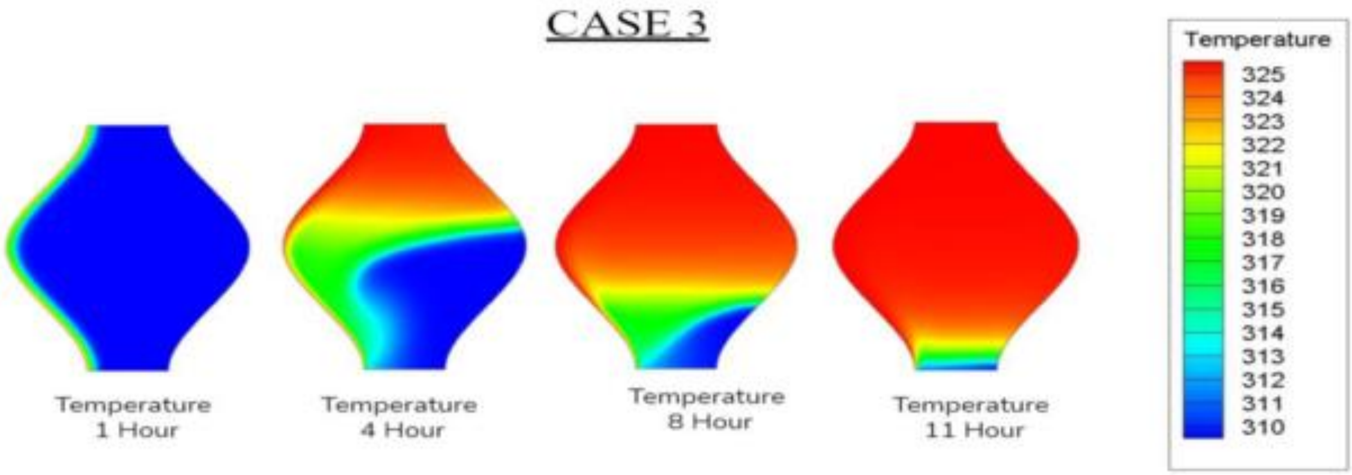


Figure:7 case-3 Battery temperature versus discharge time

2. Melting Fraction:

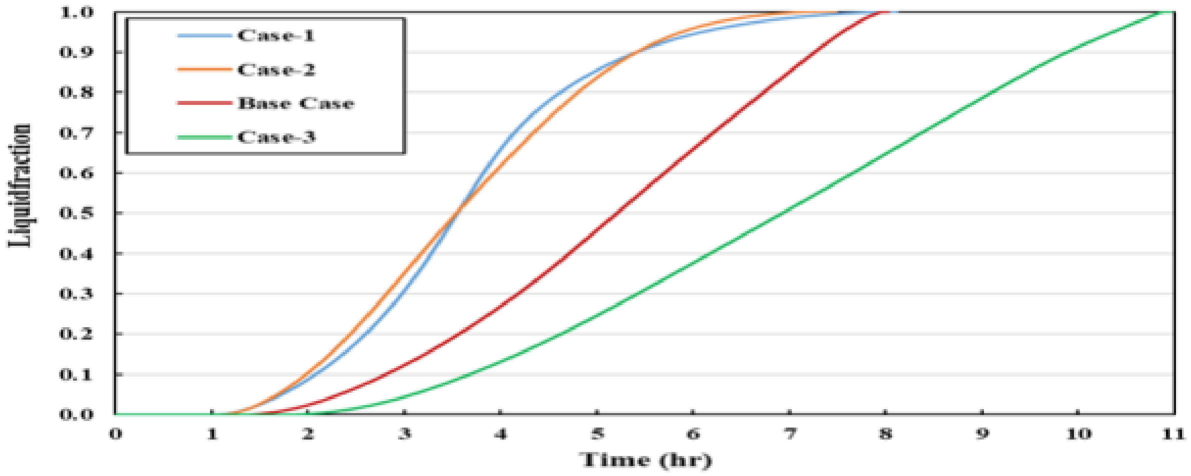


Figure:8 temperature curve for battery and of PCM liquid fraction with respect to discharge time variations

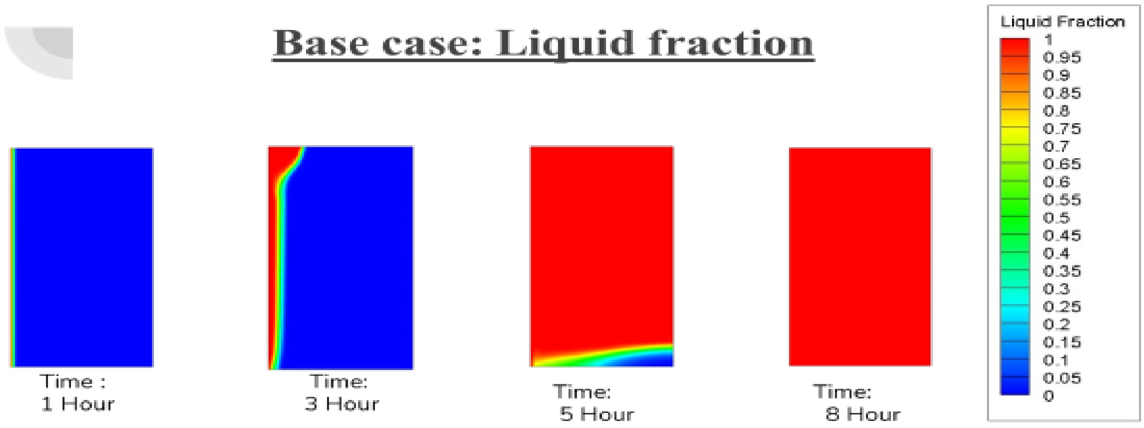


Figure:9 base case temperature curve for battery PCM liquid fraction with respect to discharge time

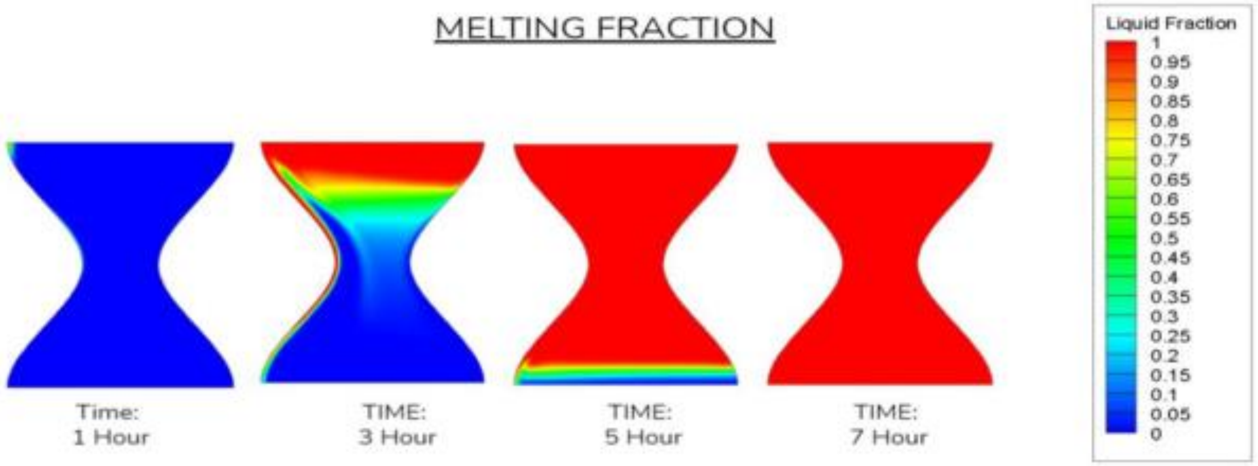


Figure:10 case-1 temperature curve for battery PCM liquid fraction with respect to discharge time

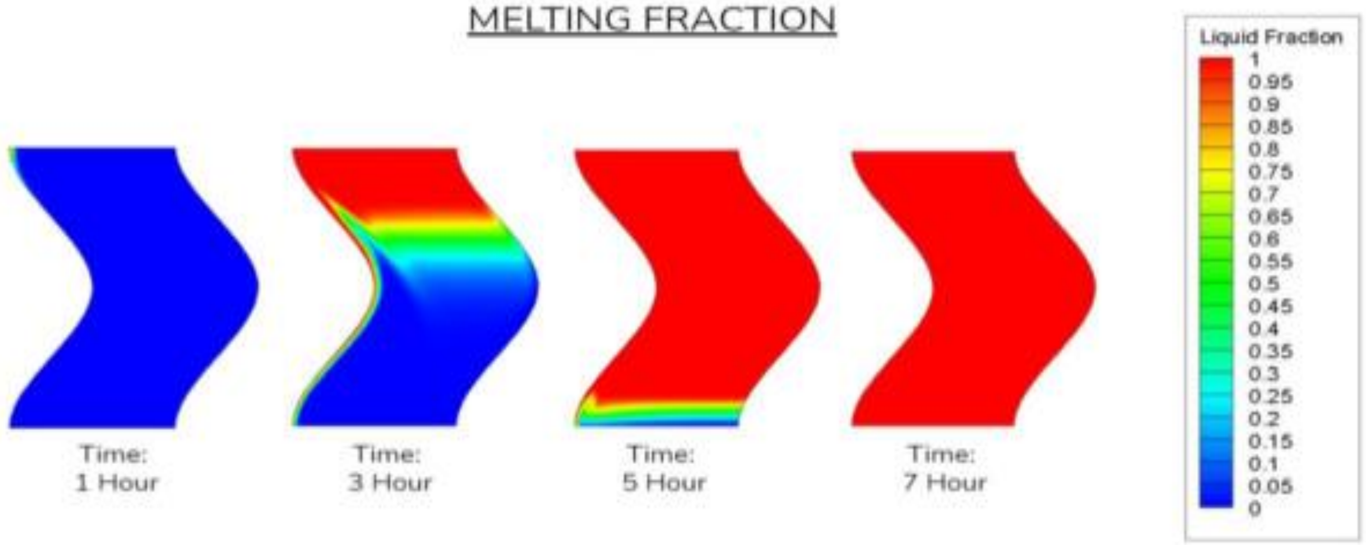


Figure:11 case-2 temperature curve for battery PCM liquid fraction with respect to discharge time

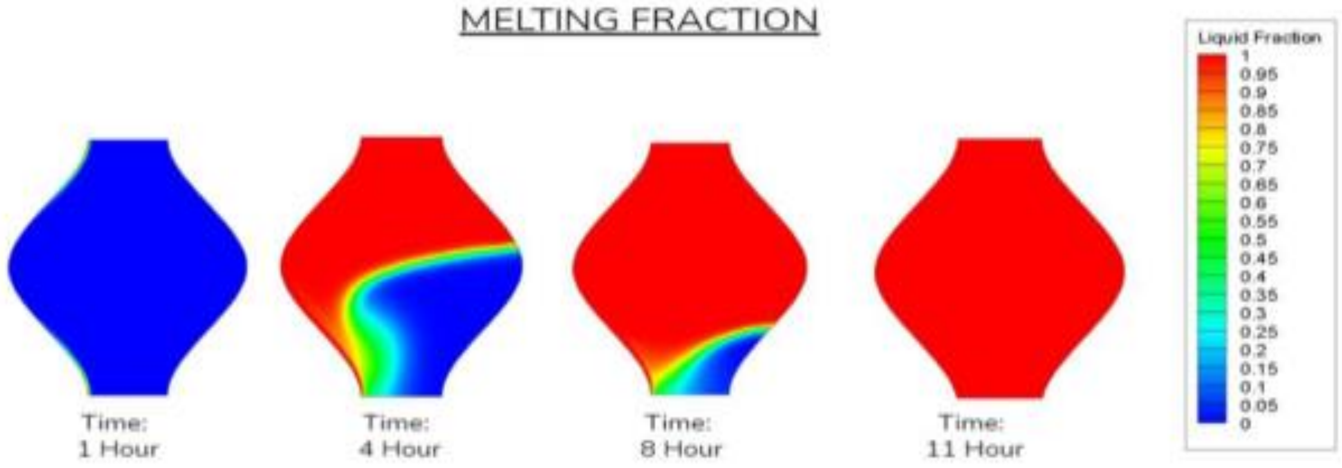


Figure:12 case-3 temperature curve for battery PCM liquid fraction with respect to discharge time

For the different cases the melting fraction also varied with time for the different cases, the PCM used for this simulation is RT50, the melting temperature starts from 300.15 k after one hour of observation the melting started to take place at different rates for different cases, as the area which is exposed for to the heat source is also different. The melting range is from 0 to 1. As shown in the graph, the melting fraction for the different cases are shown. It is evident that case 3 took a longer time to melt, which is 11 hours to completely convert into liquid. While the other cases took relatively less time to become liquid. As per the liquid fraction, greater the time the PCM takes to melt, greater will be the heat holding capacity of the PCM. where as in other cases, case 2 took less time to convert into liquid at 8 hours. Each pack had different melting times. All the melting of the PCM is observed in x direction as the heat incident on the y face.

CONCLUSIONS

Influence of the PCM on the battery thermal management was studied. As we all know, inside an electric vehicle, the system which generates the most amount of heat energy is the Battery. So in order to control and optimize the overall performance of the vehicle we

are employing various strategies and experiments on the design of the available battery cells in the market. So, in the paper, we have taken Lithium Ion battery pouch cells which

are widely used in electric cars. In the paper our major focus was on the encapsulation of the PCM pouch inside the battery packs. In order to achieve that, we have done the design and simulation of the software ANSYS Fluent. The viability of using PCM incorporated in electric vehicles to increase the performance of the battery by using CFD methodology and obtained results will be presented in terms of graphs, temperature contours etc. Results show that PCM integrated in different designs of pouches, the

battery had an average temperature of 304.4 – 306.2 K. The pouches were incorporated in between the batteries to maintain the optimum temperature. The analysis was done for 3 different designs of PCM pouch. It was found that case 3 encapsulation of the PCM offers better liquid fraction time of 11 hours, compared with that of the base case which showed the liquid fraction time of only 9 hours, where the battery can be maintained within the optimum temperature. The case1, case2, PCM encapsulation, showed similar results as that of the base case; they both offered a similar liquid fraction time of 8 hours. Hence, we can conclude that the PCM encapsulation in the case 3 has potential to reduce the temperature of the batteries, for better performance.

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