Effect of cell geometry and PCM material and thickness on the performance of Lithium-ion battery

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1. INTRODUCTION & OBJECTIVE

The internal combustion engine powered vehicles have been serving the society for more than 150 years. The automotive industry has undoubtedly made a room for the grow th of other industries, changed the life style but also added huge wealth to the nations. However, with the consumption of petroleum derived fuels, the automotive vehicles have also become bone of contention due to local and global air pollution [1]. Though there is a swift change in the vehicle model variants and technology improvisation but could not mitigate the pollution levels as desired. Of late, the trend has been shifted toward the use of alternative source powered vehicles , electric vehicles, in its neat form majorly powered by electro chemical batteries and electric motor.

There are different kinds of electric vehicles have been made such as battery powered electric vehicles and plug-in hybrids. The battery being an essential component, many types of batteries viz; lead-acid, Nickle-metal hydride, nickel cadmium and lithium ion batteries have been developed. However, due to its high power/energy density and long cycle life[2].

Lithium-ion batteries have occupied prominence in the electric vehicle applications.No doubt, LIBs are very popular and prone for degraded performance at elevated temperature due to either charge and discharge cycles or high or low ambient temperature. There is asmall temperature window [15-40^{o}C] within which the battery performance is optimal. Beyond this range, the batteries are subjected to electric, thermal and mechanical abuse leading to the problem of thermal runaway. Thermal runaway though it is undesirable but also lead to catastrophic hazards such as fire/explosion [3-5]. Many studies have been taken place to mitigate the undesirable phenomena with the use of battery thermal management techniques such as air/liquid and heat pipe systems in active or passive mode. Though the air cooling systems are simple ,compact but couldn’t control the temperature due to poor heat capacity. Phase Change Materials [PCMs] have become source of passive cooling methods besides storing energy. There are organic, inorganic and eutectic PCMs that have been tried out. Organic PCMs have explored to the large extent but are flammable. Also, it is noted from literature that thermal conductivity of PCM plays an important role in effective heat dissipation and thus better thermal management. Many studies are also done to enhance the heat transfer by supporting the PCMs with microencapsulation, fins and nano-materials as additives.

The present work focusses on a prismatic type LIB single cell and mitigation of peak battery temperature is addressed by choosing a battery cathode as lithium iron phosphate [LFP]. The effect of battery cell volume and provision of PCM with varying thickness and two kinds of PCM materials-organic and inorganic have been used.

Table1. Properties of organic PCM used in modelling

PCM	Paraffin wax(RT40)
Phase change temperature range	38°C-43°C
Density solid	880kg m^{-3}
Density liquid	760kg m^{-3}
Latent heat capacity	165 kJ kg^{-1}
Specific heat capacity (solid)	3.0 kJ $kg^{-1}k^{-1}$
Specific heat capacity (liquid)	2.30 kJ $kg^{-1}k^{-1}$
Thermal conductivity	0.21 $Wm^{-1}K^{-1}$
Volume expansion	12.5%

2. RESULTS & HIGHLIGHTS OF IMPOINTANT POINTS

The computation study is carried out by modelling a battery cell, dimensions of which have been selected from literature [6]. The cell is modelled using ANSYS 21.0R with properties of battery cell layers and Phase Change Materials, both organic and inorganic, RT Therm and Sodium Sulphate Deca hydrate have been chosen respectively.

The dimensions of cell chosen from literature and a thickness of the cell has been changed to study variation of thickness as well as overall volume of the cell body.

Simulations are performed firstly without any PCM under high discharge conditions of C-rating viz;5C,6C and 8C. It is observed, that as the discharge is increased, the cell drained quicly and peak temperature also increased.

In addition, the thickness of PCM is varied from 2-6 mm and the variation of thermal conductivity in terms of inorganic and organic PCMs is investigated.

It is concluded that higher thickness is required at higher discharge rates and with in increase in cell overall volume [length*width*thickness], the peak cell temperature at the end of discharge has reduced.

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