“Design & Modelling of Cold Plates for Efficient Thermal Performance of Li-ion Battery Modules- A Review”

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Abstract: This review paper estimates the thermal concert and research-oriented work of immersion cooling for an Electric Vehicle battery module which is composed of Battery-ion cells. Usefulness of immersion cooling in educating maximum cell temperature, cell's temperature incline, cell-to-cell temperature difference, and pressure drop in the module are explored by direct judgement with a battery module. Parametric analyses are performed at different module discharge C-rates and coolant flow rates to understand the sensitivity of each cooling strategy to important system presentation parameters. Results validate that immersion cooling due its higher thermal conductance leads to a lower maximum cell temperature and lower temperature gradients within the cells at high discharge rates. However, a higher rate of heat refusal and poor thermal properties of the insulator fluid results in a much higher temperature non-uniformity across the module. At lower discharge rates, the two cooling methods show similar thermal performance. Additionally, owing to the lower viscosity and density of the considered dielectric fluid, an immersion-cooled battery module performs significantly better.

I. INTRODUCTION

The propagation of Electric Van that outclass their internal ignition engine counterparts, is demanding higher energy density Li-ion battery packs, capable of sustaining high power expulsion, and be able to fast-charge, all while accomplishing high safety standards. An effective, and optimal Thermal Management System is therefore crucial for preventing the cells from over-heating, which in turn could main to enhanced battery cell degradation, or an unsafe occurrence such as thermal runaway. Also, a well-designed is compulsory for wider terrestrial adoption of EVs, notably in very hot, or very cold climates, all while continuing cells temperature within an optimal range during vehicle operation. strategies have been projected to lower the peak cell infections in a battery module. These systems include convective air cooling, fluid cooling, two-phase vapour freezing using heat pipes, Phase Change Materials or a combination of these.

II. LITERATURE REVIEW

Due to their high thermal conductivity, fluid cooling systems are known to be most effective at dissipating the high heat generated by the cells inside an EV battery module. Therefore, in this work, we focus our attention on an indirect fluid cooling system based on cold plates.

In order to conduct numerical heat transfer analysis using software there should be mathematical model which shows the physics of the problem, input variables and the relationship through these parameters. It concerns with the initial and the boundary conditions and its valid range of variation with the governing equations. For ANSYS fluent based simulations, initially the physical model has been modeled in CAD software, then it has imported and presented in ANSYS. The model required the initial and boundary
conditions to accomplish the formulation for simulation and are also illustrated. The heat generation rate is assumed to be the only heat source in the cell zone. The boundary conditions around the cell and positive/negative tabs which are connected to the cell are defined under free convection. Simulation domain momentum equation is not considered. The energy equations are the governing equations which analyze the temperature distribution and heat transfer in the model. Without the location is closer to the bottom side of the cell. A large thickness around the cell will have longer depth in curvature which, in turn provides better cooling in cell [11].

**Heat generation due to contact resistance:**

Heat generation in the cell and the battery pack can be planned by modeling numerical by using the calorimetric method. Parameters concerning with phase change temperature, joule heating, electrochemical reactions and change in temperature with insulation material will change the heat generation whereby the cells surface temperature. The following energy balanced equation is used for the heat generation due to its contact resistances and the values are planned from Equation (1) [12]:

Accurate estimation can maximize the performance of the battery and protect the battery to prevent overcharge and over discharge. It provides a measure of the amount of electric energy stored in a battery. It is analogous to fuel gauge on a conventional internal combustion engine vehicle [13]. It is a dimensionless number between 0 and 1 representing in a percentage. It has noted that a zero does not mean that the battery is full empty, only that the battery cannot be discharged anymore without causing permanent damage to it [14].

State of Health (SOH)

The mathematical definition of SOH is not easy and differs for different applications one of the commonly adopted equations [15] G.N. Lewis began remarkable work on battery-ion battery in 1912, but it was not until the early 1970s that the first non-rechargeable battery batteries were made commercially available. To develop rechargeable battery batteries in the 1980s many attempts failed due to instabilities in the anode material which was made by using metallic battery.

Battery batteries are grouped into two categories due to high energy densities in battery batteries than legacy batteries (up to 100 times higher): Primary and Secondary batteries. Secondary (rechargeable) battery batteries comprise of rechargeable cells which contain an intercalated battery compound for the anode and cathode. “Battery-ion” batteries are the common name used for rechargeable battery-ion batteries. There are four basic cell designs: button/coin cells, polymer/pouch cells, cylindrical cells, and prismatic cells [16]. The battery cell voltage is planned using the energy of chemical reaction taking place inside the cell. It is the work of chargeable battery to convert chemical energy into electrical energy and vice versa. The positive and negative electrode are referred to as the cathode and anode respectively. The basic setup of a battery has three main divisions: the positive electrode, the separator, and the negative electrode. The battery is connected to an external load using current collector plates. In case of Li-ion cells, a copper collector is used for the positive electrode [17].

The anode composite material defines the name of the Li-ion battery and is usually made up of a mixture of carbon, while the electrolyte can be made of fluid, polymer, or solid materials. The anode is the electrode capable of supplying electrons to the load. In case of solid or polymer material, the electrolyte act as a separator. The material properties are taken from Kim’s papers [4] and [3].

Corrosion reaction takes place at the anode where the trapped battery particle starts to deintercalated or diffuse towards the electrolyte-solid interface excruciating battery ion into ions and electrons move finished the solution due to the possible difference while the electrons move through the current collector because the electrolyte solution acts as an electronic insulator [18]. The whole singularity of intercalation and deintercalation is reversible as battery ions pass back and forth between the electrodes during charging and discharging [19]. Unfortunately, due to cell material deprivation and other irreversible chemical reactions, the cell capacity and power degrade with the number of cycle and usage [20].

**Fundamental Models**

A battery cell’s behavior is usually described by the “fundamental” models, beginning from its physical foundation principles. The literature on fundamental models is quite extensive [21] for a review of the work proposed in the last two decades. Fuller, Doyle first approach to model Li-Ion with two composite electrodes and a separator at the University of California, Berkeley in the first half of the 90s. A literature review of this topic that most of the modern models are the derivatives of the original work which is considered a milestone for the argument. In their original works [22] and [23], Fuller et al. modeled the galvanostatic charge and discharge of a dual battery-ion insertion cell, shown in Figure 2.5. Models providing a representation of the input/output relationship of a system without investigating the fundamental physics are referred to as ‘humanistic’. Examples of phenomenological models are the equivalent circuit models. Quoting [27], the equivalent circuit model is a simple structure, it still captures sufficient dynamics under both temperature and variation, in this way it makes it applicable for use with real-time model-based estimation algorithms in automotive applications. For the modelling of the electrical part of batteries equivalent circuits are often used. They consist of a series. In [28] a first-order equivalent circuit model with parameters scheduled on SoC and temperature is presented. SOC is an approach related to the electrical model. Figure 2.7 depicts the electrical equivalent circuit. The simple first-order model is able to adequately compute the voltage-current relationship of the battery over a wide range of operating conditions due to the SOC and temperature scheduling of the open circuit voltage $E_0$, internal resistances $R$.
and $R_0$, and capacitance $C_0$ $C_N$ is the nominal capacity of the cell, $SoC_i$ is the initial state of charge and $\eta$ is the Coulombic efficiency of the cell, here supposed to be equal to 1[29]. The performance of batteries strictly depends on the internal temperature field [30], thus the electrical model is coupled with a lumped thermal model.

CONCLUSION

The literature review is finished by referencing the various research work done. The conclusion is found to be in terms of efficiency of the lithium battery cell used in the electric vehicle. There should be a scope for optimization of the design of battery arrangement. And it can be done by modifying the geometry of the cells used inside the assembly. This can be done and checked with the simulation software.

REFERENCE


[16] Battery Data Set NASA Ames Prognostic Data Repository


