ABSTRACT

The ever-increasing global environmental concerns have paved the way for electric vehicles (EVs) to hold deep roots in the transport market. Lithium-ion (Li-ion) batteries are the most explored and central part of the EV. Li-ion batteries are preferred due to their high energy density, power density, service life, and low self-discharge rates. However, the dependence of the cell performance on the operating temperature has limited customer satisfaction due to issues of safety and longevity. In this regard, many vehicle manufacturers' prime focus is designing and developing an effective battery thermal management system (BTMS). A reliable, cheap, energy-efficient, and simple structure are some of the primary needs for an effective BTMS. BTMS has been categorized into two main categories, (i) Active cooling systems (ACSs) and (ii) Passive cooling systems (PCSs). The ACSs are further subdivided into two categories, (i) Air cooling systems and (ii) Liquid cooling systems. Many leading EV manufacturers have widely adopted air-cooled BTMS in their battery packs. However, the air-cooled BTMS is inefficient in hyper ambient conditions and involves bulky structures. Liquid-cooled BTMS is more effective than air-cooled BTMS, but leakage and non-uniform temperature distribution are troublesome when employed in the battery pack. Additionally, the ACSs consume energy for their operation, referred to as parasitic energy consumption. PCSs do not consume parasitic energy and, thus, are most explored by researchers.

This thesis explores liquid and phase change material (PCM) cooled battery packs through numerical and experimental studies. A novel PCM-fin structure that works well under high ambient and discharge rates has been proposed. The effect of PCM's mass and fin length directly influenced the thermal performance. The proposed model was a combination of PCM and fins. For the seamless operation of EVs in a hot climate, this study examined a novel passive cooling system.

This cooling system features two distinct types of heat extraction media: (i) PCM-based isothermal storage-based heat sink and (ii) fin-based augmented thermal transport-based heat sink. These two sub-components were investigated in mutually competitive and complementing scenarios to understand the relative contributions of each component in heat extraction and realize the maximum cooling potential achievable from a combined implementation. The extensive and intensive properties of the retrofit were clubbed together under a new non-dimensional index, which has been called variable system response (VSR). The results of the parametric study were used to propose a set of two correlations. Different combinations of the design variables achieved a cooling of 142.1 W.

Furthermore, comprehensive research on liquid cooling mini-channels was carried out to determine the best combination of geometric and thermos-fluidic parameters of the mini-channels. The volume average battery temperature at the end of the driving cycle for the beat case was 313.31 K. The study showcases the importance of less intense cooling, which results in low power consumption (0.85 W) by the ACS.

Finally, the thesis compares the popular battery types: (i) cylindrical and (ii) prismatic for the passive cooling system. The study reveals that a cylindrical battery stores more heat at low ambient temperature conditions when compared to a prismatic battery. Also, design attributes are different for the PCM cooling system in the two lithium-ion batteries owing to the shape factor. This study attempted to cap the maximum temperature with in permissible limits through the PCM cooling system.