

High-Performance Immersion Cooling of Li-ion Batteries: Addressing Thermal Challenges in EVs

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Extended Abstract

Lithium-ion (Li-ion) batteries are widely used as the primary energy storage solution in electrical vehicles (EVs) due to their high energy density and efficiency. However, excessive heat generation during high C-rate charging and discharging can increase the temperature of the battery pack beyond its operating safety limits (15-40 °C) [1]. The excessive accumulation of heat might result in thermal runaway, posing serious safety risks such as fire or explosion. Therefore, effective heat dissipation is required during these processes. Tremendous amount of research has been conducted over the years to manage the temperature of the battery within its optimal operating limits. While thermal management strategies such as natural and forced air convection, phase change materials (PCMs), and heat pipes, have been explored, they often fail to maintain optimal battery temperatures under high loads [2]. Among these, immersion cooling has emerged as a highly effective solution due to the direct contact between the battery and a dielectric liquid, enabling efficient heat dissipation.

Immersion cooling is classified into single-phase and two-phase methods which are further divided as passive (static or free convection) and active (flow-assisted) methods [1]. The dielectric liquid in the single-phase immersion cooling remains in its liquid state throughout the experiment offering stability and simplicity. In contrast, the dielectric liquid in two-phase immersion cooling goes through a phase change, typically from liquid to vapour, enhancing heat removal through absorption of latent heat. While two-phase systems can provide extremely high cooling efficiency, they often require more complex system design and control.

In this study, an advanced immersion cooling method by integrating spray to enhance convection heat transfer has been used to further improve the heat transfer performance. A spray of dielectric liquid (Novec 7200) is directed onto the battery surface, increasing the contact area and promoting more effective convective heat transfer compared to conventional flow-based immersion cooling systems. A 9S7P battery pack, made of 18650 Li-ion batteries, with a capacity of 17.5 mAh was tested while subjected to 4 C-rate (70 A) charging and discharging. Thermocouples were placed on different cells to capture detailed temperature profiles and monitor the thermal behaviour throughout the experiment. Experimental results demonstrate that spray immersion cooling achieves lower peak temperatures and improved cell-to-pack temperature uniformity compared to conventional flow-based immersion cooling. These improvements not only reduce the risk of thermal hotspots but also contribute to better overall performance, increased safety, and potentially longer battery lifespan. These findings highlight the potential of spray-assisted immersion cooling as an advanced thermal management strategy for safer and more efficient EV battery systems.

References

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