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Thermal Runaway Mitigation Assessment by Passive Hybrid Thermal Management System with Phase Change Material and HFE-7000 Dielectric Liquid

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Extended Abstract

Hybrid battery thermal management systems (BTMS) using phase change materials (PCMs) can absorb and store large amounts of heat during phase change. However, they require an additional active cooling method to efficiently remove this stored heat from the system. Among active cooling methods, cooling with forced convection by air and indirect liquid cooling trough metallic plates or serpentines are some of the most analysed approaches. In these last, the working fluid as coolant is normally a refrigerant or water-glycol.

In the current work, a BMTS is proposed where the cylindrical cells are held by a PCM. The PCM holder intercalates orifices to hold the cells with pipes containing Novec HFE-7000 dielectric liquid [1]. This liquid has its boiling point at 34ºC, lower than water-glycol mixtures, which can be useful in cooling applications where rapid heat absorption is required. For instance, in the presence of a thermal runaway event in a cell, they could potentially enable a faster reaction since the boiling process would be triggered earlier. Besides offering a range of low saturation temperatures, dielectric liquids are chemically inert, compatible with most materials of high-power electronics and chips, environmentally friendly, and easy to handle and use.

The aim of study is to assess the capability of the proposed hybrid BMTS to mitigate a thermal runaway event in cell, preventing the fire propagation and ensuring the safety of the system. To this end, several steps are completed thoroughly.

First, a thermal runaway experiment is performed in an Accelerated Rate Calorimeter (ARC) device to obtain characterize the heat dissipation of a LG 18650 cylindrical cell. After careful examination and postprocessing of the experimental data, the heat generation extracted from the thermal runaway experiment is used to feed a CFD model of the proposed BTMS. The boiling process is modelled using an experimental correlation proposed by El-Genk et al. [2] to reduce the complexity of the model and provide a computationally efficient yet accurate solution.

Numerical results show that the proposed BMTS is capable of mitigating heat generation rates up to 400 W and transient temperatures increases up to 5 C/s. The current approach then provides a safe solution that can handle many of the external abuses that can experience a cell. Electrical abuses like forced overcharging/discharging, high C-rate scenarios, internal/external short circuits or thermal abuses like external heating typically generate less heat than the threshold reached in this study. Mechanical abuses like nail penetration or other destructive tests would require a dedicated analysis.

References

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