INTISARI

Baterai *lithium-ion* (*Li-ion*) banyak digunakan pada kendaraan listrik (EV) karena densitas energi tinggi dan umur pakai panjang. Namun, performa dan keamanannya sangat dipengaruhi oleh suhu operasi, dengan kisaran optimal 25–40 °C. Ketidakefisienan sistem manajemen termal (BTMS) dapat memicu penurunan kapasitas, kinerja, hingga risiko *thermal runaway*. Metode *immersion cooling* dengan fluida dielektrik menjadi solusi potensial karena memiliki efisiensi perpindahan panas tinggi dan mampu menjaga keseragaman suhu baterai.

Penelitian ini mengkaji performa *immersion cooling* menggunakan fluida HFE 7100 dan fluida SF3 dengan menggunakan baterai tunggal LFP 18650 dan NMC 18650. Penelitian dilakukan mencelupkan secara simetris ke dalam cairan dielektrik fluida HFE-7100 (berbasis *hydrofluoroether*) dan fluida SF33 (berbasis *hidrofluoroolefin*) menggunakan fasilitas *immersion cooling test*. Parameter yang diamati meliputi distribusi temperatur, temperatur rata-rata, *heat transfer coefficient*, *absorbed heat*, dan *pressure drop*, pada variasi laju pengosongan (*C-rate*) dan laju aliran fluida 0,25 LPM, 0,50 LPM dan 0,75 LPM.

Hasil menunjukkan bahwa temperatur rata-rata meningkat dengan bertambahnya *C-rate*, dan menurun seiring kenaikan laju aliran fluida. *Heat transfer coefficient* baterai LFP 18650 mencapai 176,89 W/m²·K (0,25 LPM), 189,82 W/m²·K (0,50 LPM), dan 232,86 W/m²·K (0,75 LPM). Pada baterai NMC 18650, nilai masing-masing sebesar 171,44 W/m²·K (0,25 LPM), 286,10 W/m²·K (0,50 LPM), dan 334,12 W/m²·K (0,75 LPM) pada *C-rate* 3C. Peningkatan laju aliran di atas 0,50 LPM menghasilkan *pressure drop* yang signifikan tanpa peningkatan perpindahan panas yang sebanding. SF33 menunjukkan performa lebih baik dibanding HFE 7100. Pada akhir pelepasan untuk *immersion cooling* fluida HFE 7100 (*berbasis hydrofluoroether*) dan Fluida SF33 (berbasis *hydrofluoroolefin*), temperatur rata-rata akhir sebesar 33,10 °C dan 32,70 °C untuk baterai NMC 18650, sedangkan untuk baterai LFP 18650 temperatur rata-rata akhir sebesar 31,53 °C dan 29,80 °C pada *discharge rate* 3C.

Kata Kunci: *Immersion cooling, dielectric fluid, thermal management, lithium-ion battery, heat transfer coefficient, thermal runaway.*

ABSTRACT

Lithium-ion (Li-ion) batteries are widely used in electric vehicles (EVs) due to their high energy density and long service life. However, their performance and safety are greatly affected by operating temperature, with an optimal range of 25–40 °C. Inefficiency in the thermal management system (BTMS) can lead to a decrease in capacity, performance, and even the risk of thermal runaway. Immersion cooling methods using dielectric fluids offer a potential solution due to their high heat transfer efficiency and ability to maintain battery temperature uniformity.

This study examines the performance of immersion cooling using HFE 7100 fluid and SF3 fluid with a single LFP 18650 and NMC 18650 battery. The study was conducted by symmetrically immersing the batteries in the dielectric fluids HFE-7100 (hydrofluoroether-based) and SF33 (hydrofluoroolefin-based) using an immersion cooling test facility. The parameters observed included temperature distribution, average temperature, heat transfer coefficient, absorbed heat, and pressure drop, at varying discharge rates (C-rate) and fluid flow rates of 0.25 LPM, 0.50 LPM, and 0.75 LPM.

The results show that the average temperature increases with increasing C-rate and decreases with increasing fluid flow rate. The heat transfer coefficient of the LFP 18650 battery reached 176.89 W/m²·K (0.25 LPM), 189.82 W/m²·K (0.50 LPM), and 232.86 W/m²·K (0.75 LPM). For the NMC 18650 battery, the values are 171.44 W/m²·K (0.25 LPM), 286.10 W/m²·K (0.50 LPM), and 334.12 W/m²·K (0.75 LPM) at a C-rate of 3C. Increasing the flow rate above 0.50 LPM results in a significant pressure drop without a corresponding increase in heat transfer. SF33 demonstrates better performance than HFE 7100. At the end of discharge for immersion cooling with HFE 7100 fluid (hydrofluoroether-based) and SF33 fluid (hydrofluoroolefin-based), the average final temperature was 33.10 °C and 32.70 °C for the NMC 18650 battery, while for the LFP 18650 battery, the average final temperature was 31.53 °C and 29.80 °C at a discharge rate of 3C.

Keywords: Immersion cooling, dielectric fluid, thermal management, lithium-ion battery, heat transfer coefficient, thermal runaway.