

INTISARI

Kebutuhan energi global yang meningkat akibat pertumbuhan populasi dan industri memicu emisi gas rumah kaca dari bahan bakar fosil. Kendaraan listrik (EV) menjadi solusi untuk mengurangi dampak lingkungan, dengan penjualan global mencapai lebih dari 3,3 juta unit pada tahun 2021. Baterai lithium-ion (LIBs) dipilih sebagai teknologi penyimpanan karena efisiensi tinggi dan umur panjang, Namun perlu diketahui bahwa performanya sangat dipengaruhi oleh temperatur operasional. Temperatur ideal berkisar antara 15°C hingga 35°C, dan *thermal runaway* dapat menyebabkan kebakaran atau ledakan, sehingga manajemen termal menjadi penting.

Penelitian ini menganalisis kinerja pendinginan pada baterai lithium-ion tipe Lithium Iron Phosphate (LFP) dengan sistem *immersion cooling* menggunakan fluida dielektrik berbasis hidrokarbon GTL Shell S3X. Metode mencakup pengujian distribusi temperatur, koefisien perpindahan panas, kalor yang diserap fluida dan efisiensi pendinginan pada variasi laju pengosongan (*C-rate*) 1,5 C, 2 C, dan 2,5 C, serta laju aliran fluida 0,35 Lpm, 0,5 Lpm, dan 0,65 Lpm.

Hasil penelitian menunjukkan bahwa distribusi temperatur dipengaruhi oleh posisi baterai terhadap *inlet* dan *outlet* serta polaritas kutub baterai. Pada metode *natural cooling*, temperatur tertinggi ke terendah tercatat pada *channel* awal-tengah-akhir, sedangkan pada *flow immersion cooling*, urutan tertinggi ke terendah tengah-akhir-awal. Peningkatan *C-rate* meningkatkan *heat transfer coefficient* dan kalor yang diserap fluida. Pada *flow rate* 0,35 Lpm, nilai *heat transfer coefficient* berturut-turut untuk *C-rate* 1,5 C, 2 C, dan 2,5 C adalah 104,44 W/m²·K, 137,31 W/m²·K, dan 159,5 W/m²·K. Pada *C-rate* 2,5 C, peningkatan *flow rate* dari 0,35 Lpm ke 0,65 Lpm juga meningkatkan *heat transfer coefficient* dan kalor yang diserap. *Flow rate* 0,5 Lpm direkomendasikan karena memberikan keseimbangan terbaik antara transfer panas dan efisiensi pompa.

Kata Kunci: Baterai lithium-ion, *immersion cooling*, manajemen termal, koefisien *heat transfer coefficient*, *C-rate*, GTL Shell S3X, laju aliran fluida, baterai LFP, *thermal runaway*, distribusi temperatur, efisiensi pendinginan

ABSTRACT

The increasing global energy demand due to population and industrial growth has led to increased greenhouse gas emissions from fossil fuels. Electric vehicles (EVs) are emerging as a solution to mitigate environmental impacts, with global sales reaching over 3.3 million units in 2021. Lithium-ion batteries (LIBs) are preferred as the storage technology due to their high efficiency and long lifespan. However, it is crucial to note that their performance is significantly influenced by operational temperature. The ideal temperature range is between 15°C and 35°C, and thermal runaway can lead to fires or explosions, making thermal management essential.

This study analyzes the cooling performance of lithium-ion batteries using Lithium Iron Phosphate (LFP) with an immersion cooling system utilizing dielectric hydrocarbon fluid Shell S3X GTL. The methods include testing temperature distribution, heat transfer coefficients, heat absorbed by the fluid, and cooling efficiency at varying discharge rates (*C-rates*) of 1.5 C, 2 C, and 2.5 C, as well as fluid flow rates of 0.35 Lpm, 0.5 Lpm, and 0.65 Lpm.

The results indicate that temperature distribution is influenced by the battery's position relative to the inlet and outlet, as well as the polarity of the battery terminals. In the natural cooling method, the highest to lowest temperatures were recorded in the initial-middle-final channels, while in flow immersion cooling, the order was highest to lowest from middle-final-initial. An increase in *C-rate* enhances the heat transfer coefficient and the heat absorbed by the fluid. At a flow rate of 0.35 Lpm, the heat transfer coefficient values for *C-rates* of 1.5 C, 2 C, and 2.5 C were 104.44 W/m²·K, 137.31 W/m²·K, and 159.5 W/m²·K, respectively. At a *C-rate* of 2.5 C, increasing the flow rate from 0.35 Lpm to 0.65 Lpm also improved the heat transfer coefficient and heat absorbed. A flow rate of 0.5 Lpm is recommended as it provides the best balance between heat transfer and pump efficiency.

Keywords: Lithium-ion batteries, immersion cooling, thermal management, heat transfer coefficient, *C-rate*, GTL Shell S3X, fluid flow rate, LFP batteries, thermal runaway, temperature distribution, cooling efficiency