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Studi Eksperimen Transfer Panas dan Distribusi Suhu Pada Sel Baterai Tunggal Samsung INR 18650-25R
Menggunakan Metode Pendinginan Pasif Phase Change Material Lauric Acid
Rafli Maulana Balgis, Ir. Indro Pranoto, S.T., M.Eng., Ph.D., IPM., ASEAN Eng.
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INTISARI

Baterai Lithium-ion 18650 menjadi komponen energi utama kendaraan listrik di tengah tekanan global dekarbonisasi. Pembangkitan panas akibat resistansi internal saat pengosongan arus tinggi berpotensi mendorong suhu sel melampaui batas aman 40°C dan memicu thermal runaway. BTMS pasif berbasis *Phase Change Material* (PCM) *Lauric Acid* menawarkan pendinginan tanpa energi eksternal, namun efek variasi fraksi pengisian pada sel 18650 tunggal belum dikaji secara eksperimental.

Sel tunggal Samsung INR 18650-25R (2500 mAh) diuji dalam wadah aluminium 6061 dengan empat konfigurasi NC, PCM 50%, 75%, 100% menggunakan *Lauric Acid* (titik leleh 43,5°C) pada laju 1C, 2C, dan 4C dengan Rigol DL3021. Temperatur dari lima termokopel tipe-K (T1–T3 aksial, T4–T5 lateral) direkam melalui Omron ZR-RX45. Analisis mencakup distribusi temperatur, *heat generation , heat flux*, panas sensibel dan laten, serta koefisien perpindahan panas (h).

Seluruh PCM menurunkan temperatur sel di semua laju pengosongan. Pada 4C DoD 95%, NC mencapai $T_{b,avg}$ 60,73°C yang melampaui batas aman, sementara PCM 50%, 75%, dan 100% hanya mencapai 48,60°C, 46,33°C, dan 44,90°C (reduksi 12,13°C, 14,40°C, dan 15,83°C). PCM 100% mencatat efisiensi reduksi η = 45,86% dan h = 502,6 W/m²K, dibandingkan 243,9 W/m²K pada NC. Transisi fase hanya teramati pada 4C fase akhir PCM 50%, 75%, dan 100% mencapai titik leleh masing-masing pada detik ke-590, 702, dan 789, dengan perlambatan laju kenaikan temperatur 40,6%, 30,8%, dan 21,7%. Mekanisme dominan adalah panas sensibel fase padat dengan panas laten aktif hanya di akhir 4C.

Kata kunci: Baterai Lithium-ion, *Phase Change Material, Lauric Acid, Battery Thermal Management System*, pendinginan pasif

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ABSTRACT

The 18650 lithium-ion battery has become the primary energy storage component of electric vehicles amid global decarbonization pressure. Heat from internal resistance during high-rate discharge can push cell temperatures beyond 40°C and trigger thermal runaway. PCM-based Battery Thermal Management Systems offer passive cooling without external power, yet the effect of varying Lauric Acid infill fractions on a single 18650 cell remained experimentally unexplored.

A single Samsung INR 18650-25R cell (2500 mAh) was tested in an aluminum 6061 enclosure across four configurations NC, PCM 50%, 75%, 100% using Lauric Acid (melting point 43,5°C) at discharge rates of 1C, 2C, and 4C with a Rigol DL3021. Five K-type thermocouples (T1–T3 axial, T4–T5 lateral) recorded temperature via an Omron ZR-RX45. Analysis covered temperature distribution, heat generation, heat flux, sensible and latent heat absorption, and heat transfer coefficient (h) estimation.

All PCM configurations reduced battery temperatures across all discharge rates. At 4C, DoD 95%, NC reached $T_{b,avg}$ of 60,73°C exceeding the safe limit while PCM 50%, 75%, and 100% reached only 48,60°C, 46,33°C, and 44,90°C (reductions of 12,13°C, 14,40°C, and 15,83°C). PCM 100% achieved η = 45,86% and h = 502.6 W/m²·K versus 243.9 W/m²·K for NC. Phase transition was observed only at 4C near end-of-discharge PCM 50%, 75%, and 100% reached the melting point at 590 s, 702 s, and 789 s, with temperature rise rate reductions of 40,6%, 30,8%, and 21,7%. Solid-phase sensible heat dominated throughout discharge with latent heat contributed only at the end of 4C discharge.

Keywords: Lithium-ion battery, Phase Change Material, Lauric Acid, Battery Thermal Management System, passive cool