INTISARI

Kebutuhan energi untuk pemanasan air bersifat fluktuatif mengikuti pola beban musiman (*seasonal load*), terutama pada malam hari dan saat cuaca mendung ketika radiasi matahari tidak tersedia. Kondisi ini diperparah oleh dominasi energi fosil di Indonesia yang meningkatkan emisi gas rumah kaca dan menurunkan ketahanan energi nasional. Sebagai solusi, dikembangkan sistem penyimpan energi termal berbasis *Phase Change Material* (PCM) *Stearic acid* yang memanfaatkan kalor laten untuk menjaga ketersediaan energi termal secara berkelanjutan di tengah fluktuasi beban tersebut.

Penelitian ini bertujuan merancang sistem penyimpan energi termal terintegrasi PCM melalui heat exchanger yang menggabungkan PCM, batang induksi, dan pipa Heat Transfer Fluid (HTF), sekaligus mengamati performa termalnya pada proses *charging* (pelelehan PCM) dan *discharging* (perpindahan kalor ke air HTF). Analisis dilakukan berdasarkan prinsip termodinamika dan perpindahan panas pada kondisi tunak dan ideal, dengan variasi daya pemanas 300, 600, dan 900 W serta laju aliran massa discharging 2, 3, dan 4 L/min.

Hasil penelitian menunjukkan bahwa pada proses charging, variasi daya heat stove berpengaruh terhadap waktu pelelehan PCM, pada 300 W PCM meleleh sempurna dalam ±300 menit, pada 600 W dalam 130–150 menit, sedangkan pada 900 W pelelehan tidak konsisten lebih cepat akibat distribusi panas yang kurang merata, dengan sebagian titik baru meleleh penuh pada menit ke-220. Pada proses discharging, peningkatan laju aliran massa mempercepat tercapainya kesetimbangan termal antara temperatur inlet dan outlet air, yaitu pada menit ke-75 (2 L/min), menit ke-60 (3 L/min), dan menit ke-30 (4 L/min), meskipun temperatur PCM tetap lebih tinggi dibanding air hingga akhir pengujian akibat rendahnya konduktivitas termal PCM. Secara keseluruhan, rancangan heat exchanger dengan konfigurasi batang induksi tertentu dan pipa HTF tembaga berdiameter ½” terbukti dapat memenuhi kebutuhan kalor pelelehan PCM, sehingga sistem penyimpan energi termal ini berpotensi menjadi solusi penyimpanan energi termal yang efisien dan berkelanjutan untuk pengembangan teknologi energi terbarukan di masa depan.

Kata Kunci: Penyimpanan Energi Termal, *Phase Change Material* (PCM), Perancangan, Variasi Laju aliran Massa, Variasi Daya.

ABSTRACT

Water heating energy demand is inherently fluctuating, following a seasonal load pattern that becomes most pronounced at night and under overcast conditions, when solar radiation is unavailable. This challenge is further compounded by Indonesia's continued reliance on fossil fuels, which contributes to rising greenhouse gas emissions and undermines national energy security. As a solution, a thermal energy storage system based on Stearic acid as the Phase Change Material (PCM) was developed, harnessing latent heat to sustain thermal energy availability amid such load fluctuations.

This study aims to design a PCM-integrated Thermal Energy Storage (TES) system through a heat exchanger combining PCM, induction rods, and Heat Transfer Fluid (HTF) piping within a rectangular tank, while also predicting its thermal performance during charging (PCM melting) and discharging (heat transfer to the HTF water flow) processes. The analysis was conducted based on thermodynamic and heat transfer principles under steady, idealized conditions, with heater power varied at 300, 600, and 900 W and discharging mass flow rates set at 2, 3, and 4 L/min.

The results show that, during charging, heater power variation influenced PCM melting time, complete melting occurred in approximately 300 minutes at 300 W and within 130–150 minutes at 600 W, whereas at 900 W melting did not proceed consistently faster, owing to uneven heat distribution, with full melting at certain points only reached by the 220th minute. During discharging, increasing the mass flow rate accelerated the attainment of thermal equilibrium between inlet and outlet water temperatures, occurring at the 75th minute (2 L/min), the 60th minute (3 L/min), and the 30th minute (4 L/min), although the PCM temperature remained consistently higher than that of the water throughout testing, reflecting the limiting effect of the PCM's low thermal conductivity. Overall, the heat exchanger design featuring induction rod configuration and ½” copper HTF piping proved capable of fully meeting the heat requirements for PCM melting, positioning this PATS-PCM system as a promising, efficient, and sustainable thermal energy storage solution for future renewable energy technology development.

Keyword: Thermal Energy Storage, Phase Change Material (PCM), System Design and Experimental Investigation, Variation in Power, Variation in Flow Rate.