INTISARI

PEMFC menjadi populer untuk pembangkitan listrik karena suhu operasi rendah, kompak, dan start-up cepat, namun kelemahan utamanya adalah disipasi panas tinggi, sekitar separuh energi konversi terbuang sebagai panas, yang menantang untuk didaur ulang karena tergolong low-grade (50–100 °C). ORC dipandang sesuai untuk memanfaatkan panas buang ini dan tercatat mampu meningkatkan kinerja sistem pada kisaran suhu operasi PEMFC.

Penelitian memodelkan integrasi PEMFC–ORC keadaan tunak. Aspen Custom Modeler dan Aspen Plus digunakan untuk mensimulasikan model PEMFC dan ORC. Variasi arus PEMFC dan fluida kerja diambil untuk melihat pengaruhnya terhadap kinerja ORC. Beberapa parameter PEMFC dan titik operasi dikontrol secara konstan. Kinerja dievaluasi melalui efisiensi ORC, daya ORC, kebutuhan daya pompa, dan laju massa sirkulasi pada beberapa fluida kerja.

Variasi fluida kerja memengaruhi efisiensi dan keluaran daya. Efisiensi tertinggi dicapai R245FA (5,163%), diikuti R1234ZE (4,963%), R1233ZD (4,94%), dan R1234YF (4,86%). Namun pada daya maksimum yang dicapai pada arus tertinggi diungguli oleh R1234YF (3,68 kW), disusul R245FA (3,66 kW), R1234ZE (3,65 kW), dan R1233ZD (3,49 kW). Perbedaan peringkat efisiensi dan daya dijelaskan oleh kebutuhan daya pompa yang berbeda, dengan R1234ZE dan R1234YF cenderung memerlukan daya pompa tertinggi, sementara R1233ZD dan R245FA relatif rendah. Disisi lain, laju massa kondensasi dan ORC menunjukkan bahwa R1234ZE tertinggi dan R245FA terendah. Temuan ini menunjukkan adanya *trade-off*, di mana pilihan fluida kerja perlu menimbang target efisiensi vs. target daya serta konsekuensi desain, yakni kebutuhan pompa dan sizing laju massa. Selain itu, fluida rendah-GWP juga terbukti masih bisa bersaing terhadap R245FA, dilihat dari selisih performa yang tidak terpaut jauh.

Kata Kunci: *Proton Exchange Membrane Fuel Cell*, *Organic Rankine Cycle*, panas tingkat rendah, Global Warming Potential rendah, pemanfaatan panas buang, analisis termodinamika.

ABSTRACT

Proton Exchange Membrane Fuel Cells (PEMFCs) are popular for power generation due to their low operating temperature, compactness, and fast start-up; however, a major drawback is high heat dissipation, about half of the converted energy is lost as heat, which is difficult to recover because it is low-grade (50–100 °C). The Organic Rankine Cycle (ORC) is well-suited to utilize this waste heat and has been reported to enhance system performance within the PEMFC operating temperaturrange.

This study models a steady-state PEMFC–ORC integration. Aspen Custom Modeler and Aspen Plus were used to simulate the PEMFC and ORC models. PEMFC current and working fluid were varied to assess their effects on ORC performance, while several PEMFC parameters and operating points were held constant. Performance was evaluated in terms of ORC efficiency, ORC power, pump power requirement, and circulating mass flow rate across several working fluids.

Working-fluid selection affects both efficiency and power output. The highest efficiency was achieved by R245FA (5.163%), followed by R1234ZE (4.963%), R1233ZD (4.94%), and R1234YF (4.86%). In contrast, the maximum power at the highest current was delivered by R1234YF ((3.68) kW), followed by R245FA ((3.66) kW), R1234ZE (3.65) kW), and R1233ZD (3.49 kW). Differences arise partly from pump-power demand, with R1234ZE and R1234YF generally requiring higher power and R1233ZD/R245FA the least; condensation and ORC mass flow rates are highest for R1234ZE and lowest for R245FA. These results reveal clear trade-offs, indicating that fluid choice should balance efficiency, power, and design implications (pump sizing and mass-flow requirements). Overall, low-GWP fluids proven to be remain competitive with R245FA.

Keywords : *PEMFC, ORC, low-grade heat, low-GWP working fluids, waste heat recovery, thermodynamic analysis.*