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Editorial

Organic Rankine Cycle: Effective Applications and Technological Advances

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As the energy demand continues to increase across the globe, the utilisation of waste and sustainable energy sources, as well as the implementation of diverse energy systems, are essential. The organic Rankine cycle (ORC) plays an important role—this promising technology has already been successfully implemented in hundreds of applications, mainly for distributed electricity generation. ORC systems are flexible and can be powered by a range of energy sources. Early advances focused on waste heat recovery (WHR) in industrial applications, internal combustion engines and gas turbine exhausts, light- and heavy-duty vehicles, and marine applications; these directions continue to attract scientific and industrial research attention. ORC systems also offer the ability to be paired with biomass and concentrated solar systems, geothermal energy and other such sources. While much is known about ORC systems, their overall performance is generally limited and cost-prohibitive. In order to promote the implementation of ORC systems and propel this valuable technology to the forefront of the energy market, further insight and developments are necessary. In this Special Issue, the featured authors contribute to a better understanding of ORC systems, their performance and components, and provide invaluable recommendations for optimal system design, operational parameters, turbines, expanders, and heat exchanger technologies.

Ochoa, Peñaloza, and Forero [1] performed the thermoeconomic optimisation of a natural gas engine WHR system. They considered simple, regenerative, and double-stage ORC integrated with a GE Jenbacher engine type 6. A novel model was proposed, which allows the integration of economic considerations into exergetic analysis for different system configurations. Their study concludes that double-stage ORC, with 85% and 80% pump and turbine efficiencies, respectively, and evaporator and condenser pinch point temperature differences of 35 and 16 °C, respectively, achieves a maximum net power of 99.52 kW. In addition to reporting natural gas engine data that were not previously available in the literature, this study offers a framework for ORC thermoeconomic analysis.

Koo, Oh, Choi, Jung, and Park [2] investigated cold energy recovery for an LNG-powered ship. The performance of nine working fluids was assessed across various pressure levels. The optimisation of the proposed systems was performed, as well as sensitivity analysis and economic assessment. The study concludes that medium-pressure engines with direct expansion, multi-condensation levels, and a high evaporation temperature exhibit the best performance in terms of exergy efficiency, net power output, and actual annualized cost. This study suggests that a typical LNG supply could be replaced by an ORC system.

Turbines and expanders are a key component of ORC systems. Kolasiński [3] reviewed applications of multi-vane expanders reported in the literature, as well as experimental results and modelling approaches. The design and operating principles of multi-vane expanders applied in small-power and micro-power ORCs are comprehensively discussed. Various characteristics of multi-vane expanders, including expander design, geometry, dimensions, operating conditions, durability, working fluid, power output, and efficiency,

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are analysed. It is concluded that multi-vane expanders remain an attractive technical solution for ORC systems among other expander types.

Hromádka, Sirový, and Martínek [4] took an innovative approach to improve the sustainability and flexibility of cogeneration power plants. Their inspiration comes from cogeneration power plants operating for decades with original technologies, including backpressure turbines, which are still used in a number of cogeneration power plants. The drawback of backpressure turbines is the heat demand for optimal operation; when facing a lack of heat demand, their efficiency rapidly decreases. The authors showed that this problem can be addressed by introducing an ORC system. The paper is based on a case study of a Pilsen cogeneration power plant, where subcritical ORC, with R-600a as the working fluid, achieving an efficiency of 3.755%, can be employed with a return on investment in 3.3 years.

Pan and Wang [5] applied an experimental method consisting of a small low-grade heat ORC system equipped with a radial flow turbine, and R245fa and R123 as the working fluids, varying the operational parameters. When the condensation pressure/temperature was kept constant, the hot water outlet temperature and the mass flow rate increased with increasing evaporation pressure. The rate of heat transfer and the transmission–generation efficiency also increased. However, increasing the evaporation pressure led to a decrease in turbine isentropic efficiency. It was concluded that the optimal evaporation temperature was 69.2 °C when R245fa was employed. When the evaporation pressure/temperature was kept constant, the outlet temperature of the cooling water increased, and the mass flow rate of the cooling water decreased with increasing condensation pressure. Turbine isentropic efficiency increased, yet the transmission–generation efficiency decreased with increasing condensing pressure. In this case, an optimal condensation temperature of 29.1 °C was suggested for R245fa. It was also found that turbine performance is dependent on the type of working fluid used, as well as the type of nozzle. The operational parameters dictate the performance of the whole system.

Bull, Buick, and Radulovic [6] looked into the sizing of heat exchangers for ORC systems utilising R1234yf. Net power output and thermal efficiency were evaluated for a range of pressure levels. A detailed design methodology was developed for plate heat exchanges (PHX) and shall and tube heat exchanger (STHX) types, and the overall heat transfer area was evaluated. Heat transfer rate decreased with increasing cycle pressure: preheater area increased, while evaporator and superheater areas were reduced; both precooler and condenser areas decreased with increasing pressure. The STHX design required a 40% larger heat transfer area on the hot side and a 60% larger area on the cold side compared with PHX. In addition to reporting on the heat exchanger size requirements, this paper offers a comprehensive methodology for sizing different heat transfer components.

Yu, Li, Lu, Huang, and Roskilly [7] proposed an innovative cascade cycle combining a trilateral cycle and an organic Rankine cycle (TLC-ORC) in order to achieve s better temperature match between the working fluid and the heat source. Compared with dual-loop ORC, where net power output tends to decrease with increasing evaporation temperature, in a TLC-ORC system a linear increase was observed. Similar trends were noted for thermal and exergy efficiency. An increase in the net power output with a decrease in evaporating temperature was observed for both dual-loop ORC and TLC-ORC, with the latter achieving significantly greater power outputs and generally higher efficiencies. A dual-loop ORC using cyclohexane as the high-temperature working fluid, at high and low evaporation temperatures of 470 K and 343 K, respectively, achieved a net power output of 8.8 kW and a thermal efficiency of 18.7%. In contrast, TLC-ORC, operating between the same evaluation temperatures but using toluene, yielded a new power of 11.8 kW and 25% thermal efficiency. The exergetic efficiency was more than 31% higher for the TLC-ORC system.

As our scientific knowledge and understanding of ORC systems grow, so will the global utilisation and implementation of this valuable technology, leading to the better use of available heat sources and more reliably distributed electricity and power generation.

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