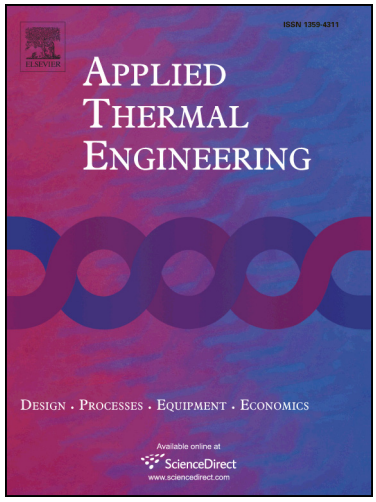

Research Paper

Multi-objective optimization and grey relational analysis on configurations of organic Rankine cycle

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Multi-objective optimization and grey relational analysis on configurations of organic Rankine cycle

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Abstract

Concerning the comprehensive performance of organic Rankine cycle (ORC), comparisons and optimizations on 3 different configurations of ORC (basic, regenerative and extractive ORCs) are investigated in this paper. Medium-temperature geothermal water is used for comparing the influence of configurations, working fluids and operating parameters on different evaluation criteria. Different evaluation and optimization methods are adopted in evaluation of ORCs to obtain the one with the best comprehensive performance, such as exergoeconomic analysis, bi-objective optimization and grey relational analysis. The results reveal that the basic ORC performs the best among these 3 ORCs in terms of comprehensive thermodynamic and economic performances when using R245fa and driven by geothermal water at 150 ° C. Furthermore, R141b shows the best comprehensive performance among 14 working fluids based on the Pareto frontier solutions without considering safe factors. Meanwhile, R141b is the best among all 14 working fluids with the optimal comprehensive performance when regarding all the evaluation criteria as equal by using grey relational analysis.

Keywords: Organic Rankine cycle; Exergoeconomic analysis; Multi-objective optimization; Grey relational analysis; Geothermal resource

1 Introduction

With increasing consumption of fossil fuels, environmental problems and global warming become increasingly serious in recent years. Organic Rankine cycle (ORC), Kalina cycle and trilateral power cycle (TLC) have been proposed and applied extensively for the conversion of low-medium- grade heat into power. Compared with the difficult two phase expansion of TLC and the complex system structure of Kalina cycle, ORC has characteristics of simple structure, high reliability and easy maintenance [1]. ORC abides by the principle of steam Rankine cycle, but uses organic working fluids with low boiling points to recover low-medium- grade heat [2]. Although ORC has gained a moderate development in last several decades, it suffers its lower energy efficiency compared to the steam Rankine cycle, as well as the higher investment cost due to its larger areas of heat exchanger and the immaturity of expanders. Therefore, researchers are motivated to develop advanced configurations and flexible working fluids to improve the thermodynamic and economic performance of ORC.

In terms of the influence of working fluids on ORC, the effects of fluid structures and thermodynamic properties have been investigated by many researchers for the basic ORC (BORC): Chen et. al [3] performed a screening of 35 working fluids, while Bao et. al. [4], Drescher et. al.[5] and Quoilin et. al. [6] analyzed different working fluids for energy recovery applications. However, majority of researches only restricted themselves to the thermodynamic performance, other performances such as economic performance and environmental performance were generally neglected. Another key aspect is the advanced ORC configurations. In fact, the effect of the advanced configurations on ORC has been investigated such as regenerative ORC (RORC), extractive ORC (EORC) and so on. Different configurations such as superheated cycle, regenerative cycle and their combinations were compared with different thermodynamic criteria [2]. Mathematical models for steam Rankine Cycle, ORC and Steam-Organic Rankine Cycle (S-ORC) power systems were developed to explore the feasibility of the hybrid system which combines the fluid-low temperature waste heat steam and low-boiling point organic working fluids [7]. Unfortunately, large numbers of components are involved in advanced configurations compared to BORC, which suggesting the need of increasing investment costs in spite of its better thermodynamic performance. Therefore, it is important to trade off the thermodynamic and economic performance of these advanced configurations of ORCs with different working fluids.

With respect to the analysis and optimization with different evaluation criteria, numerous researchers have devoted their efforts on single