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Optimization of an adapted Kalina cycle to an actual municipal solid waste power plant by using NSGA-II method

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ABSTRACT

In this paper thermodynamic and thermoeconomic analyses and even optimization of a Kalina cycle (KC) which is adapted to an actual solid waste power plant with a 5.66 MW installed capacity are presented as an alternative solution which is utilized to produce additional power from the exhaust gas of the plant. Up to now there is almost no study related with an adapted KC to a typical municipal solid waste power plant, and also no study based on an optimization, thermodynamic and thermoeconomic analyses of such a system together. All these facts show the novelty of this study. Herein the waste heat with a temperature of 566 °C is utilized by the adapted KC. According to the analyses of the first and second law of thermodynamics on the system, it is deduced that the electricity of 954.6 kW can be produced with the exergy efficiency of 24.15%. Furthermore, this power production can be improved by using non-dominated sorting genetic algorithm method (NSGA-II) in MATLAB software program. According to the optimization study, the deviations of the net power output and the total cost rate are found to be +3.62% and −1.47 $/h, respectively for the cycle.

1. Introduction

In recent years, alternative energy production methods are utilized as an important issue for all countries due to increasing amount of energy requirement. Beside to developing alternative energy production methods, innovative attempts are becoming important in order to utilize existing power production plants efficiently [1]. In this context, power cycles with ammonia-water mixtures as working fluid utilizing different kinds of heat sources for power and heat generation can be considered in order to improve the efficiency of solid waste power plants. This ammonia-water mixture cycles named as Kalina cycle were designed by Alexander Kalina using a bottoming cycle instead of the Rankine cycle in combined cycle power plants in 1989 [2]. Since then the cycle was designed, many studies have been conducted on the use and development of the Kalina cycle. Zhang et al. [3] conducted a review study on the Kalina cycle in order to show advantageous of the cycle as a bottoming cycle for a combined-cycle energy system as well as for generating electricity using low-temperature heat resources. Different Kalina systems and their different applications in the open literature were considered regarding to the heat sources and working fluid properties. It was concluded that the Kalina cycle had a better thermodynamic performance than the Rankine cycle and organic Rankine cycle with respect to both energy and exergy efficiency. Cao et al. [4] performed a thermodynamic analysis of a Kalina cycle driven by low-grade heat source and conducted to parametric analysis selecting five key parameters which were expander inlet pressure, expander inlet temperature, concentration of ammonia-water basic solution, terminal temperature difference of high temperature recuperator (HTR) and terminal temperature difference of low temperature recuperator (LTR). In addition to the parametric analysis, an optimization was also carried out by means of Genetic Algorithm method in order to define optimum exergy efficiency of the system. It was found that, an optimum expander inlet pressure could be achieved to maximize exergy efficiency. It was also concluded that the heat recovery steam generator caused the most exergy destruction in the cycle. Fallah et al. [5] carried out conventional and advanced exergy analyses of a Kalina cycle using a geothermal heat source. It was found that the highest exergy destruction was occurred in the condenser, followed by the evaporator, the turbine, the LTR and the HTR with respect to conventional analysis. On the contrary to this, the

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