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PERFORMANCE ASSESSMENT OF HIGH-TEMPERATURE KALINA CYCLE FOR WASTE HEAT RECOVERY FROM A DIESEL ENGINE

Mortaza Yari*, Faramarz Ranjbar, Seyed Mohammad Seyed Mahmoudi, Farzad Mohammadkhani
Faculty of Mechanical Engineering, University of Tabriz, Tabriz, Iran

ABSTRACT
Using the ammonia-water mixture as a working fluid for the power cycles has the potential to increase the efficiency as the heat transfer process, in this case, occurs at constant pressure but at variable temperatures. In the present work, a high-temperature Kalina cycle is proposed to produce power from the exhaust and coolant heat of a Diesel engine, in which, the working fluid of the cycle is preheated by the engine coolant and then the fluid enters evaporator and absorbs the exhaust gas energy. Energy and exergy relations are developed for the system components, and exergy efficiency, as well as exergy destruction rates, are determined. A parametric study is also performed to show the effects of ammonia concentration in the fluid on the system performance. The results show that the proposed cycle generates a power equivalent to 22.19% of the engine power. It is revealed from the exergy analysis that the evaporator has the highest exergy destruction rate among the components. Also, the parametric study shows that increasing the ammonia concentration at the turbine inlet from 0.5 to 0.8 increases the energy and exergy efficiencies.

Keywords: *waste heat recovery, Diesel engine, Kalina cycle, exergy analysis, parametric study*

INTRODUCTION
Recently, depletion of fossil fuels and environmental pollution has increased the interest in efficient energy conversion methods. One of the most reliable ways to achieve this purpose is maximum use of fuel energy through waste heat recovery from energy systems. The Internal Combustion Engines (ICEs) are the primary power sources for automobiles, trucks, ships, locomotives, and also, they can be used for stationary power production applications. Over the past century, periods of high fuel costs and concerns about foreign oil dependence have caused to complex engine designs to decrease fuel consumption. However, only about 40% of the total fuel energy is converted to the useful power in an ICE and the remaining energy is wasted mainly through exhaust gas and coolant of the engine [1]. The temperature of the exhaust gas is usually above 673 K, while the cooling water enters the engine at a temperature between 343 K and 358 K, leaving it at a temperature between 363 K and 368 K. Thus, the exhaust gas and the cooling water can provide valuable sources for the waste heat recovery, and consequently, for improving the energy efficiency and reducing the fuel consumption and the engine emissions [2].

As an alternate for the Rankine cycle, the Kalina cycle was introduced in 1984 [3]. This cycle can be used as a bottoming cycle in waste heat recovery applications. The working fluid of the cycle is the ammonia-water mixture. As a zeotropic mixture, the phase change of the working fluid occurs at a constant pressure but at variable temperatures. This improves the temperature distribution in the heat exchangers and causes to a reduction in the component exergy destruction. The composition of the mixture is determined by the ammonia concentration which is defined as the ammonia ratio in the mixture in mass base [4].

The Kalina cycle has been the attention of many researchers in recent years. Junior et al. [5] evaluated the performance of the Kalina cycle to waste heat recovery from the exhaust of a cement factory with a daily production of 2.1 thousand tons clinker. Also, a parametric study is performed to show the effects of the ammonia concentration on the system performance. Results of the study showed that the Kalina cycle can produce about 2429 kW power from the waste heat recovery process. The thermal and exergy efficiencies for the process are determined to be 23.3% and 47.8%, respectively. Wang et al. [6] compared the performance of the Kalina and Organic Rankine Cycle (ORC) to produce power from multi-stream waste heat recovery. They divided the multi-stream waste heat into the three kinds, straight, convex and concave waste heat. They reported