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A Short Review on Kalina Cycle

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Abstract

This paper provides an overview of various studies on the Kalina cycle and their applications. The century-old Rankine cycle is the foundation for modern power facilities. However, a modified Rankine cycle known as the Kalina cycle has proven to be more efficient than the conventional Rankine cycle and may be able to provide the additional power required for medium- and low-temperature sources and residual heat recovery. Comparing the effectiveness of the Kalina cycle and the Rankine cycle in converting electrical energy from low-temperature sources, Kalina cycle seems more suitable for low temperature power generation.

Keywords: *Kalina cycle, Low temperature, Heat recovery.*

1. INTRODUCTION

The Kalina cycle was created by Alexander Kalina in the late 1970s and early 1980s as an innovative cycle. The goal of this cycle is to extract usable work out of a low-temperature heat source. As a result, because the fluid leaving the turbine in other power cycles is at low temperatures, we may utilize the heat from the fluid leaving the turbine to generate usable work. The operating fluid of the Kalina cycle, unlike other power cycles, is a combination of two fluids with different boiling points. In the majority of cases, a solution of water and ammonia is used in the application. To make the vapor, a solution of water and ammonia is heated in a boiler. Because ammonia's boiling point is -33.3°C, which is lower than water's boiling point, there will be a higher concentration of ammonia in the vapor. The temperature and pressure of this rich combination drop as it expands into the turbine. The major issue now is that, because the concentration of ammonia is higher (almost 70%), the condensation temperature is lower (as seen in the graph of Ammonia mass fraction vs Temperature), so we must employ the separator. A separator is a device that separates a mixture into lean and rich mixtures, lowering its concentration. This device lowers the concentration of the mixture coming out of the condenser and feeds it to the condenser intake, where it is combined with the mixture flowing out of the turbine, lowering its concentration. With the help of the pump, the residual mixture is delivered to the boiler.

2. EARLIER STUDIES

Zhu et. al [1] The performance of S-CO_2 Brayton combined cycles, as well as the ORC (Organic Rankine Cycle) with the Kalina cycle (KC) as a bottom cycle, is shown here. Here the ratio of the combined cycle's efficiency to the maximum volume flow rate was used to assess the cycle's performance. An evaluation of several concentrations of ammonia in water is done in this research, and it is found that at 0.85 ammonia-water concentration, thermal efficiency improves by 1.79 %.Nabat et. al [2] In this paper they coupled the Cryogenic Energy Storage (CES) system with the Kalina cycle and seebeck generator in this work to improve the efficiency of the CES system, which is currently inefficient. According to the thermodynamic study, the integrated system improved performance by 61.6 % and increased overall energy storage density to 109.4 MJ/m^3.

Wu et. al [3] In this study, they presented a model of a novel Kalina cycle and organic Rankine integrated with each other, such that a dual-pressure Kalina cycle (DPKC) as the topping cycle and a dual-pressure organic Rankine cycle (DPORC) as the bottoming cycle, with escalation done by studying thermodynamics at the microscopic scale and constructal theory. They discovered the appropriate tube exterior diameters of the evaporators in the DPKC and DPORC to enhance the net rate of change of energy production of the Kalina-organic Rankine combined cycle system. When compared to the initial one, they gradually boosted net power output by 2.62 %, 5.41 %, 15.05 %, and 16.17 %, respectively.Zhang and Li [4] To get expansion work, he replaced the expansion valve with an expander. 1) In Kalina Cycle Systems 11, 34, and 34 g, he replaced the throttle valve placed in between the absorber and recuperator with a single-screwed throttle valve. 2) Removing the original throttle valve and replacing it with a single screw expander which is located between the recuperator and the separator. He compared both cycles to their respective original cycles and discovered that both cycles outperform the original cycle.

Parvathy and Varghse [5] changed the Kalina cycle in this study by incorporating two turbines in stages with a reheater in between. They modelled and examined the thermodynamics for various intermediate pressures and their effects on various parameters such as the temperature of the separator, a steam fraction at the small-pressure turbine's outlet, total work production, total heat given, and efficiency of the cycle. According to the simulation results, the updated cycle's efficiency has increased by 4.04 %.Cheng et. al [6] In their study, they did a dynamic analysis of the KC. This was done to ensure that the operation was safe due to variations in input heat energy and the working load. With the angular speed of the turbine as the controlled variable, the pump speed regulation strategy and combination of pump speed regulation and valve opening regulation strategy are introduced and compared to the valve opening regulation strategy. The short length time and overshoot are both reduced by 56.3 and 67.9%, respectively.

Akimoto et. al [7] lowered the heat source's temperature requirements and suggested a combined system that comprises a gas-fired heat pump cycle and a KC to generate power from little temperature difference in this paper. They transferred energy from the absorption cycle's absorber to the Kalina cycle's evaporator in this integrated cycle. They enhanced the power generation performance by 81% as a result.Fan and Dai [8] Two common S-CO_2 Brayton cycles, the SSC (simple S-CO_2 cycle) and the RSC (recompression supercritical CO_2 cycle) are combined with KC called RSC-KC (recompression supercritical CO_2Kalina cycle) in this paper to improve nuclear power plant efficiency. Nuclear power plants use the supercritical CO_2 cycle. They introduced a valve opening regulation strategy and compressor speed regulation strategy for the topping S-CO_2 cycle, while the sliding pressure control strategy was used for the bottoming KC, with the goal of increasing exergic efficiency and lowering the Levelized cost of electricity (LCOE). After analyzing the data, they discovered that the RSC-KC outperforms the SSC Kalina cycle by 6.37 % and 7.53 %, respectively, in terms of excergic improvement.

Kalan et. al [9] They looked into the system which is a modified KC integrated with a double-effect absorption refrigeration cycle powered by an internal combustion engine's exhaust gas. Exergy efficiency is enhanced by 2.22 %, and the overall cost is lowered by 8.16 %, according to exergy and economic analysis.Zhuang et. al [10] The escalation of unwanted heat recovery is the subject of this research. They devised the double Kalina cycle for this purpose. The suggested cycle uses a combination of the pinch-based extended D-G model and the expanded transshipment model to find the best arrangement for optimizing power output and heat source outlet temperature. Power production is improved by 12.55 % and 34.89 %, respectively, while exergy efficiency is improved by 11.6 % and 8.49 % when compared to the cascade KC and basic KC.Panchal and Shah [11] used low and medium enthalpy brine solutions to transmit heat to the working fluid in this article. They found from the experiment that when the percentage content of ammonia increases, overall efficiency and effectiveness rise, and the heat transfer coefficient can reach 900 W/m^2K.Pirmohamadi et. al [12] To increase the overall system performance, they have incorporated the Nitrogen Brayton Cycle operated by the sodium reactor system (SRS) as a topping system and the KC and vapour compression cycles as bottoming cycles in this work. Thermal and exergetic efficiency was found to be 34 % and 62 %, respectively, after exergoeconomic research. Steam generators were shown to have the highest exergy destruction when viewed from an exergy standpoint. They used parametric analysis to learn more about it.

Akimoto et. al [13] They devised the micro Kalina cycle of 10 KW power generation in this work, which uses heat energy sources which is nothing but hot water in the spring season at a temperature of 373K and has the Lorenz cycle characteristics. After further investigation, it was shown that the micro Kalina cycle can produce 9.4-11.0 kW of power at present warm water conditions in the spring (373K, 4000 kg/h). The micro Kalina cycle was shown to be 50% more efficient than the R245fa-based micro-organic Rankine cycle.

Hossain et al. [14] They suggest two modified cycles based on KCS-34 in this study. They placed a two or more-phase expansion device between the Kalina steam divider and the second heat regeneration device in the first modified cycle, and between the mixer and the second generator in the second modified cycle. They investigated the effects of changing the cycle's crucial decision factors on the cycle's performance. For the first adjusted cycle, there is a 6.35 % increase in efficiency by decreasing the pressure of the fluid at the inlet of a turbine to 58 bar and the concentration of ammonia to 80%.Dehghani [15] To tackle the low-efficiency challenge, he suggested a systematic strategy for optimizing the three unique Kalina-trilateral-based systems. This precise method combines thermodynamics and deep learning to speed up the calculation process. He devised a strategy that combines thermodynamics and deep learning to speed up the calculation process by using substitutive models of the systems which are evolved using an LSTM network. In addition, the multi-objective optimization issue is solved using the strength Pareto evolutionary algorithm (SPEA-II). From the thermodynamic point of view and economic point of view, objective functions were enhanced by 74.3 %and 34 %, respectively, as compared to the base cycle.

A thorough literature analysis revealed knowledge gaps. First, the ammonia-water combination limits researchers to the Kalina cycle for low-grade WHR. This bottoming cycle for medium- and high-grade temperature sources remains unworkable. Second, prior research showed the Kalina cycle had low thermal efficiency. Researchers favour the ORC because of this weakness. Third, the solo or integrated TLC system is seldom evaluated. Analysing this alternate cycle will show its thermal, environmental, and economic benefits.

3. CONCLUSION

The following conclusions are drawn after a detailed review on Kalina Cycle:

- The Kalina cycle, which functions as a bottoming cycle, boosts the overall performance of the cycle.
- The performance of the Kalina cycle is superior than that of the organic Rankine cycle.
- The Kalina cycle may be improved by adding a few adjustments, such as exchanging the throttling device with an expander while maintaining the ideal value for each parameter (temperature, pressure).
- Studying supercritical and high-temperature ammonia-water combination characteristics may help explain the Kalina cycle. This new technology favours hybrid and combination cycles.

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Declaration of Competing Interest

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