Archna Yadav, 2021, 9:3
ISSN (Online): 2348-4098
ISSN (Print): 2395-4752

A Implementation of Exergy Analysis for Industrial Applications Using Organic Rankine Cycle (ORC)

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Abstract- Solar energy is utilized in a combined ejector refrigeration system with an organic Rankine cycle (ORC) to produce a cooling effect and generate electrical power. This study aims at increasing the utilized share of the collected solar thermal energy by inserting an ORC into the system. As the ejector refrigeration cycle reaches its maximum coefficient of performance (COP), the ORC starts working and generating electrical power. This electricity is used to run the circulating pumps and the control system, which makes the system autonomous. For the ejector refrigeration system, R134a refrigerant is selected as the working fluid for its performance characteristics and environmentally friendly nature. The COP of 0.53 was obtained for the ejector refrigeration cycle. The combined cycle of the solar ejector refrigeration and ORC is modeled in EBSILON Professional. Different parameters like generator temperature and pressure, condenser temperature and pressure, and entrainment ratio are studied, and the effect of these parameters on the cycle COP is investigated. Exergy, economic, and exergoeconomic analyses of the hybrid system are carried out to identify the thermodynamic and cost inefficiencies present in various components of the system.

Keywords: - ORC,Cycle, Energy etc

I. INTRODUCTION

The conventional vapour-compression refrigeration system (VCRS), which uses working fluids that are harmful to the environment, is dominating in the refrigeration sector all over the world. The solar ejector refrigeration system (SERS), which uses solar energy as the driving energy, is the alternative for VCRS. Thus, it helps to decrease the indirect environmental impact though reducing the CO_2 emissions coming from electricity generation.

The maintenance cost required of the ejector refrigeration system (ERS) is meagre. Solar energy is the most abundant, vast, and inexhaustible source of energy for a clean environment. Researchers have started investigating the replacement of high-priced fossil fuels with alternative renewable energy sources such as wind, solar, and geothermal. As the supply of solar energy is highly compatible with the demand, the use and implementation of solar energy in air conditioning and refrigeration applications have gained more attention over the last decades.

The conventional solar cooling and refrigeration cycles include sorption machines such as adsorption and absorption machines, or desiccant wheels. Furthermore, SERS is competitive with the mentioned technologies as they have lower cost, no moving parts, simple system design, and can be driven by low-grade thermal sources.

The solar energy can be used to drive an organic Rankine cycle (ORC) to generate electrical power Combined cycles and systems were proposed by several researchers to maximize the utilization of wasted heat and renewable energy and reduce fossil fuel consumption to alleviate environmental problems.

II. METHODOLOGY

First, we construct thermodynamic state-point equations and then develop a polynomial for thermodynamics with the aid of software or, obtained straight from the reference. Engineering equation solver (EES) was utilized to construct an ORC cycle mathematical model.

The physical model, mass and energy balance, suppositions, equations of state points and thermodynamic characteristics were utilized. The selection of the working fluid has a major effect on the system performance in ESS software, on the ORC system and on the operating circumstances.

The thermodynamic models of organic working fluids were created and computed using EES software under various refrigerants. The thermal efficiency, capacity generation, etc. of the ORC system will be calculated and compared with R600a, R290, R134a.

1. Engineering Equation Solver (EES) software:

EES (pronounced "ease") is a General-purpose equation solving software capable of numerically solving hundreds of related non-linear algebraic and differential equations.

Furthermore, the software can solve differential and integral equations, optimize them, evaluate uncertainties, do linear and nonlinear regression, convert units, verify unit consistency, and generate graphs for publication quality. The equation database for thermodynamic and transporter properties, which is high-precision and can be used for hundreds of compounds with equation solving capacity, is a key component of EES.

2. Simulation Results of the SRC Power Generation System:

SRC's working fluid is water. The outlet temperature of the turbine should be set to 45°C, and the outlet pressure is the corresponding saturation pressure, as well as the working fluid condensing temperature, which is 37°C. The turbine's enthalpy-enthalpy efficiency ratio is 0.8, while the pump's enthalpy-enthalpy efficiency ratio is 0.7.

Table 1. The simulation results of the SRC power system.

Parametric Table

Table 1

1..10	1 $T_{H,in}$ [C]	2 $\eta_{overall}$	3 $\eta_{th,rankine}$	4 P_{actual}
Run 1	80	7.564	11.28	197.7
Run 2	110	9.685	14.44	253.2
Run 3	140	11.42	17.02	298.6
Run 4	170	12.89	19.21	337.1
Run 5	200	14.19	21.13	370.8
Run 6	230	15.37	22.89	401.7
Run 7	260	16.5	24.57	431.3
Run 8	290	17.64	26.27	461.2
Run 9	320	18.88	28.12	493.6
Run 10	350	20.41	30.4	533.6

The findings of the SRC power producing system are presented in the simulation model provided in Table 1. The SRC system's operating fluid is water. Overall efficiency, thermal efficiency, and power output all improve as the heat source temperature rises. It has also been noted that as the heat source temperature rises, so does the vaporizing temperature.

As a result, the temperature disparity between the evaporator increases, resulting in irreparable loss. Furthermore, the exergy efficiency falls.

3. Working Principle and Mathematical Models of SRC and ORC.

A heat source system (heat steam waste at low mid-temperature), a rankine cycle system, and a refrigerant system comprise the power generation system (cooling water). The ORC system, on the other hand, employs organic work fluid with a low boiling point rather than water and high pressure vapour. The ORC system operates on the same premise as the standard SRC system, but not in the same way. The schematics of two cycles are shown in Figs. 2

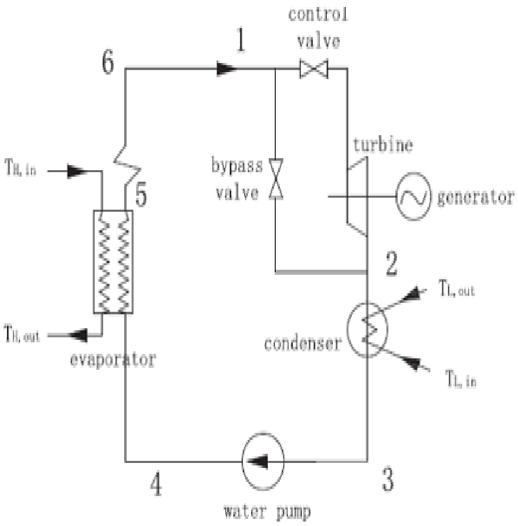

Fig 1. Schematic of SRC cycle.

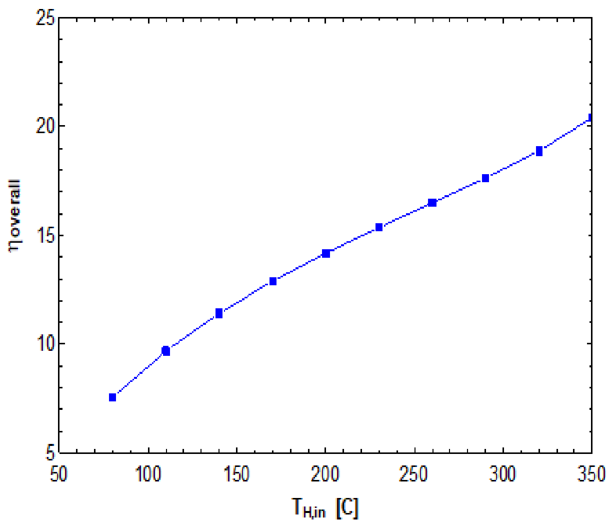

Fig 2. Variation of overall efficiency with heat source temperature.

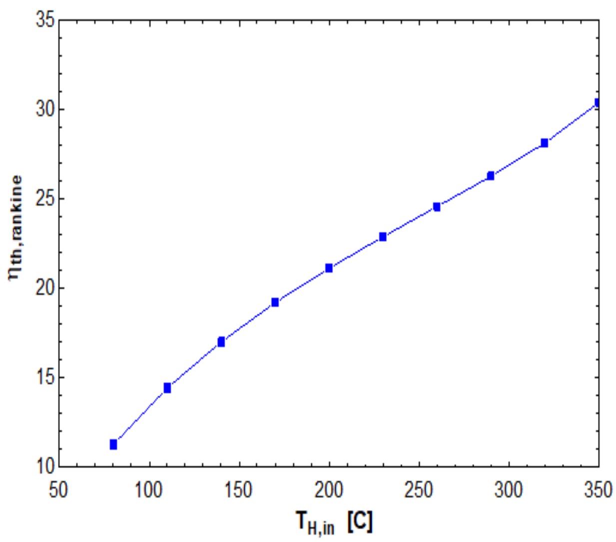

Fig 3. Variation of Rankine efficiency with heat source temperature.

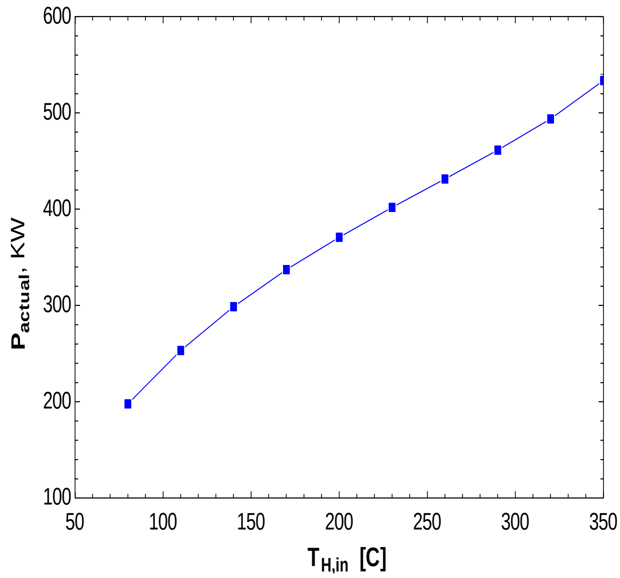

Fig 4. Variation of power output with heat source temperature.

The simulation result for the SRC power generating system Turbine efficiency was adjusted from 70 to 88 percent in order to get simulated results. Following that, the overall efficiency, rankine efficiency, and power generating capacity are assessed.

Table 2. The simulation results of the SRC power system with varying turbine efficiency.

Parametric Table

Table 1 | Table 2 | Table 3

1..10	η_t	$\eta_{overall}$	$\eta_{th,rankine}$	P_{actual}	$W_{P,act}$ [KJ/Kg]	$W_{T,act}$ [KJ/Kg]
Run 1	0.7	10.3	15.35	268.3	0.2826	401.6
Run 2	0.72	10.9	15.79	284.9	0.2826	413.1
Run 3	0.74	11.51	16.23	301	0.2826	424.5
Run 4	0.76	12.15	16.67	317.5	0.2826	436
Run 5	0.78	12.79	17.11	334.5	0.2826	447.5
Run 6	0.8	13.46	17.55	351.9	0.2826	459
Run 7	0.82	14.14	17.98	369.7	0.2826	470.4
Run 8	0.84	14.84	18.42	388	0.2826	481.9
Run 9	0.86	15.56	18.86	406.7	0.2826	493.4
Run 10	0.88	16.29	19.3	425.9	0.2826	504.9

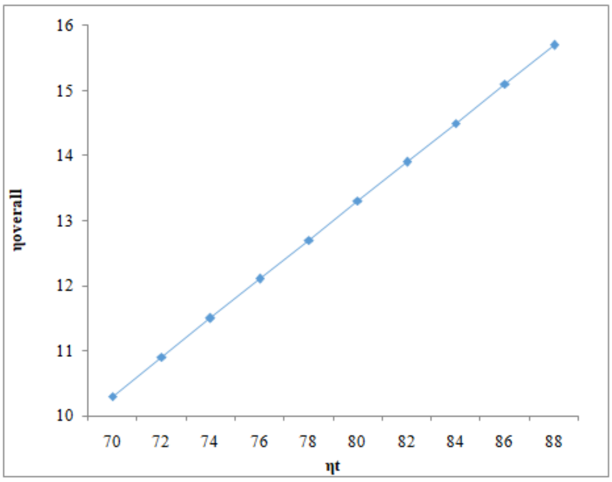

Fig 5. Variation of overall efficiency with turbine efficiency.

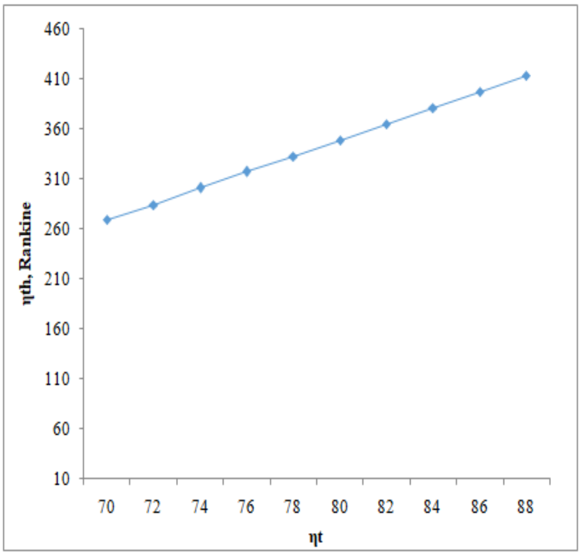

Fig 6. Variation of Rankine efficiency with turbine efficiency.

III. RESULTS VALIDATION

ORC cycle has been compared to the results published by Zhang et al (2016).

Table 3.

Working fluid	Qin (kW)	Wt (kW)	Wp (kW)	Ht
R141b Zhang et al. (2016)	7404.14	1235	65	15.81
R141b (Present study)	7398.22	1202	62	15.46

From the above table results are validated and they are satisfactory.

IV. CONCLUSION

Thermodynamically, the SRC and ORCs were studied using different working fluids with the EES programme. In terms of net power production, overall efficiency, and Rankine efficiency, the impact of the working fluid on the ORC performance has been described.

It demonstrates that when heat source temperature increases, overall efficiency, rankine efficiency, turbine work, and power output rise in the case of an SRC system. R290 has higher overall efficiency and thermal efficiency in the 70-88 percent range of turbine efficiency, but R600a and R134a are comparable. R290 is recommended for increased overall efficiency or Rankine efficiency if the ORC will be operated with higher turbine efficiency.

We know from power generation simulation and computation that the system's power generation increases as turbine efficiency increases. As shown in figure 4.2.23, R290 has a higher power generation capacity across the turbine efficiency range of 70% to 80%, but R134a and R600a have almost the same capacity. R290 is recommended if the ORC will be used to increase turbine efficiency. R290 has a lower discharge temperature, which helps to extend the compressor's life.

The primary source of irreversibility is refrigerant viscosity, which affects the condensation and boiling heat transfer coefficients. R290 has a lower viscosity and higher thermal conductivity, both of which improve condenser and evaporator performance. Because R290 has a greater specific heat, it has a lower discharge temperature. Higher thermal efficiency is due to the fact that a higher latent heat of evaporation implies a lower refrigerant mass need. The lower liquid density of R290 reflects the lower refrigerant mass required, resulting in less friction and enhanced heat transfer coefficients in the evaporator and condenser.

V. FUTURE SCOPE

The current study evaluates the performance of an organic Rankine cycle (ORC) system in terms of energy and exergy analyses. Furthermore, in view of escalating fossil fuel depletion and an urgent need to conserve the environment in response to increased energy demand; this job may be done utilizing a combined Rankine-ORC (RORC) and vapour compression refrigeration cycle (VCRC). As a result of the availability of renewable energy sources or waste heat, access to newly developed technology for creating mechanical work (or electrical power) and cooling has become possible.

The combined Rankine cycle (ORC) and vapour compression refrigeration cycle are extremely efficient and effective methods of using renewable or waste heat (VCRC). For a better understanding, an alternate design configuration of the combined ORC-VCRC must be explored further.

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