Sourabh Singh Patel, 2023, 11:4
ISSN (Online): 2348-4098
ISSN (Print): 2395-4752

Energy Analysis Of Triple Effect Lithium Bromide Absorption Refrigeration System

M.Tech. Scholar Sourabh Singh Patel, Prof. Nitin Tenguria
Department of Mechanical Engineering
SIRT, Bhopal ,MP,India

Abstract- The decreasing supply of fossil fuels like natural gas, coal, and oil and the growing negative effect of these fuels make renewable energy sources more and more essential. Therefore, absorption refrigeration systems (ARSs) have been increasingly preferred over vapor compression refrigeration systems in recent years. Here are some of ARS primary benefits: They may make use of several renewable energy sources (such geothermal or solar) and, depending on the working fluid pairs employed in the system, do not deplete the ozone layer.therefore, in this paper, a thermal analysis on energy analysis of triple effect lithium bromide absorption refrigeration system has been done.

Keywords- Energy, thermal performance, triple effect, absorption refrigeration system

I. INTRODUCTION

Thermodynamic analyses of ARSs and the performance parameters of the cycle have been the subject of several academic investigations. In their extensive literature review on ARS, Karamangil et al. (2010) looked at how different factors, such as operating temperatures (for the generator, evaporator, condenser, and absorber) and working fluid (LiBr-H2O, NH3-H2O, NH3-LiNO2), affected the system's performance indicators (COP and circulation ratio, CR). The study found that compared to RHE and SRHE, SHE has the greatest impact on COP, with a 66% rise in system COP.

Exhaust heat powers a new air-cooled non-adiabatic ejection-absorption refrigeration cycle developed by Li et al. (2017). The thermodynamic analysis of an ARS powered by Diesel engine byproduct heat was conducted by Ouadha and El-Gotni (2013). By altering the temperatures of the cycle's generator, condenser, absorber, and evaporator, a comprehensive thermodynamic analysis of the cycle was carried out over a range of operating situations. They found that the system performed better with greater temperatures in the generator and evaporator and lower temperatures in the condenser and absorber.

thermal exchangers are utilized to recover thermal energy in the ARS, hence Kaynakli and Yamankaradeniz (2003) looked at how this component of the system affected the COP. Based on the results of this research, it has been determined that the solution heat exchanger (SHE) is the optimal heat exchanger for the system. The study of Abed et al. (2015) centered on improving the efficiency with which the ejector-flash tank-ARS utilised NH3-H2O for heat recovery. Incorporating RHE into the planned cycle resulted in a 4.85% increase in refrigeration capacity.

Sencan (2007) evaluated the efficiency of NH3-H2O ARS using a neural network model. To reduce the temperature of the intake air in an internal combustion engine utilizing the engine's exhaust gas as a heat source, Novella et al. (2017) did a thermodynamic study of an absorption refrigeration cycle. In general, this research studied the system's effects on the COP and looked at the many aspects impacting the ARS's first law efficiency.

Bademlioglu et al. (2018) used Taguchi and ANOVA to investigate the effect of parameter weights on ORC's first-law efficiency. Evaporator temperature, condenser temperature, and turbine isentropic efficiency were shown to have the greatest impact on the ORC's thermal efficiency, with a combined effect ratio of 70% being computed for the study's parameters. Taguchi analysis was used by Coskun et al. (2012) to find the important parameters and optimal operating conditions for a waste heat recovery application. Arslanoglu and Yigit (2017) used the Taguchi technique to rank the significance of several characteristics on the optimal insulating thickness. Furthermore, ANOVA was used to calculate the influence ratio of each parameter.

However, comprehensive research that takes a statistical approach to assessing all these characteristics and estimating their contribution ratios on the system's performance has yet to be found in the literature. This study aims to identify which parameters have the most impact on the ARS's COP values and rank them according to their significance using Taguchi techniques. Furthermore, several statistical analysis techniques are utilized to ascertain the best and worst working circumstances and then compare the outcomes.

II. VAPORAB SORPTION REFRIGERATION SYSTEM

A Vapor Absorption Refrigeration System (VARS) is a type of refrigeration system that cools or refrigerates a space or substance by absorbing and desorbing a refrigerant within an absorbent medium, rather than using a mechanical compressor as in traditional Vapor Compression Refrigeration Systems (VCRS). In a Vapor Absorption Refrigeration System, heat is used as the primary energy source to drive the refrigeration cycle. These systems are known for their energy efficiency and are particularly well-suited for certain applications and environments [9].

III. TRPPLE EFFECT VAPOUR ABSORBTION SYSTEM

A Triple Effect Vapor Absorption System is a highly efficient variation of an absorption cooling system used for air conditioning, refrigeration, and other cooling applications. It utilizes the principle of multiple absorption cycles to achieve greater energy efficiency compared to single or double-effect systems. In a triple effect system, there are three distinct absorption cycles or stages, each with its own generator, absorber, and condenser. Here's a detailed description of the working principle of a Triple Effect Vapor Absorption System, along with a simplified figure First Effect (High-Temperature Stage):

- In the first effect, a high-temperature heat source (usually steam or hot water) is used to heat a solution of a strong absorbent (typically lithium bromide - LiBr) in the generator. The high temperature causes the refrigerant (usually water) to evaporate from a concentrated solution of the absorbent.
- The vaporized refrigerant, now in its gaseous state, is drawn off from the first generator and directed to the first condenser, where it is condensed into a liquid using a cooling medium, often water
- The condensed refrigerant is then collected and sent to the first evaporator, where it evaporates, absorbing heat from the surroundings and creating a cooling effect.

Second Effect (Intermediate-Temperature Stage):

- The partially spent absorbent from the first effect (i.e., the absorbent with a lower concentration of refrigerant) is transferred to the second generator, where it is further heated, but at a lower temperature compared to the first generator.
- This lower temperature causes the remaining refrigerant to evaporate from the absorbent solution in the second generator.
- The vaporized refrigerant from the second generator is then condensed in the second condenser, releasing heat.
- The liquid refrigerant is collected and directed to the second evaporator, where it evaporates, absorbing more heat from the surroundings and producing additional cooling.

Third Effect (Low-Temperature Stage):

- The absorbent solution, now with a very low concentration of refrigerant, is transferred to the third generator, which operates at an even lower temperature.
- In the third generator, the remaining refrigerant is evaporated from the solution.
- The vaporized refrigerant from the third generator is condensed in the third condenser, releasing more heat.
- The liquid refrigerant is collected and sent to the third evaporator, where it evaporates, absorbing additional heat and providing the final cooling effect.

Overall Operation:

- In a Triple Effect Vapor Absorption System, each effect operates at successively lower temperatures. As a result, the system utilizes heat more efficiently, making it highly energy-efficient and suitable for applications where waste heat or low-grade heat sources are available.

- The heat source for each effect can be provided by various means, such as steam, hot water, or even solar energy, depending on the application and availability of heat sources.
- The three cooling effects from the evaporators can be used for different purposes or distributed to

$$\dot m_3 + \dot m_{13} - \dot m_4 - \dot m_8 - \dot m_{14} = 0$$

$$\dot m_3 h_3 + \dot m_{13} h_{13} - \dot m_4 h_4 - \dot m_8 h_8 - \dot m_{14} h_{14} = 0$$

$$\dot m_3 \dot\psi_3 + \dot m_{13} \dot\psi_{13} - \dot m_4 \dot\psi_4 - \dot m_8 \dot\psi_8 - \dot m_{14} \dot\psi_{14} - I_{gen} = 0$$

various cooling loads, enhancing the system's versatility and efficiency.

$$\dot m_{4e} + \dot m_{4f} + \dot m_{15} - \dot m_5 - \dot m_{16} = 0$$

$$\dot m_{4e} h_{4e} + \dot m_{4f} h_{4f} + \dot m_{15} h_{15} - \dot m_5 h_5 - \dot m_{16} h_{16} = 0$$

$$\dot m_{4e} \dot\psi_{4e} + \dot m_{4f} \dot\psi_{4f} + \dot m_{15} \dot\psi_{15} - \dot m_5 \dot\psi_5 - \dot m_{16} \dot\psi_{16} - I_{con} = 0$$

$$\dot m_7 + \dot m_{10} + \dot m_{11} - \dot m_1 - \dot m_{12} = 0$$

$$\dot m_7 h_7 + \dot m_{10} h_{10} + \dot m_{11} h_{11} - \dot m_1 h_1 - \dot m_{12} h_{12} = 0$$

$$\dot m_1 - \dot m_2 = 0$$

$$\dot m_7 \dot\psi_7 \quad {}_{12}\dot\psi_{12} - I_{abs} = 0$$

$$\dot m_1 h_1 - \dot m_2 h_2 + W_{pump} = 0$$

$$\dot m_1 \dot\psi_1 - \dot m_2 \dot\psi_2 - I_{pump} = 0$$

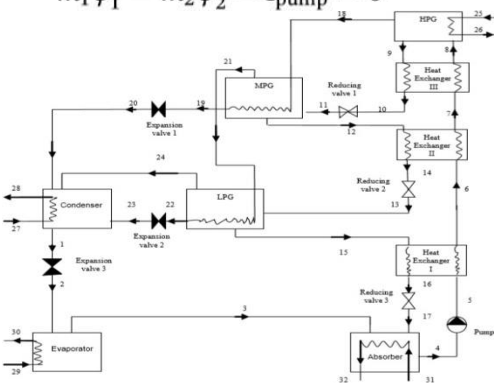

Fig1: Working principle of triple effect absorption figuration system

IV. RESEARCH METHODOLOGY

Mass conservation

This involves the examination of mass balance, considering the total mass and the individual materials within the solution. In the case of a steady-state flow system, the governing equations for the conservation of mass and the conservation of specific materials are as follows:

$\sum m_i - \sum m_o = 0$

$\sum m_i X_i - \sum m_o X_o = 0$

where, mis the mass flow rate and Xisthemassfraction of Li Bring the solution.

First law analysis

The expression for the first law of thermodynamics for each component of the absorption system is as follows:

$\sum Q - \sum \dot W = \sum m_0 h_0 - \sum m_i h_i$

Pump:

wp = m1v1(P2 -P1)/1000

Using eq. (1)and(2),the mass balance of each component to fabs options Systemare developed as follows:

Main Generator:
Condenser:
Evaporator:
Absorber:
Pump:

The overall efficiency of the absorption system is assessed by calculating its Coefficient of Performance

$$\dot m_6 + \dot m_{17} - \dot m_7 - \dot m_{18} = 0$$

$$\dot m_6 h_6 + \dot m_{17} h_{17} - \dot m_7 h_7 - \dot m_{18} h_{18} = 0$$

$$\dot m_6 \dot\psi_6 + \dot m_{17} \dot\psi_{17} - \dot m_7 \dot\psi_7 - \dot m_{18} \dot\psi_{18} - I_{evp} = 0$$

(COP):

$$COP = \frac{Qe}{Q_{HTG} + W_p}$$

V. RESULT AND DISCUSSION

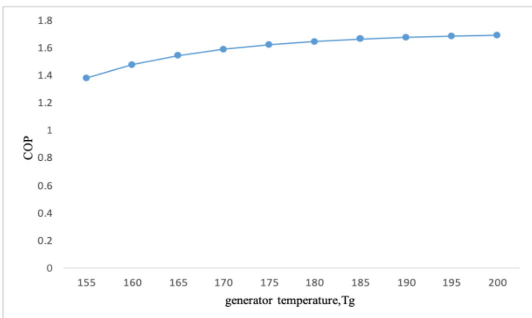

Fig.2 Effect of generator exit temperature on COP

The generator exit temperature plays a significant role in determining the Coefficient of Performance (COP) in absorption refrigeration systems. The COP is a measure of the cooling or refrigeration efficiency of the system, indicating how much cooling you can achieve for a given amount of input energy. Specifically, in the context of absorption refrigeration systems, the generator exit temperature impacts COP in the following ways:When the generator exit temperature is increased, it leads to a greater temperature difference between the high-temperature source (typically steam or hot water) and the generator, resulting in more heat being transferred into the generator.

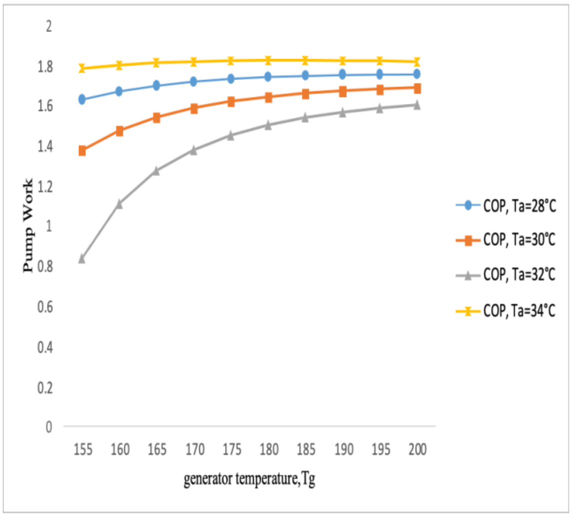

Fig 3 Effect of generator temperature on COP at different absorber temperature

The Coefficient of Performance (COP) of an absorption refrigeration system can be influenced by the generator exit temperature, and this effect can vary depending on the absorber temperature. Here's how the generator exit temperature can impact COP at different absorber temperatures:

Effect of Generator Exit Temperature at High Absorber Temperature:

- When the absorber temperature is relatively high, a higher generator exit temperature can have a more significant impact on COP.
- An increase in the generator exit temperature in this scenario can lead to a more substantial temperature difference between the generator and the absorber, resulting in enhanced heat transfer in the absorber.
- This, in turn, can improve the performance of the absorption cycle, leading to a higher COP at high absorber temperatures.

Effect of Generator Exit Temperature at Low Absorber Temperature:

- Conversely, when the absorber temperature is low, the impact of the generator exit temperature on COP may be less pronounced.
- With a lower absorber temperature, the temperature difference between the generator and the absorber is naturally smaller, limiting the potential for significant improvements in heat transfer.
- As a result, changes in the generator exit temperature may have a relatively smaller effect on the COP when the absorber temperature is low.

VI. CONCLUSION

T The generator temperature has a direct and significant impact on the COP of an absorption refrigeration system. A higher generator temperature generally leads to a higher COP, indicating improved cooling efficiency, while a lower generator temperature typically results in a lower COP, indicating reduced efficiency due to the decreased temperature difference in the desorption process. Optimizing the generator temperature is essential for achieving the desired cooling efficiency in absorption refrigeration systems, particularly when considering the availability of heat sources.

REFERENCES

1. Mohtaram, S., & Weidong, W. Thermodynamic Investigation of an Ejector Expansion Transcritical Co2 Cycle (Eetc) and Single Effect Lithium Bromide Water VapourAbsorption Refrigeration System (Vars) for Enhanced Energy Efficiency and Sustainable Cooling (2023). Available at SSRN 4469958.
2. Aktemur, C., & Ozturk, İ. T. (2023). Thermodynamic optimization of utilization of LiBr+ LiCl/H2O solution mixture on a single-effect absorption chiller driven by solar energy. Journal of Solar Energy Engineering, 145(5), 051003.
3. Sharma, D. K., Sharma, D., & Ali, A. H. H. (2023). Multi-attribute decision-making tools for selection of PCMs as latent heat thermal energy storage integrated with solar-driven LiBr-H2O vapor absorption system. International Journal of Ambient Energy, 1-9.
4. Zhang, X., Cai, L., Ma, Z., Liu, J., & Zhang, X. (2023). Experimental investigation on single-effect and compression-assisted absorption

refrigeration systems using two low-GWP HFC-based working pairs. Thermal Science and Engineering Progress, 43, 101999.

5. Ibrahim, N. I., Rehman, S., Al-Sulaiman, F. A., & Ani, F. N. (2023). A systematic thermodynamic performance assessment of a solar-driven double-effect absorption chiller integrated with absorption energy storage. Applied Thermal Engineering, 221, 119868.
6. Li, Y., Zhou, C., Wang, Y., & Luo, C. (2023). Performance analysis of a double-effect absorption refrigeration cycle using a low-temperature ethanol solution as the working pair. Case Studies in Thermal Engineering, 42, 102699.
7. Zendehnam, A., &Pourfayaz, F. (2023). Sensitivity analysis of avoidable and unavoidable exergy destructions in a parallel double-effect LiBr–water absorption cooling system. Energy Science & Engineering, 11(2), 527-546.
8. Lubis, A., Giannetti, N., Alhamid, M. I., Saito, K., &Yabase, H. (2023). Dynamic analysis of single–double-effect absorption chiller with variable thermal conductance during partial-load operation. Applied Thermal Engineering, 218, 119424.
9. Azhar, M. (2023). First Law Optimization and Review of Double and Triple-Effect Parallel Flow Vapor Absorption Refrigeration Systems. Processes, 11(8), 2347.
10. Gambhir, D., Sherwani, A. F., & Arora, A. (2022). Parametric optimization of blowdown operated double-effect vapour absorption refrigeration system. Journal of Thermal Engineering, 8(1), 78-89.
11. De, R. K., & Ganguly, A. (2022). Enviro-economic analysis of a solar-assisted double-effect vapour absorption system based cold storage. International Journal of Ambient Energy, 43(1), 5366-5375.
12. Ahmad, T., Azhar, M., Sinha, M. K., Meraj, M., Mahbubul, I. M., & Ahmad, A. (2022). Energy analysis of lithium bromide-water and lithium chloride-water based single effect vapour absorption refrigeration system: A comparison study. Cleaner Engineering and Technology, 7, 100432.
13. Azhar, M., & Siddiqui, M. A. (2020). Comprehensive exergy analysis and optimization of operating parameters for double effect parallel flow absorption refrigeration Cycle. Thermal Science and Engineering Progress, 16, 100464.
14. Azhar, M., & Siddiqui, M. A. (2019). Exergy analysis of single to triple effect lithium bromide-water vapour absorption cycles and optimization of the operating parameters. Energy conversion and management, 180, 1225-1246.
15. Dubey, A. M. (2022). Modified vapour absorption refrigeration cycles. International Journal of Ambient Energy, 43(1), 2194-2200.
16. Azhar, M., & Siddiqui, M. A. (2021). Energy and exergy optimisation of parallel flow direct and indirect fired triple effect vapour absorption systems. International Journal of Exergy, 34(4), 385-410.
17. Kumar, S., Sehrawat, V., & Gupta, T. (2022)Performance Evaluation of a Solar Powered Triple Effect Vapour Absorption System. Dr. VK Gorana, Dr. Shiv Lal, 5, 180.