International Journal of Scientific Research & Engineering Trends
Volume 6, Issue 5, Sept-Oct-2020, ISSN (Online): 2395-566X

Thermodynamic Analysis of Triple Effect LiBr-H2O Vapour Absorption Refrigeration System

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***Abstract*-The absorption refrigeration system (ARS) is becoming more important because it can produce higher cooling capacity than vapor compression systems, and it can be powered by other sources of energy (like waste heat from gas and steam turbines, sun, geothermal, biomass) other than electricity. In the recent years, the interest in absorption refrigeration system is growing because these systems have environmentally friendly refrigerant and absorbent pairs. In this study, a detail energetic analysis of triple stage LiBr-H20 absorption system using First law of thermodynamics is done. A EES code using computer simulation program is developed for simulating the cycle and the validation of results with past studies is also done. Mass, energy and exergy balance equations and the various complementary relations constitute the simulation model of the triple effect refrigeration system.Further, the effect of exit temperature of generator, absorber, condenser and evaporator on COP, solution concentration and other parameters are studied. It was found in the study that COP increases with increasing the generator exit temperature keeping the absorber exit temperature constant but when the absorber exit temperature is increased COP tends to decrease and the concentration of weak solution leaving HP generator (Xw3), MP generator (Xw2) and LP generator (Xw1) also increases with increase in generator exit temperature, while it decreases with increase in condenser exit temperature.**

***Keywords*-Absorption Refrigeration System (ARS), vapor compression systems, COP, solution concentration, EES code, energetic analysis, triple effect refrigeration system.**

I.INTRODUCTION

The triple effect series absorption refrigeration system as shown in figure 1 consists of an evaporator, an absorber, a condenser, three generators, three heat exchangers, a solution pump, three expansion valves and three reducing valves. As shown in figure 1, the vapour (refrigerant) is generated thrice. The first generation is by external heat input at high pressure generator (HPG).

The second and third generations are accomplished by internal heat exchange at medium pressure generator (MPG) and low pressure generator (LPG) respectively. Thus more vapour is generated for a unit heat input as compared with the single effect and double effect systems. Because a tripleeffect system runs at higher temperatures, it requires new chemistry and new materials to resist the corrosion that accompanies high temperatures.

A suitable working fluid is probably the single most important factor in any refrigeration system. The cycle efficiency and Operating characteristics of an absorption refrigeration system depend on the properties of refrigerant, absorbent and their mixtures.

The most important thermo-physical properties are heat of vaporization of refrigerant, heat of solution, vapor pressure of refrigerant and absorbent, solubility of refrigerant insolvent, heat capacity of solution, viscosity of solution and surface tension and thermal conductivity of the solution.

Apart from this, the other selection criteria for the working fluids are their toxicity, chemical stability and corrosively. Vapor Absorption Refrigeration Systems belong to the class of vapor cycles similar to vapor absorption refrigeration systems.

However, unlike vapor absorption refrigeration systems, the required input to absorption systems is in the form of heat. Hence, these systems also called as heat operated or thermal energy driven systems. Both vapor absorption and absorption refrigeration cycles accomplish the removal of heat through the evaporation of a refrigerant at a low pressure and the rejection of heat through the condensation of the refrigerant at a higher pressure.

The basic difference is that a vapor absorption system employs a mechanical compressor to create the pressure differences necessary to circulate the refrigerant whereas an absorption system uses heat source and the differences cause an absorption system to use little to no work input, but energy must be supplied in the form of heat.

II. LITERATURE REVIEW

Agarwal et al. (2020) analyzed an absorption-compression cascade refrigeration system (ACCRS) theoretically for low temperature cooling applications. It comprises of a triple effect H2O-LiBr series flow vapor absorption refrigeration system in higher temperature section associated with vapor compression refrigeration (VCR) system using R1234yf refrigerant in lower temperature section.

Chen et al. (2020) conducted Energy and exergy analyses on a proposed hybrid system consisting of a phosphoric acid fuel cell (PAFC) and a triple-effect compression–absorption refrigerator with [mmim]DMP/CH3OH as working fluid (HFCAR). The HFCAR system was

Dubey et al. (2020) present a comprehensive understanding of both simple and complex refrigeration cycles. Moreover, current status emphasising any improved performance in vapour absorption refrigeration cycles has been discussed. A theoretical investigation of different vapour absorption cycles, incorporating an ejector, generator absorber heat exchanger and booster compressor, has been made.

Waseem et al. (2020) focused on the comparative analyses of multigeneration systems integrated with an electrolyzer for the production of hydrogen, for work rate a regenerative Rankine Cycle and finally for the cooling effect vapor absorption cycle was used. The power produced by both proposed systems was observed to yield some difference based on their positioning in the system and similarly, the rate of hydrogen production from the electrolyzer was also observed.

Azhar et al. (2020) discussed comprehensive exergy analysis for double effect parallel flow direct as well as indirect fired vapour absorption refrigeration systems using Lithium bromide-water as working fluid. The temperatures in the main generator and intermediate generator and condenser are optimized parametrically.

Gupta et al. (2020) presented system that consists of an ejector organic Rankine cycle (EORC) integrated with a triple pressure level absorption system (TPAS) based on parabolic trough collector (PTC) solar field.

Sun et al. (2020) uses an economized-cycle vaper compression refrigeration system as an example to investigate the energy and exergy performance of R513a used as a drop-in replacement for R134a. Differing from previous research, this study examines the entire system operating zone to identify the performance differences in terms of capacity, COP, exergy destruction rate, and exergy efficiency between R513a and R134a systems

Mohammadi et al. (2020) proposed different novel integrated cogeneration and trigeneration configurations based on a carbon dioxide parallel compression economization-vapor compression refrigeration cycle with a 1000 kW capacity and evaporator temperatures of −35 °C to −45 °C.

Abusaibaa et al. (2020) evaluated the feasibleness of using a absorption solar cycle in Najaf, Iraq in this study. In the system proposed, a 105,6kW SEAC is powered by Evacuated Tube Collectors (ETC). TRNSYS (version 18) simulation is performed to select the various system parameters and optimize them to increase solar system efficiency, and this simulation develops a solar cooling model that simulates reality and is used effectively for cooling service buildings.

Azhar et al. (2019) Presented analysis carried out by various investigators on exergy of the absorption cycles have been discussed. To fill the gap in the knowledge on exergy destruction rate in the absorption system, optimization of the single to triple effect direct and indirect fired absorption cycles have been conducted for a wide range of operating conditions.

Toghyani et al. (2019) used nanofluid as working fluid in a solar parabolic trough collector (PTC) for solar cooling and hydrogen production. The combined system is composed of five sub-systems including PTC, Rankine cycle, thermal energy storage, triple effect absorption cooling system (TEACS), and proton exchange membrane (PEM) electrolyzer.

Mishra et al. (2019) propose four cascaded half effect, single effect, double effect and triple effect Lithium/Bromide vapour absorption– compression refrigeration systems using fifteen ecofriendly refrigerants such as hydrocarbons, HFC and HFO refrigerants and natural refrigerants to produce cooling capacity at -30 °C. Azhar et al. (2019) Presented Thermodynamic analysis of double effect parallel and series flow direct fired absorption systems with lithium bromide–water has been carried out for different operating conditions.

Bagheri et al. (2019) investigated a parallel flow double-effect water-lithium bromide absorption refrigeration cycle using comprehensive exergy-based analyses. The exergy destruction of each device is calculated and used for further analysis. The performance of the system is optimized for maximum coefficient of performance and exergy efficiency, considering the distribution ratio as a variable using the Golden Section method.

Singh et al. (2019) carried out A building energy simulation study to analyze the performance of a triple-hybrid single-effect vapor absorption cooling system (VACS) operated by solar, natural gas, and auxiliary electricity-based cogeneration. A high capacity small

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office building subjected to different climatic conditions is considered.

Mishra et al. (2019) develop an integrated solar refrigeration system where waste heat from different energy resources assists a combined vapour absorption compression system, and to analyze feasibility & practicality of that system of thermodynamically for improving its COP and exergetic efficiency by reduction of irreversibilities in terms of exergy destruction /losses occurred in the system components.

Chahartaghi et al. (2019) the effect of some key parameters on coefficient of performance (COP) in two novel arrangements of double effect lithium bromide–water absorption chillers with series and parallel flow have been studied. The main components of these cycles are generators, absorber, condensers, evaporator and heat exchangers.

Alazazmeh et al. (2019) investigate the thermodynamic performance of a novel solar powered multi-effect refrigeration system. The proposed cycle consists of a solar tower system with a heliostat field and central receiver (CR) that has molten salt as the heat transfer fluid, an absorption refrigeration cycle (ARC), an ejector refrigeration cycle (ERC), and a cascade refrigeration cycle (CRC).

III. METHODOLOGY

The present analysis is governed by the first and second laws of thermodynamics. The energy and exergy analyses of absorption- compression (triple effect H2O-LiBr series flow) cascade refrigeration system (ACCRS) have been executed. In which, R1234yf has been used as working fluid in the vapor compression section. Conservation of mass and material, energy balance and exergy balance principles have been applied to each system components. Heat transfer and work interaction of inlet and outlet streams are governed with the control volume approach for each system component. Steady state governing equations have been developed.

IV. RESULT AND DISCUSSION

A detail energetic analysis of LiBr-H20 absorption system of is done in this current study. First law of thermodynamics has been used for performing analysis. Further, an EES code has been developed using computer simulation program for simulating the cycle and validation of results with published literature.

1. Effect of generator temperature

In this section the effect of generator temperature on heat flow rate in generator (QHTG,), absorber (Qa), condenser (Qc), and evaporator (Qe), COP, Circulation ratio and concentration of absorption system has been discussed.

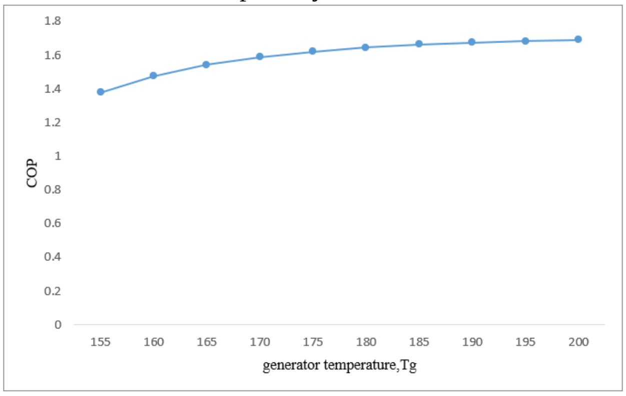

Fig 1 Effect of generator exit temperature on component's COP.

Fig. 1. shows the effect of generator exit temperature on the COP, With increase in generator exit temperature The generator COP increases gradually.

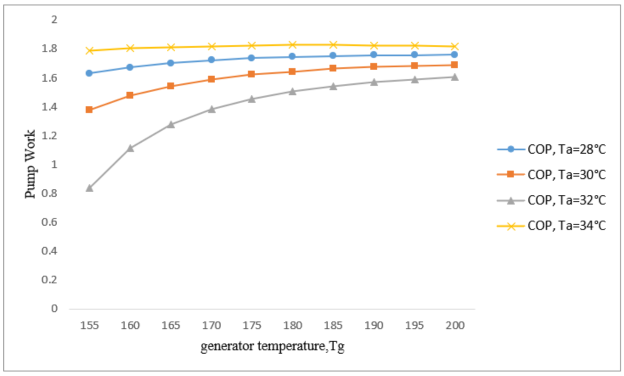

Fig 2 Effect of generator exit temperature on component's COP at different absorber temperature.

Fig. 2. shows the effect of generator exit temperature on the COP, with increase in generator exit temperature the generator COP increases gradually. From the figure it can be seen that the cop, at particular generator exit temperature, is decreasing with absorber temperature from 28C To 32C and then is greater for 34C .

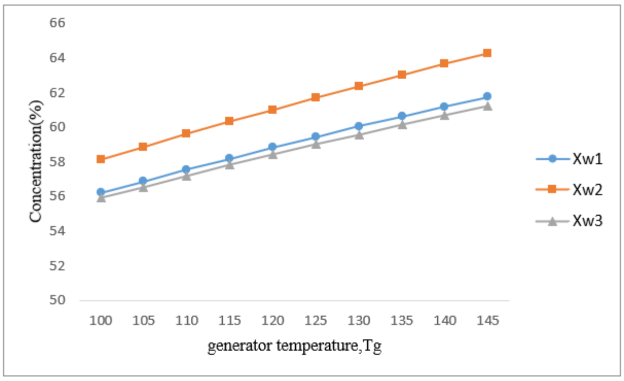

Fig 3 Effect of generator exit temperature on concentration.

The above figure shows the effect of generator exit temperature on the concentration of weak solution leaving HP generator (Xw3), MP generator (Xw2) and LP generator (Xw1), With increase in generator exit temperature the concentration is increasing proportionally.

2. Effect of evaporator temperature

In this section the effect of evaporator temperature on heat flow rate in generator (QHTG,), absorber (Qa), condenser (Qc), and evaporator (Qe), COP, Circulation ratio of absorption system has been discussed.

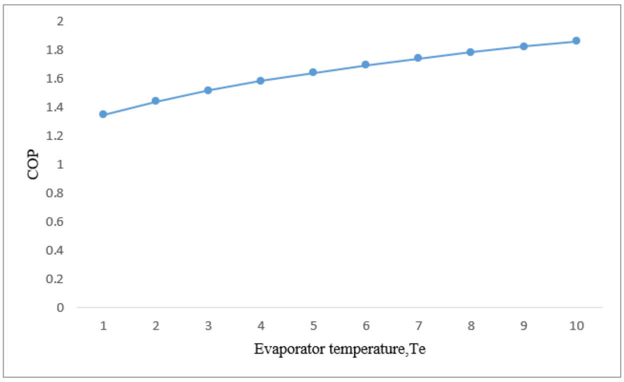

Fig 4 Effect of evaporator exit temperature on COP.

The above figure Shows the variation of COP, with evaporator exit temperature Te. The COP is increasing with evaporator exit temperature.

3. Effect of condenser temperature

In this section the effect of condenser temperature on heat flow rate in generator (QHTG,), absorber (Qa), condenser (Qc), and evaporator (Qe), COP, Circulation ratio of absorption system has been discussed.

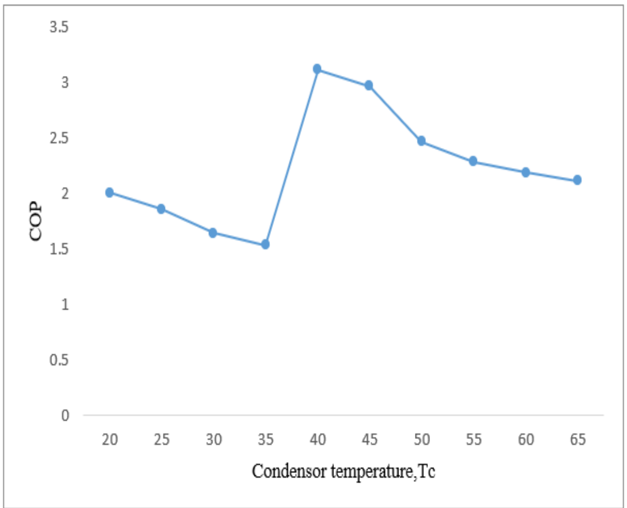

Fig 4. 5 Effect of condenser exit temperature on COP

The above figure shows the effect of evaporator exit temperature on the COP, With increase in evaporator exit temperature THE COP of the system decreases gradually except for the temperature range 35-40.

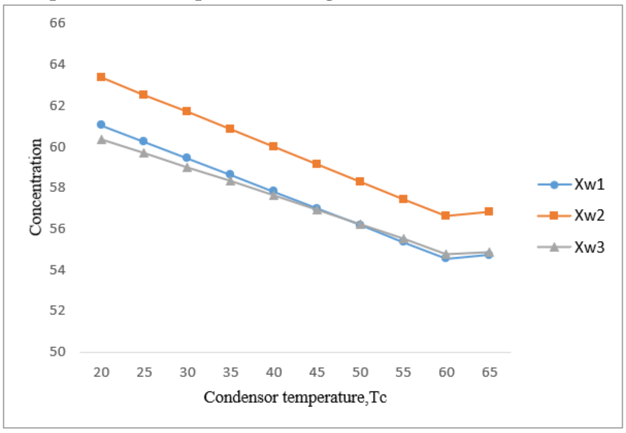

Fig 6 Effect of condenser exit temperature on weak solution concentration.

The above figure shows the effect of condenser exit temperature on the concentration of weak solution left from HP generator (Xw3), MP generator (Xw2) and LP generator (Xw1) .

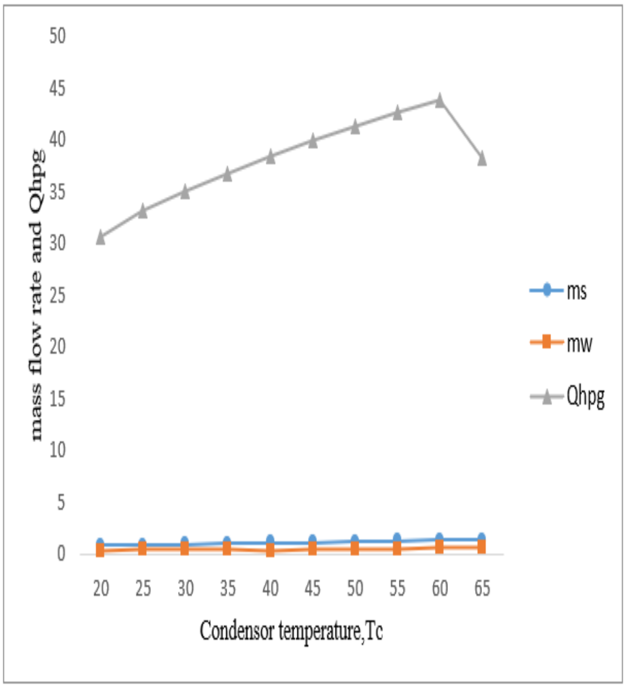

Fig 7 Effect of condenser exit temperature on mass flow rate and generator heat.

The above figure shows the effect of condenser exit temperature on the mass flow rate of strong and weak solution and heat of HP generator. With increase in condenser exit temperature THE heat of HP generator increases upto condenser temperature 60 C and then decreases. While the mass flow rate of both strong and weak solution is increasing with condensor temperature.

V. CONCLUSION

The concluding remarks from the results of this paper can be written as follows:

- It was found in the study that COP increases with increasing the generator exit temperature keeping the absorber exit temperature constant but when the absorber exit temperature is increased COP tends to decrease.
- The COP increases with the increase in the evaporator exit temperature as well as generator temperature
- The concentration of weak solution leaving HP generator (Xw3), MP generator (Xw2) and LP generator (Xw1) also increases with increase in generator exit temperature, while it decreases with increase in condenser exit temperature.

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