Thermodynamic Analysis of Single StageWater Absorption System

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ABSTRACT: Absorption refrigeration systems are the cooling systems that use heat as input for operation instead of electricity. This type of refrigeration system reduces the fossil fuel consumption, indirectly restricts the CO2 emission to the atmosphere, and restricting at the same time the usage of toxic refrigerants. In this study, A detail energetic analysis of single stage LiBr-H_20 absorption system of is done. 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 experimental one. The effect of exit temperature of generator, absorber, condenser and evaporator on COP, heat load, circulation ratio have been analysed and validated. The operating parameters are selected as generator temperature (74°C), absorber temperature (23°C), condenser temperature (35°C) and evaporator temperature (5°). It was found in the study that COP increases with increasing the generator exit temperature keeping the condenser exit temperature constant but when the condenser exit temperature is increased COP tends to decrease.The COP increases with the increase in the evaporator exit temperature as well as generator temperature.

KEYWORDS: Absorption refrigeration systems, LiBr-H_20 absorption system, EES code, generator temperature , absorber temperature, condenser temperature , evaporator temperature

I. INTRODUCTION

Absorption refrigerator is a chemically driven refrigeration system which uses an absorbent- refrigerant combination as the main working pair. In case of LiBr+water combo, LiBr solution works as absorbent whereas water works as refrigerant.

As working absorbent is an electrolyte solid in a solution form, higher concentration can lead to crystal formation which can block the pipes, hence it is needed to have a high pressure in the condenser and generator so that crystallization won't happen at the working temperatures.

A single effect vapour absorption system consists of a generator, an absorber, a condenser, an evaporator, a solution heat exchanger (SHE), a refrigerant heat exchanger (RHE), a solution expansion valve, a refrigerant expansion valve and a pump

Water enters the evaporator at low temperature and pressure. Here water is in vapour – liquid state. This water refrigerant absorbs heat from the substance to be chilled and gets fully evaporated. Then this water vapour enters the absorber section at constant pressure. Concentrated LiBr solution is present in absorber. Since water is highly soluble in LiBr solution, water vapour is absorbed through this concentrated solution making it dilute. In generator, heat is supplied to the solution. This heat is generally the waste heat. Water vaporises from the solution and moves to the condenser and the dilute LiBr+water solution becomes concentrated again and moves to the absorber. Condenser block is used as a device to condense the water vapour to liquid water. This can be done by passing normal cooling water or air flow. After condenser, a valve is places to decrease the pressure. Normally a heat exchanger is used between generator and absorber so that heat can be exchanged between dilute solution and concentrated solutions. Pump is used to move the dilute solution from absorber to the heat exchanger so that the required flow rate can be maintained.

II. METHODOLOGY

First law of thermodynamics has been used to perform the analysis. Conservation of mass and energy balance have been applied to each components of absorption system. In this way, steady state equations have been formulated.

Mass conservation

It includes mass balance of total mass and each material of the solution. For steady state-flow system, the governing equations of mass and type of material conservation are:

$\sum m_i - \sum m_o = 0$ (1)

$\sum m_i X_i - \sum m_o X_o = 0$ (2)

where, m is the mass flow rate and X is the mass fraction of LiBr in the solution.

First law analysis

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

$\sum \dot{Q} - \sum \dot{W} = \sum m_0 h_0 - \sum m_i h_i$ (3)

The overall performance of absorption system is determined by evaluating its coefficient of performance (COP):

$COP = \frac{Qe}{Q_{HTG} + W_p}$ (4)

where, Qe is the refrigerant effect, Q_G is the heat rate in generator and W_p is the pump work.

III.

RESULT AND DISCUSSION

Effect of generator temperature

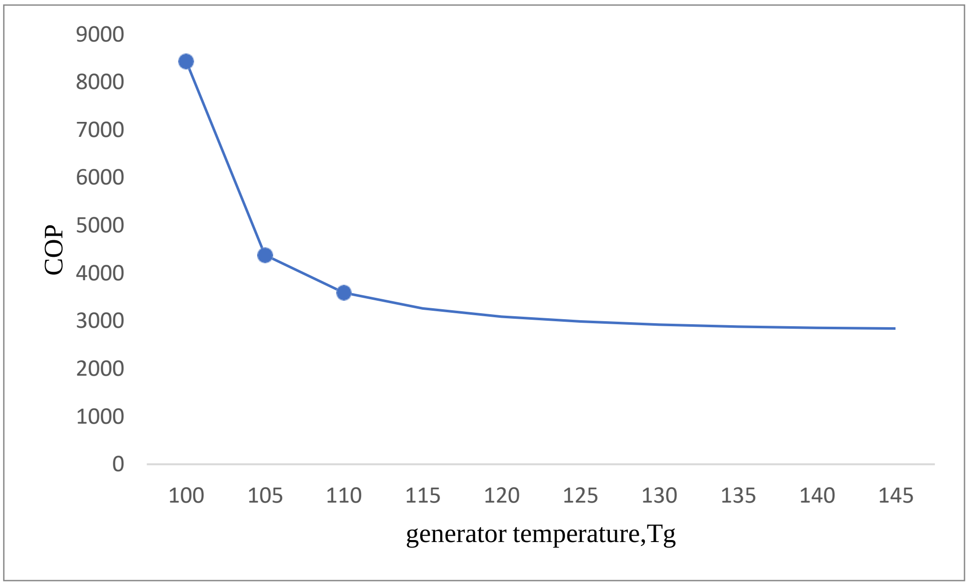

Fig 1: Effect of generator exit temperature on component's COP

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

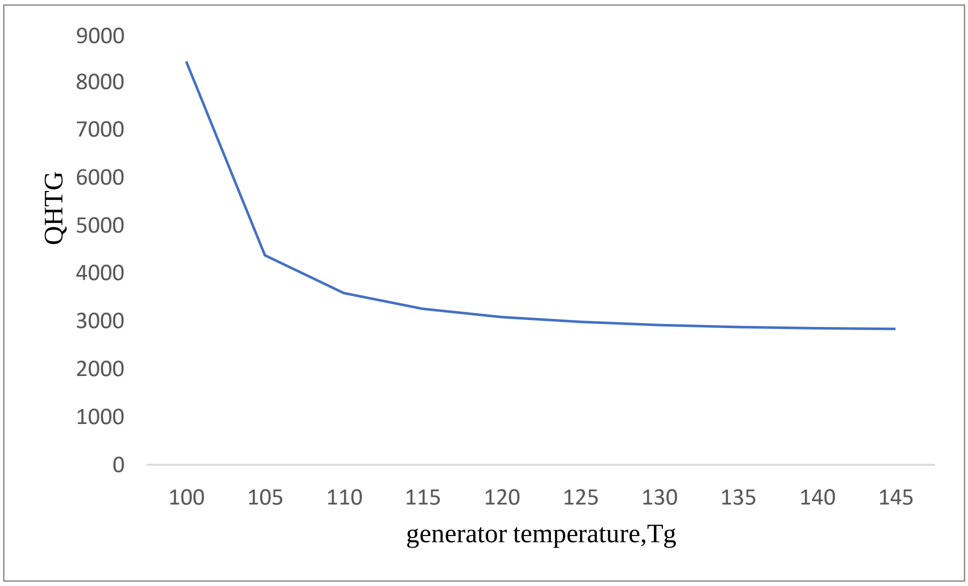

Fig 2: Effect of generator exit temperature on component's heat load

Fig. 2. shows the effect of generator exit temperature on the HEAT load of generator, With increase in generator exit temperature THE generator heat load decreases gradually

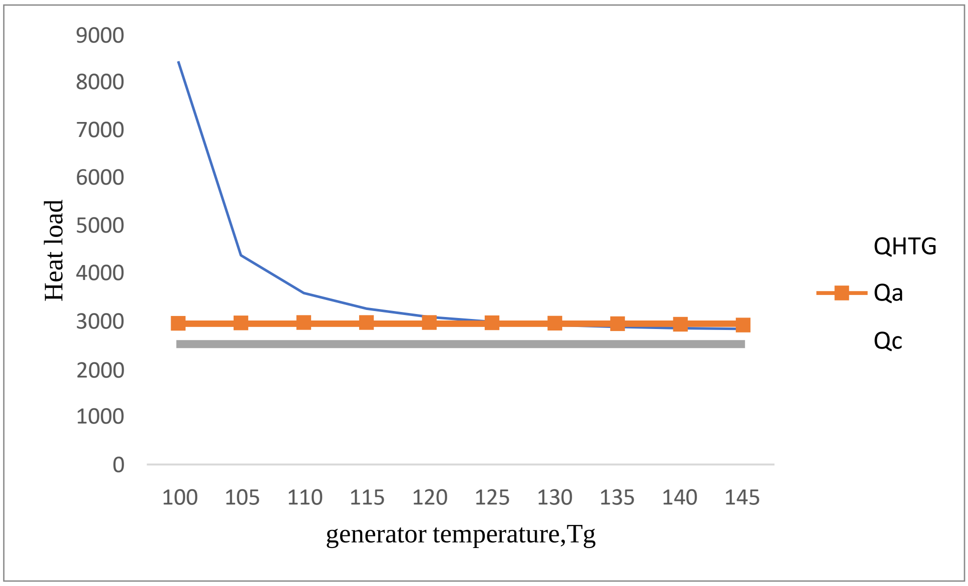

Fig 3 Effect of generator exit temperature on component's heat load

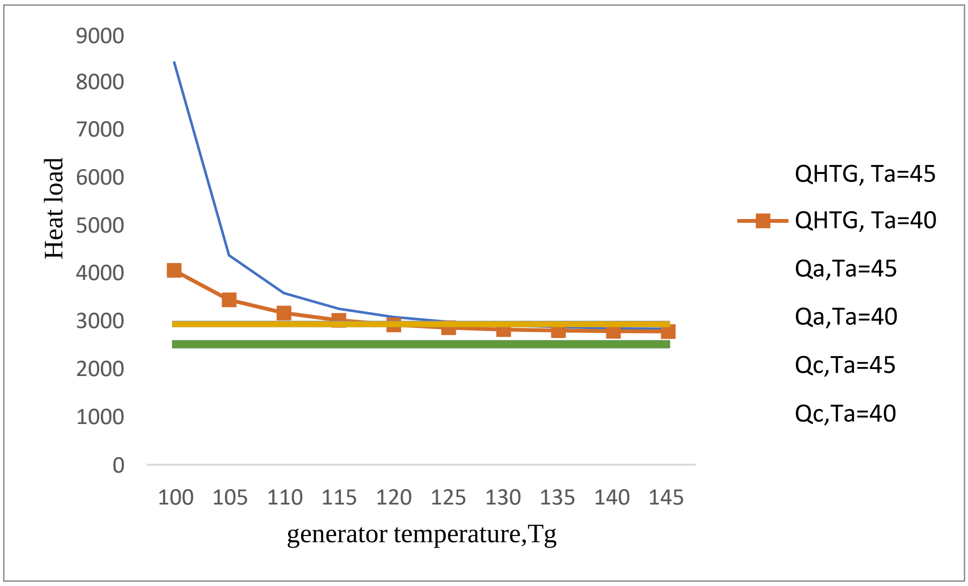

Fig 4. Effect of generator exit temperature on component's heat load

Fig. 3 and 4, shows the effect of generator exit temperature on the generator heat load and the heat rejection in absorber and condenser. With increase in generator exit temperature both absorber and generator heat load decreases gradually but total average heat load on generator is higher than that of absorber. As the condenser temperature increases the whole system gets pressurized & average heat load on generator and absorber rises by 9.38% and 9.49% respectively when absorber temperature increases from 40 ^{0}C to 45 ^{0}C.

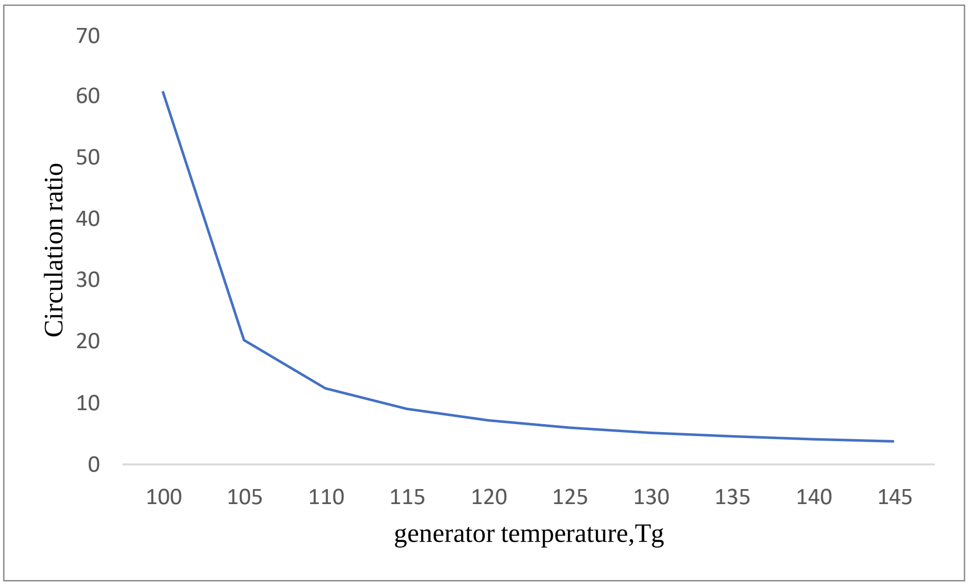

Fig 4 Effect of generator exit temperature on component's CR

The above figure shows the effect of generator exit temperature on the circulation ratio, With increase in generator exit temperature the circulation ratio decreases gradually.

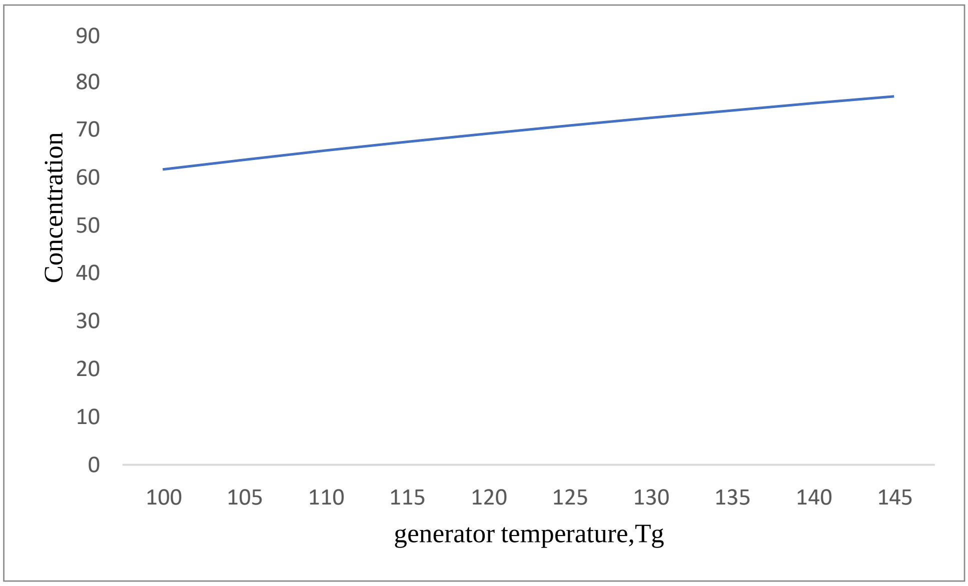

Fig 5 Effect of generator exit temperature on concentration

The above figure shows the effect of generator exit temperature on the concentration of strong solution, with increase in generator exit temperature the concentration is increasing proportionally.

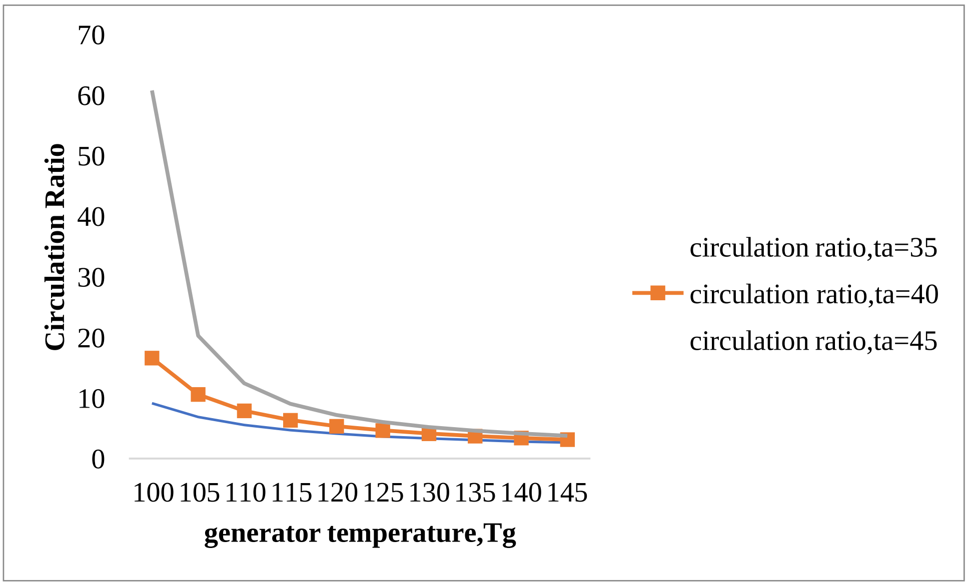

Fig 6 Effect of generator exit temperature on CR

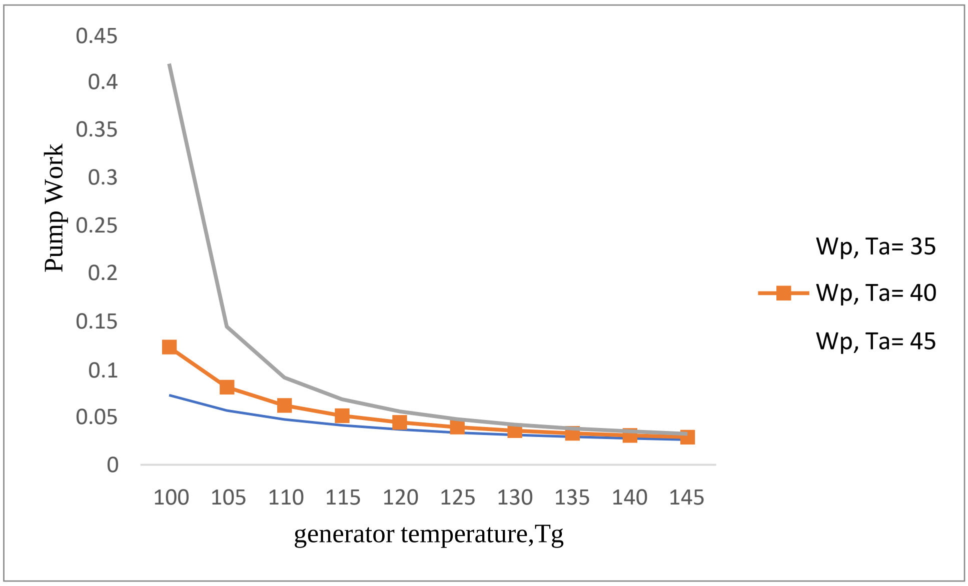

Fig 7 Effect of generator exit temperature on Wpump

The effect of increase in generator exit temperature on refrigerant concentration, circulation ratio and pump work are presented in Fig. 7 &8. With increase in absorber exit temperature and constant condenser temperature, there is no effect on the refrigerant mass fraction at the inlet of generator and refrigerant mass fraction decreases in the solution coming from generator to absorber and hence the LiBr concentration increases. With decrease in refrigerant mass fraction the demand of pump work decreases due to reduced circulation ratio. As the system absorber temperature increases from 35 0C to 450C the average refrigerant concentration and circulation ratio gets increased by 16% and 51.54% respectively due to which demand of pump work is increased by73.4%

IV. CONCLUSION

In the proposed work, a comparative thermodynamic performance evaluation of single stage LiBr -Water vapour refrigeration system is performed. first law analysis of single effect lithium bromide-water vapour absorption system is carried out. A software based program has been formulated using EES code to validate the COP and heat transfer in generator, absorber, condenser, and evaporator In this context, the COP, circulation ratio, heat load of the overall system are analyzed with the thermodynamic equilibrium equations, such as mass, energy, entropy, and exergy, and also the energy and exergy efficiency equations. In addition, The ees code validation is also done the parametric study is performed to comprehend how generator evaporator absorber and condenser temperatures influence on the COP, circulation ratio, heat load of the system for a more efficient process design. Finally, 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 condenser exit temperature constant but when the condenser exit temperature is increased COP tends to decrease.

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