

Effect of Cooling Water on the Performance of Lithium Bromide–Water (LiBr–H₂O) Absorption Based Heat Pump

Manu.S¹, T.K.Chandrashekar² and C. Girisha³

¹Assistant Professor, Department of Mechanical Engineering, Sri Siddhartha Institute of Technology, Tumkur, Karnataka, India

²Professor, MITE, Mangalore, Karnataka, India

³Professor, AMCEC, Bangalore, Karnataka, India

* Corresponding Author: manussit@gmail.com

Abstract: The need for extracting high heat from the industries has encouraged the development of Lithium Bromide-Water (LiBr–H₂O) absorption based heat pump. This paper presents a simulation study of single-stage LiBr–H₂O vapor absorption heat pump. The detailed thermodynamic analysis of the single-stage LiBr–H₂O vapor absorption heat pump was carried out in this study. The validation of this model is performed by considering the values from the literature. The effect of cooling water on flow rates, COP (Coefficient of performance) and conductance are examined.

1. Introduction

Absorption heat pumps systems have been used to produce cold since 1850. They are gaining more attraction because of eco-friendly. There are operated by using low-grade energies like geological, solar and waste heat liberated from process industries. The device uses working fluids which have no effect on ozone. The LiBr–H₂O is announcing the best working fluid pair because its properties such as a high enthalpy of vaporization, not toxic and does not require a rectification step.

Numbers of researchers like Ghaddar et al., (1997) have studied LiBr–H₂O absorption system for space cooling. The simulation was developed and performance of the system was carried for all possible climatic condition at Beirut. Yoon et al., (2003) have conducted an experimental investigation on double-effect LiBr–H₂O absorption cycle. The performance of absorption chiller system was carried by using exhaust gases to preheat the weak absorbent solution coming from the absorber to the low-temperature generator. Park et al., (2004) have studied the performance of absorption refrigeration. The study showed that performance of the absorption system greatly depends upon the inlet temperature and flow rate of the water.

Asdrubali et al., (2005) have studied the performances of single stage LiBr–H₂O absorption machine by developing mathematical model. Vega et al., (2006) have performed experimental study on the performance of absorption chiller. The result showed cooling capacity and energy supplied to the absorption chiller had uncertainty margin was around 18-20%. Castro et al., (2007) have developed prototype of an air-cooled absorption chiller of cooling capacity of 2kW



cooling using LiBr-H₂O absorbent pair obtained COP of 0.65. Adao et al., (2008) have performed test on absorption chiller with a cooling capacity of 8kW in Portugal. Pongtornkulpanich et al., (2008) have performed experimental study on the performance of an solar-absorption A/C system with a 35 kW cooling capacity operating in Thailand. Jung et al., (2009) carried experimental investigation on the performance of a solar-absorption A/C system with a cooling capacity of 10kW operating in Italy.

Melograno et al., (2009) have performed an experimental test rig for an absorption chillers having cooling capacity up to 20 kW. The authors reported that, the absorption chiller performance data for six different operating boundary conditions in this work. Agyenim et al., (2010) have studied the performance of solar-absorption A/C system of capacity of 4.5kW. The results showed the average COP of 0.48 for an average peak solar insolation of 812 W/m².

2. Cycle Description

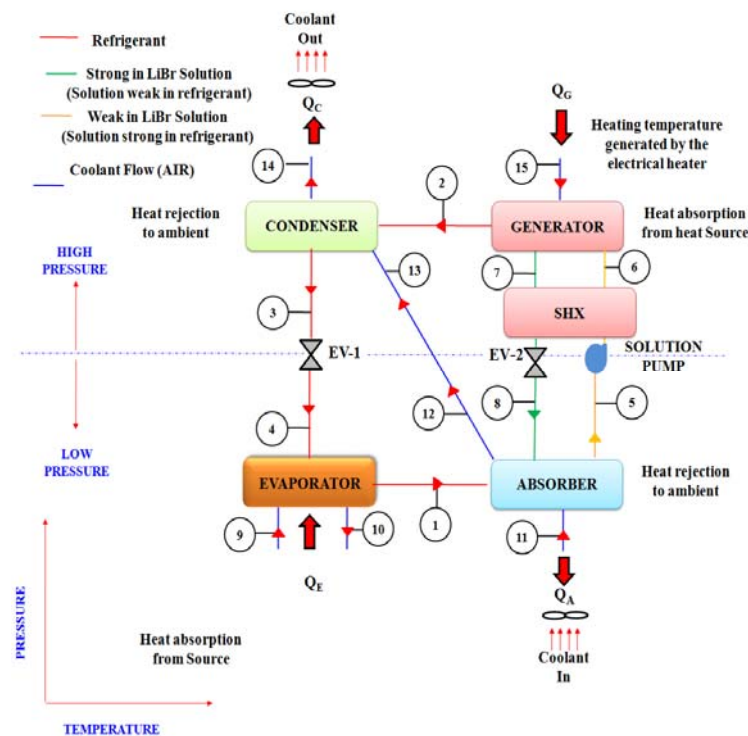


Figure 1 Shows LiBr-H₂O cycle

Figure 1 shows single effect LiBr-H₂O absorption refrigeration system. Refrigerant and absorbent used are water and LiBr. The boiling of weak solution takes place in generator by adding the heat and also vapour refrigerant is generated which is then moved to condenser. In condenser, vapour refrigerant is rejected and moved to the expansion valve where its pressure and temperature of condensed refrigerant is decreased. At low temperature and pressure, liquid refrigerant goes to the evaporator as saturated liquid and it gets vaporized by absorption of heat which is then moved to the absorber. In the absorber, vapor refrigerant (water) becomes strong solution by absorbing the strong solution coming from the evaporator. The strong solution which is left over in the generator flows to the absorber via expansion valve and solution heat exchanger. Weak solution is preheated by solution heat exchanger with absorption of heat from strong solution.

3. Simulation of LiBr-H₂O heat pump

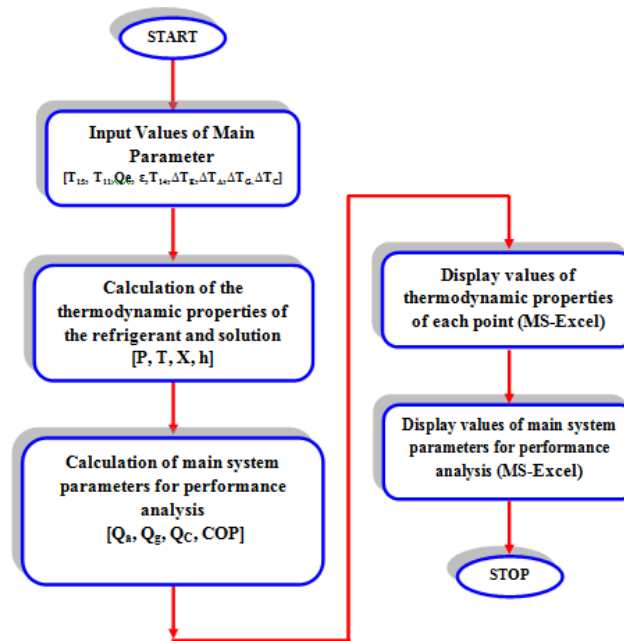


Figure 2 Block diagram of the simulation program

The program includes same input parameters such as:- Evaporator load (Q_e), Outlet cooling water temperatures respectively (T_{14}), Outlet chilled water temperatures (T_9), Outlet hot water temperatures and effectiveness (ϵ), are provided. The simulation was performed by varying inlet cooling water temperature (T_{11}). Then the program calculates the thermodynamic properties of the refrigerant and solution $[P, T, X, h]$ at all the state point as shown in **Fig 2**. Simulation of main system parameters for load analysis $[Q_e]$ was performed by using MAT lab software.

4. Validation of the Model

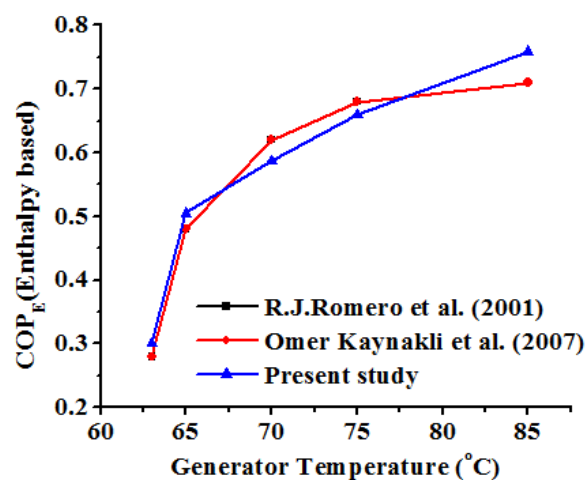


Figure 3 Comparison of COP_E values with Romero RJ et.al., (2001) and Omer Kaynakli et.al., (2007)

Table 1: Operating conditions for comparison with Romero RJ et.al., (2001) and Omer Kaynakli et.al., (2007)

Sl.No	Component	Symbol	Temperature	Unit
1	Absorber	T _a	30	°C
2	Condenser	T _c	30	°C
3	Evaporator	T _e	2	°C
4	Generator	T _g	62-90	°C
5	Effectiveness of SHX	ϵ	0	

The present model was validated by comparing the results which are available in the literature. The comparative study of COPE (Enthalpy based Coefficient of Performance) variation of the generator temperature is as shown in Fig 3. The simulations are carried based on the operating conditions of Romero RJ et.al., (2001) and Omer Kaynakli et.al., (2007) as shown in Table 1. It can be observed that, as expected, the COPE value raises with increase in generator temperature, and the results obtained from the present simulation model are in good agreement with the results of Romero RJ et al. (2001) and Omer Kaynakli et al. (2007). The small variation can be attributed to the difference between the data sets used for the thermodynamic properties.

5. Result and Discussion

Table.2 List of Input parameters for varying Inlet cooling water Temperature

Sl.No	Parameter	Symbol	Value	Unit
1.	Outlet Chilled water temperature	T ₉	25	°C
2.	Inlet cooling water Temperature	T ₁₁	28-36	°C
3.	Approaching Temperature of Evaporator	ΔT_1	2	°C
4.	Approaching Temperature of Absorber	ΔT_2		°C
5.	Approaching Temperature of Condenser	ΔT_3		°C
6.	Approaching Temperature of Generator	ΔT_4		°C
7.	Outlet cooling water Temperature	T ₁₄	45	%
8.	Evaporator Load	$\dot{Q}_e$	1	Kw
9.	Effectiveness of solution heat exchanger	ϵ	0.5	
10.	Hot water temperature	T ₁₅	75	°C

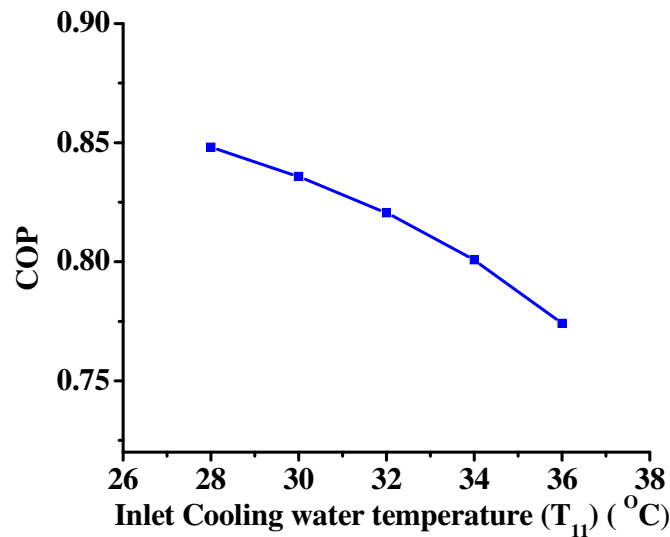


Figure 4 Shows the effect of T_{11} on COP

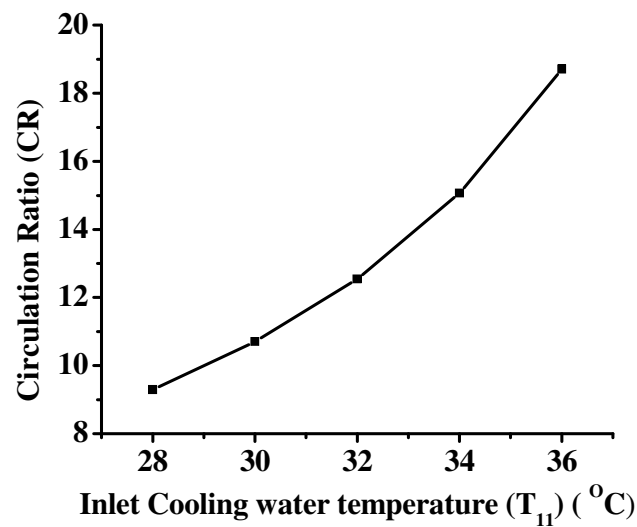


Figure 5 Shows the effect of T_{11} on COP

Fig 4 shows the effect of inlet cooling water temperature (T_{11}) on COP. Increase in T_{11} decreases of COP from 0.84 to 0.77 values this is due to increase in the circulation ratio (CR) from 9.28 to 18.70 as shown in **Fig 5**. This is due to increase in mass flow rate of weak solution from the generator at constant evaporator load. The results are good agreement in the literature. [15].

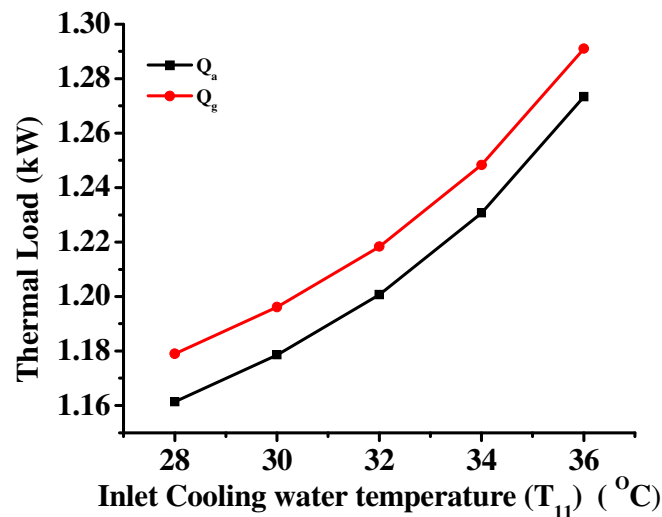


Figure 6 Shows the effect of T_{11} on Load

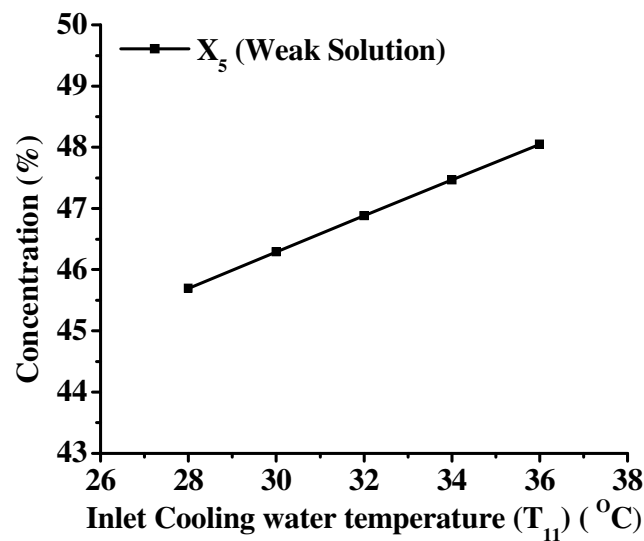


Figure 7 Shows the effect of T_{11} on X_5

Fig 6 shows the effect of inlet cooling water temperature (T_{11}) on Load. Increase in T_{11} increases at absorber load from 1.16 to 1.27kW and increases generator load from 1.17 to 1.29kW values at constant evaporator load. This is due to increase in the circulation ratio (CR) and also increase in Absorber temperature. Due to increase in absorber temperature there is an increase in weak solution concentration from 45.6 to 48% as shown in **Fig 7**. The results are good agreement in the literature [14].

6. Conclusion

The paper attempts to investigate the effect of cooling water on the performance of the system was carried. The properties are evaluated by using the values available in the literature. The conclusion as follows: Increase in T_{11} decreases of COP from 0.84 to 0.77 values this is due to increase in the circulation ratio (CR) from 9.28 to 18.70. Increase in T_{11} increases at absorber load from 1.16 to 1.27 kW and increases generator load from 1.17 to 1.29 kW values at constant evaporator load and increase in weak solution concentration from 45.6 to 48%.

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