International Journal of
Emerging Research in Management &Technology
ISSN: 2278-9359

Research Article

January 2013

Mathematical Modeling and Analysis of Absorption Refrigeration System Using Waste Heat of Diesel Genset

Yashvir Singh[1*], Deepak Kumar[2], Ajay Kumar[3], Amneesh Singla[4]
[1,2,3,4] *Mechanical Engineering, University of Petroleum and Energy Studies*
Dehradun, Uttarakhand, India-248007

Abstract:

The objective of this paper is to develop a program for thermodynamic analysis of a single effect absorption chiller using LiBr-H_2O solution as working fluid. The working temperature of generator, absorber, condenser, evaporator and effectiveness of solution heat exchanger are used as input data. The program then gives the thermodynamic properties of all state points and the overall cycle performance. The results deduced are used to study the effect of parameters on cycle performance. For example, decreasing the evaporator and increasing the condenser temperatures can improve the efficiency of the cycle. The results of this program can be used either for sizing a new refrigeration cycle or rating an existing system. It can also be used for optimization purposes.

Keywords: absorption chiller, program, efficiency.

I. INTRODUCTION

Absorption refrigeration systems differ from compression systems by the use of a heat source as the energy input in order to operate; conversely, compression- based systems require mechanical energy to operate. Thus the main advantage of the absorption systems is that they can run burning a fuel or using waste heat recovered from other thermal systems. Moreover, these systems present other advantages, such as high reliability, low maintainability and a silent and vibration-free operation. Another important aspect is the elimination of CFC and HCFC refrigerants Single-effect absorption refrigeration systems have only one heating level of the working fluid (dilute solution). Desai and Bannur [1] have performed experiments in a twin cylinder diesel engine, to recover heat from engine exhaust using a shell and tube heat exchanger.

An experimental procedure conducted by Pichel [2] on a 3517 kW capacity Li–Br absorption refrigeration machine showed that the machine can operate with hot water at 80 and 120 8C, and it was found that the cooling water connected in parallel to both absorber and condenser is more efficient than series connection. The coefficient of performance was between 0.68 and 0.72. Eisa et al. [3] determined experimentally the flow ratio (the ratio of the mass flow rate of the solution from the absorber to the mass flow rate of the refrigerant) and COP for all possible combinations of operating temperatures of the evaporator, condenser, absorber and generator, and the concentration in the absorber and the generator up to the crystallization limit. Eisa and Holland [4] performed an experimental investigation to study the effect of changes in operating conditions on the performance of LiBr–H2O absorption cooler for optimization purposes. They found that the most significant parameter affecting COP is the generator temperature. An increase in generator temperature increases the COP. The flow ratio is also an important design and optimizing parameter. Increasing flow ratio decreases the required generator temperature at the expense of reduction in COP. Eisa et al. [5] conducted more experiments on the same system of Eisa and Holland [4] to study the effect of operating temperatures of the absorber and condenser on performance. It was noticed that as the temperature difference is increased, the COP and the cooling capacity are decreased. They also found that the COP is more sensitive to the absorber temperature than to the condenser temperature.

The capacity of the absorption refrigeration system considered in this work is 356.16 KW. This capacity was chosen in order to analyze the refrigeration system to be installed Hindustan College of Science and Technology, Mathura, India.

II. SYSTEM DESCRIPTION AND MATHEMATICAL MODELING

Diesel engine used for heating the LiBr-H_2O solution have the following technical specification as shown in Table 1.

TABLE 1. TECHNICAL SPECIFICATION OF DIESEL GENSET

Engine Specification	**Description**
Model	KTA 19 G-9
Make	Cummins
No. of cylinders	6, in line
Output-Prime	448 KW
Fuel Consumption @100% load	60 ltr/hr
Combustion air intake @100% load	32.7 m^3/min
Cooling capacity	175 ltr
Bore x Stroke	159 mm x 159 mm
Exhaust Temperature	518^{o}C
Exhaust flow rate	18 m^3/min

A typical water–lithium bromide absorption refrigeration system is illustrated in figure 1. The system includes a generator, absorber, condenser, evaporator, solution heat exchanger. The determination of the thermodynamic properties of each state point in the cycle, the amount of heat transfer in each component, and the flow rates at different lines depend upon the Generator temperature , Evaporator temperature, Condenser temperature, Absorber temperature, Liquid-liquid heat exchanger effectiveness, Refrigeration load.

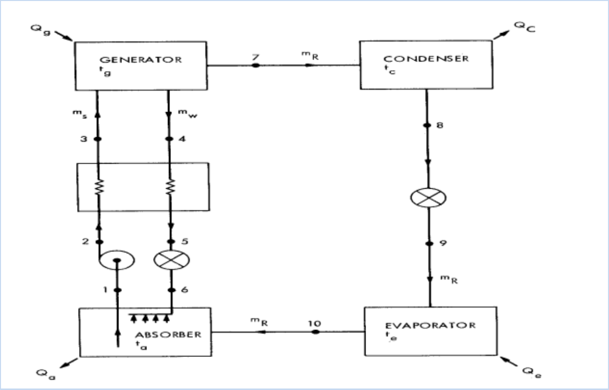

Figure 1. LiBr-H_2O absorption refrigeration system

Mass balance equations of the solution and lithium bromide at the generator can be written as follows:

$$\dot{m}_w = \dot{m}_s + \dot{m}_R \qquad (1)$$

$$\dot{m}_w x_w = \dot{m}_s x_s \qquad (2)$$

where $\dot{m}$ is the mass flow rate (kg s^{-1})), x the lithium bromide concentration, *w*, weak solution, *S*, strong solution and *R*, refrigerant.

The circulation ratio (f) can be defined as the ratio of the mass flow rate of the solution through the pump to the mass flow rate of the working fluid. It must be noted that *f* represents the required pumping energy. It can be expressed in terms of concentrations as follows:

$$f = \frac{\dot{m}_W}{\dot{m}_R} = \frac{x_s}{x_s - x_R} \qquad (3)$$

The measure of performance of refrigerators is expressed in terms of Coefficient of performance; COP, defined as:

$$COP = \frac{Q_E}{Q_G} \qquad (4)$$

The equations for the first law of thermodynamics (energy balance) for components of the system are expressed as follows:

$$\dot{Q}_G = \dot{m}_w h_5 + \dot{m}_R h_7 - \dot{m}_s h_2 \qquad (5)$$

$$\dot{Q}_A = \dot{m}_w h_6 + \dot{m}_R h_{10} - \dot{m}_s h_1 \qquad (6)$$

$$\dot{Q}_C = \frac{Q_E}{(h_{10} - h_8)}(h_7 - h_8) \qquad (7)$$

$$\dot{Q}_E = m_R(h_{10} - h_9) \qquad (8)$$

To simplify the modelling of the system, several assumptions were made: (i) The system operates in a steady state. (ii) Pressure drop along the fluid flow is negligible. (iii) In the condenser, the refrigerant condenses to a saturated liquid, while in the evaporator the refrigerant evaporates to a saturated vapor.(iv) Neglecting pump work.

In the analyses, the properties of water/steam are obtained from correlations provided by ASHRAE [6]. The properties of lithium bromide solution are obtained from correlations found in Talbi and Agnew [7].

III. RESULTS AND DISCUSSIONS

Tables 2 and 3 show the simulation results for the thermodynamic properties and heat transfer rates of each component respectively. In this simulation, calculations were performed for 351.16 kW cooling load and the parameters were taken as T_E = 10°C, T_C = 40°C, T_A=40°C, T_G=90°C, ε= 0.52 (ε is effectiveness). In Table 2, chemical composition and mass flow rates are provided along with temperature, concentration and enthalpy values of the working fluids. As seen from Table 3, compared to other components the generator heat transfer rate is the highest and the solution heat exchanger rate is the lowest.

TABLE 2.
THERMODYNAMIC PROPERTIES OF STATE POINTS (SI UNITS)

S.No.	h (KJ/Kg)	P (KPa)	x (%)	T (°C)	m (Kg/s)
1	-158	1.23	0.56	40	1.64
2	-158	7.38	0.56	40	1.64
3	-80	7.38	0.56	79.2	1.64
4	-69	7.38	62.3	90	1.49
5	-120.3	7.38	62.3	64	1.49
6	-120.3	1.23	62.3	64	1.49
7	2660.16	7.38	0	90	0.149
8	167.2	7.38	0	40	0.149
9	167.2	1.23	0	40	0.149
10	2518.9	1.23	0	10	0.149

TABLE 3.
HEAT TRANSFER RATES OF THE SYSTEM

Components	**Duty**
Generator (Q_g)	476.23 (KW)
Condenser (Q_c)	371.6 (KW)
Absorber (Q_a)	455.18 (KW)
Solution Heat Exchanger(Q_{shx})	71.08 (KW)
COP	0.789

Figure 2 shows that the COP of the system increases with generator temperature by decreasing the condenser temperature and increasing the evaporator temperature. The temperature of the condenser is varied from 36°C to 42°C and the temperature of evaporator is varied from 7°C to 11°C. The Coefficient of performance is greater when condenser temperature is highest and evaporator temperature is lowest. This is due to the decrease in the enthalpy of the refrigerant.

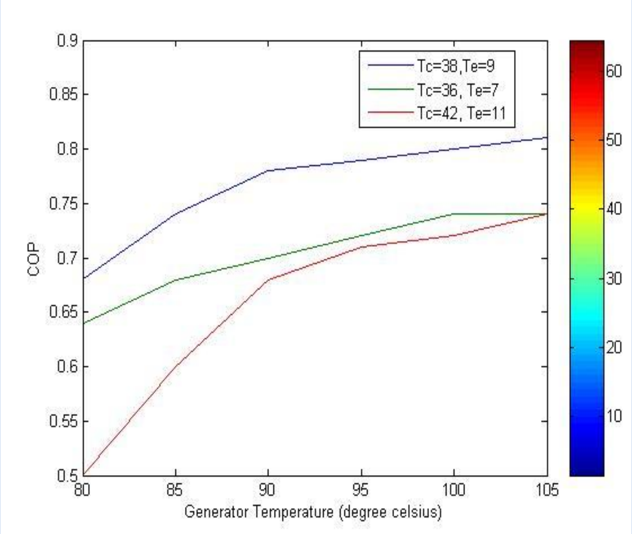

Figure 2. Variation of COP with generator temperature at given evaporator and condenser temperature

Mass flow rate ratio of the system decreases with increase in generator temperature as shown in fig. 3. When we decrease the condenser and increase the evaporator temperature, the value of mass flow rate ratio shows significant decrement for highest condenser temperature nad lowest evaporator temperature. But the mass flow rate ratio increases with increase in absorber temperature by varying the system at the same conditions is shown in fig. 4.

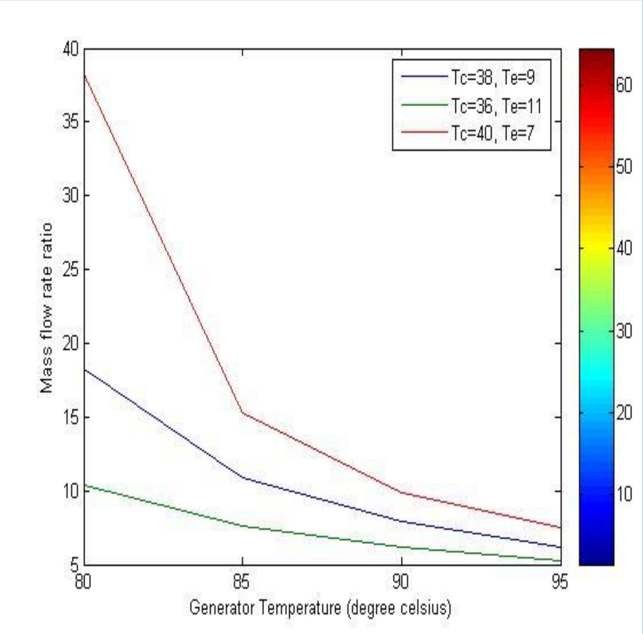

Figure 3. Variation of mass flow rate ratio with generator temperature at given evaporator and condenser temperature

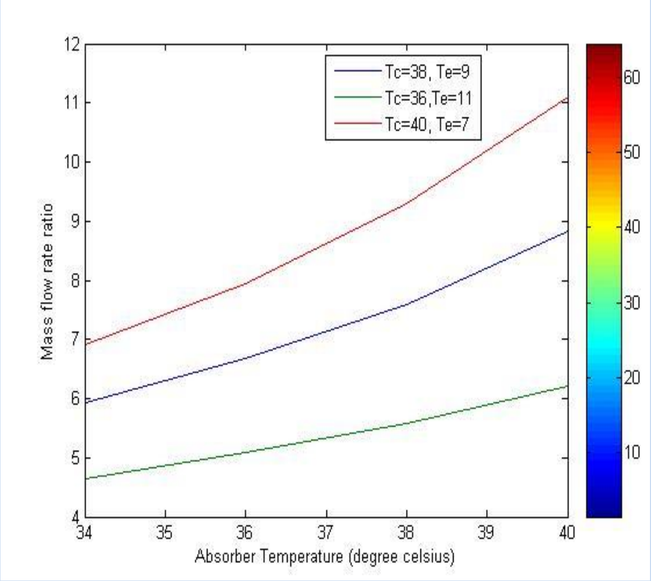

Figure 4. Variation of mass flow rate ratio with absorber temperature at given evaporator and condenser temperature

IV. CONCLUSION

Lithium bromide water absorption refrigeration cycle was analyzed, with their thermodynamic. The coefficient of performance (COP) of this cycle versus generator temperature and absorber temperature was analyzed and it was noticed that the generator temperature is an important factor at the moment to consider the optimum temperature at which a absorption refrigeration cycle operates. The variation of generator temperature and absorber temperature with the mass flow rate ratio determines the maximum temperature that should be used at the generator in order to achieve the maximum COP out of the system. The simulation was carried out for specific temperatures and pressures at the evaporator and condenser and the study must continue in order to obtain operational maps that include the heat exchanger efficiency as a variable.

REFERENCES

[1] Desai AD, Bannur PV. *Design, fabrication and testing of heat recovery system from diesel engine exhaust*. J Inst Engrs 2001; 82:111–8.
[2] Pichel, W., *Development of large capacity lithium bromide absorption refrigeration machine in USSR*.ASHRAE J., 1996, 85(8).
[3] Eisa, M. A. R., Devotta, S., and Holland, F. A. *Thermodynamic design data for absorption heat pump systems operating on water lithium bromide:* Part I: cooling. Applied Energy, 1986, 24, 287–301.
[4] Eisa, M. A. R. and Holland, F. A. *A study of the operating parameters in a water lithium bromide absorption cooler*. Energy Res., 1986, 10(2), 137–144.
[5] Eisa, M. A. R., Diggory, P. J., and Holland, F. A. *Experimental studies to determine the effect of differences in absorber and condenser temperatures on the performance of water lithium bromide absorption cooler*. Energy Convers. Mgmt, 1987, 27(2), 253–259.
[6] ASHRAE Fundamentals Handbook, 1997.
[7] Talbi M, Agnew B. *Energy recovery from diesel engine exhaust gases for performance enhancement and air conditioning*. Appl Therm Eng 2002; 22:693–702.