Scientific Journal of Impact Factor (SJIF): 5.71
e-ISSN (O): 2348-4470
p-ISSN (P): 2348-6406

International Journal of Advance Engineering and Research Development

Volume 5, Issue 04, April -2018

OPTIMIZATION OF PERFORMANCE OF WATER-LITHIUM BROMIDE REFRIGERATION SYSTEM BY SECOND LAW ANALYSIS USING MATLAB

P.Tharun sai[1], Dr.K.Appa Rao[2]

[1]*Mechanical Engineering, LBRCE*
[2]*Mechanical Engineering, LBRCE*

Abstract — *The main objective of Vapour Absorption Refrigeration system (VAR) is to produce refrigeration effect by consuming low grade energy (Heat). The basic components of VAR system are Evaporator, Absorber, Generator, Solution heat exchanger, Expansion valve, Condenser. Since VAR system is heat operated cycle. The temperatures of generator, condenser, evaporator and absorber plays crucial role on performance of the VAR system. To investigate variation of temperatures on each component of VAR system water lithium bromide system is designed for 6.18kW of Refrigeration effect, based on first law analysis and Second law analysis is going to be carried out on each component to identify irreversibilities. The attempts to enhance COP and decline irreversibilities of VAR system is going to be done by optimization of temperatures on generator, condenser, absorber by keeping refrigerating load and evaporator temperature constant and writing entire procedure of thermodynamic analysis in MAT LAB script. The MAT LAB script runs on user provided inputs of generator, evaporator, absorber and condenser temperatures to find out optimum temperatures. After finding out all optimum temperatures the program runs over optimized temperatures (or nearer to optimum temperatures care should be taken to avoid system entering into crystallization zone). And the component in VAR cycle having most irreversibilities is identified (i.e. condenser). To Decrease exergy destruction associated with the condenser to avoid entropy generation in condenser an idea is bring forward to utilize waste heat by placing heat engine. In most of thermal power plants rankine cycle with working fluid as water is used to generate power. Since in condenser the availability of heat is at low temperature compared to thermal power plants. A fluid which can be easily evaporated must be used as working fluid. So refrigerant R-134a is taken as working fluid in rankine cycle. It is placed at condenser to extract some amount of work which is simply rejecting heat at 90ºC to water at 30ºC. So after the performance evaluation(from MAT LAB) of simple VAR system along with optimized temperatures and organic rankine cycle at condenser The results shows that New proposed system will be more efficient than simple VAR system.*

Keywords- *Keywords:-MAT LAB, second law, irreversibilities, crystallization zone, and Organic rankine cycle*

I. INTRODUCTION

In recent years, global warming and ozone depletion have stimulated the researchers to focus their interest in absorption based cooling systems. These systems utilize such absorbent and refrigerant pairs, which have very low or negligible ozone depleting effect. On the other hand absorption based cooling system can be operated using waste heat energy as input. Hence industrial waste heat and heat energy from engine exhaust can be utilized to operate such system. As a result it will reduce the thermal pollution to control global warming with production of cooling effect in an eco friendly way in Reference [1, 2]. However it's COP is comparatively low from that of vapour compression refrigeration system (VCRS). This limitation can be over looked, as vapour absorption systems (VAR) are operated on low grade thermal energies and most importantly it allows avoiding use of chloro fluorocarbons(CFCs) that possess high degree of ozone depletion and a major source of electricity consumer, which causes high demand of electricity during peak summer [3]. It is crucial topromote absorption based cooling system to meet the cooling demand in place of VCRS. A number of researchers have investigated the performance a VAS with aqua-ammonia and lithium bromide (LiBr) – water as absorbent refrigerant pair, with cooling capacity ranges from 5 to 50 kW [4]. Small scale cooling system gives very low COP with slow cooling rate, which require a focus for improvement of its COP with compact designing. Additionally the small scale system must be operating on low temperature driving source. Most of the researchers inclined their work towards aqua-ammonia pair because of the low boiling temperature of ammonia (-33˚ C), which allows to go for cooling effect below 0˚ C [5, 6]. Ammonia is corrosive to copper tubing's, toxic and flammable in nature. In addition to these limitations, water as absorbent is reasonably volatile which leads to presence of appreciable amount of water vapour in ammonia vapour leaving the generator. This may result in clogging of evaporator tubing due to which an analyzer and a rectifier is used in aqua- ammonia system, which increases the system complexity [7]. Based on these restrictions of aqua-ammonia system, LiBr-water absorption system will be more suitable for study. The development of absorption technology started in the early 1700's through 1860. During this period both the H_2O-LiBr and the H_2O-NH_3 machines had been produced with the former machine introduced for cooling of industrial processes and the latter for ice making and food storage. Since then, the two machines have become commercialized and can be acquired in various cooling capacities.

Apart from other studies this paper deals with maximizing system performance by doing second law analysis on the system and running simulation of VAR system with Organic Rankine Cycle. And proposing a new model to increase COP and to decrease irreversibilities. The properties for calculations various state points for solutions at different concentration are taken from R. Gonzales3 and S. A. Nebra2[8].

II. SYSTEM DESCRIPTION AND GOVERNING EQUATIONS FOR THERMODYNAMIC ANALYSIS

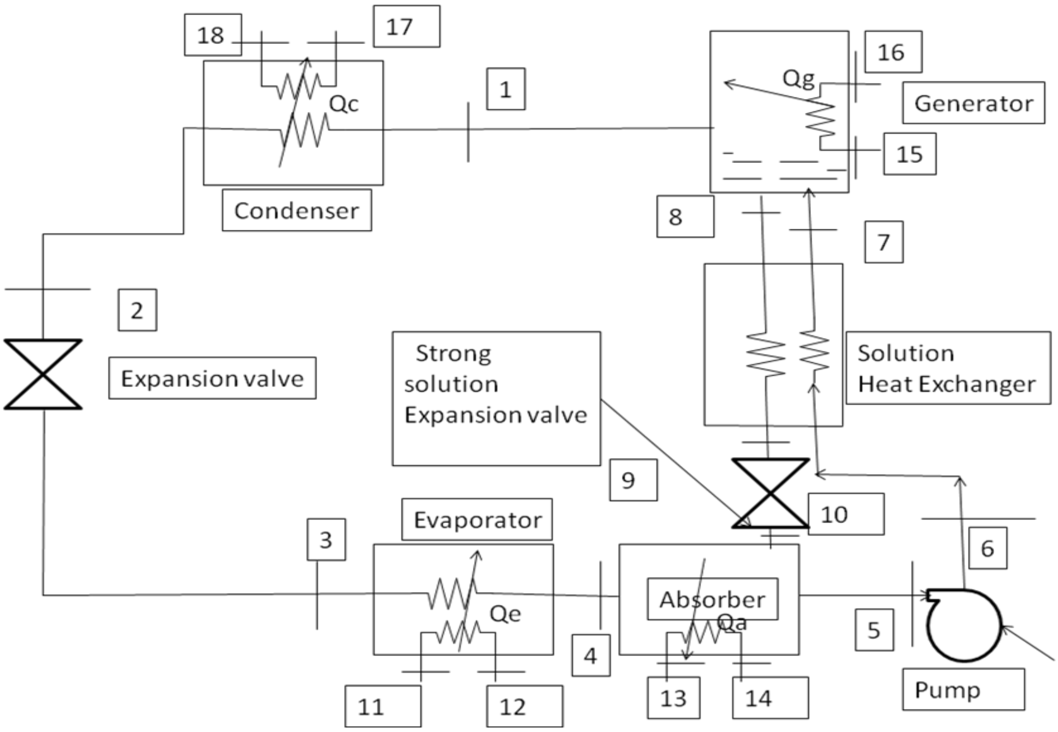

Figure1.Block diagram of Water-lithium bromide refrigeration system

Figure.1 shows main components of Vapour Absorption Refrigeration system Qg is the heat input rate from source rejecting by fluid entering at point 15 and leaving at 16.The Weak solution from the solution. Exchanger enters into generator by gaining heat water vapour at state1 enters into condenser and rejects heat to external circuit. Which flows at cooler temperature (T17) by gaining heat it gets heated taking Qc from the water vapour at Point 1 and converting it into high pressure liquid at Point 2.After the Expansion valve the pressure of refrigerant is decreased to point 3(saturated liquid).After getting Qe heat load from Evaporator circuit refrigerant gains latent heat and becomes saturated vapour at point4, Circulating Water is cooled from Point 11(T11) to Point(12) (T12).In the absorber strong solution absorbs water vapour from the evaporator and becomes weak solution at point 5.pump pressurizes weak solution up to generator pressure at point 6.After entering into solution heat exchanger Weak solution at point 6 is heated to point 7 by taking heat from strong solution coming from generator at point 8(which is equals to generator temperature). The strong solution is cooled to point 9 after heat exchanger and expanded to point 10 after strong solution expansion valve.

First law and Steady state Analysis of Water-Lithium-Bromide Vapour Absorption system

2.1.Mass conservation

min = mout

2.2.Energy conservation

(min). (ein) = (mout). (eout)

2.3.Steady state analysis on each component

2.3.1.Evaporator

$\dot{m}3 = \dot{m}4$

$m11 = m12$

$Qe = \dot{m}3(h4 - h3)$

2.3.2.Absorber

$\dot{m}3 + \dot{m}10 = \dot{m}5$

2.3.3.Refrigerant mass balance

$\dot{m}3 + \dot{m}10\,(\text{ʒ}ss) = \dot{m}5(\text{ʒ}ws)$

$\dot{m}13 = \dot{m}14$

$Qa = \dot{m}3\ h3 + \dot{m}10h10 - m5h5$

2.3.4. Pump

$Wp = \dot{m}5(h6-h5)$

2.3.5. Generator

$\dot{m}7 = \dot{m}8 + \dot{m}1$

$\dot{m}15 = \dot{m}16$

$Qg = \dot{m}1h1 + m8h8 - m7h7$

2.3.6. Condenser

$Qc = \dot{m}1(h2-h1)$

$\dot{m}17 = \dot{m}18$

2.4.Second law analysis to find out irreversibilities on each component

2.4.1.İevaporator $= T0\ [\dot{m}3\ (S4 - S3) + \dot{m}11\ (S12-S11\ )]$

2.4.2İabsorber $= T0[(\dot{m}5S5-(m3S4+\dot{m}10S10)) + \dot{m}13(S14-S13)]$

2.4.3.İshx $= T0[\dot{m}10(S9-S8) + \dot{m}5(S7-S6)]$

2.4.4.İgenerator $= T0[(\dot{m}1S1+\dot{m}8S8)-(\dot{m}7S7)+(\dot{m}15(S16-S15)]$

2.4.5. Total irreversibilities generation rate in universe

$\dot{I}total = \dot{I}generator + \dot{I}shx + \dot{I}absorber + \dot{I}condenser + \dot{I}evaporator.$

III. MATHEMATICAL MODELING OF VAPOUR REFRIGERATION SYSTEM IN MATLAB

The following MATLAB script is a sample part of the VAR model. It operates by taking inputs of Evaporator load, Evaporator temperature, Condenser temperature, generator temperature, absorber temperatures and solution entropies internal to the system, External to the system flow rates in each component are determined by giving input and output temperatures of external loads.

3.1 Initial inputs to the MATLAB script

Evaporator Load = 6.18 kW
Evaporator operating temperature = 5ºC
Condenser operating temperature = 30 ºC
Generator operating temperature = 70 ºC
Absorber operating temperature = 35 ºC
Chilled water entering temperature = 30 ºC
Chilled water cooling temperature = 5 ºC
Absorber Cooling water entering temperature = 30 ºC
Absorber Cooling water leaving temperature = 35 ºC
Generator hot water temperature at entering = 150 ºC (vapour)
Generator hot water leaving temperature = 150 ºC (liquid)

3.2. Sample MATLAB Script

```
te = input('enter evaporator operating temperature in celsius degree: ');
format long
pe = XSteam('psat_T',te);
tc = input('enter condenser operating temperature in celsius degree: ');
pc = XSteam('psat_T',tc);
tg = input('enter generator operating temperature in celsius degree: ');
css = LiBrH2O(tg,pc*10^2);
ta = input('enter absorber temperature in degree celsius: ');
T0 = input('enter surrounding temperature in degree celsius: ');
T0 = T0+273.15;
cws = LiBrH2O(ta,pe*10^2);
disp('circulation ratio = lambda')
lambda=cws/(css-cws);
fprintf('the value of lambda = %d\n',lambda);
Qe = input('enter evaporator load in kw: ');
h3 = XSteam('hL_T',te);
h4 = XSteam('hV_T',te);
mr = Qe/(h4-h3);
fprintf('mass flow rate of refrigerant = %d\n',mr);
disp('mss = mass flow rate of strong solution in kg/sec');
mss = lambda*mr;
fprintf('mass flow rate of strong solution = %d\n',mss);
disp('mws = mass flow rate of weak solution');
```



```
mws = mss+mr;
fprintf('mass flow rate of weak solution = %d\n',mws);
e = input('enter effectiveness of heat exchanger: ');
t9 = tg-(e*(tg-ta));
fprintf('the outlet temperature of weak solution in heat exchanger is t9 in ºC = %d\n',t9);
t7 = ta+(lambda/(1+lambda))*(tg-t9);
fprintf('the outlet temperature of strong solution in heat exchanger is t7 in ºC= %d\n',t7);
disp('Qa is heat liberated in absorber in kw');
h5 = EqLiBrH2O(cws,ta);
h10= EqLiBrH2O(css,t9);
Qa = mr*h4+mss*h10-mws*h5;
fprintf('heat rejected in absorber = %d\n',Qa);
disp('Wp=work done by pump');
Wp = (pc-pe)/1200;
fprintf('work done by pump = %d\n',Wp);
disp('Qg=heat absorbed in generator');
h1 = XSteam('hV_T',tg);
h8 = EqLiBrH2O(css,tg);
h7 = EqLiBrH2O(cws,t7);
Qg = mr*h1+mss*h8-mws*h7;
fprintf('the heat added in genarator Qg in kw = %d\n',Qg)
disp('Qc= heat rejected at the condenser');
h2 = XSteam('hL_T',tc);
Qc = mr*(h1-h2);
fprintf('the heat rejected in condenser in kw = %d\n',Qc);
disp('COP = Coefficient of Performance');
COP = Qe./Qg;
```

3.3. COP and Irreversibilities obtained from MATLAB script are

COP = 0.85185
İtotal = 2.369 kW
second law efficiency = 0.45631
The above results are validated with the theoretical results.

IV.METHODOLOGY TO IMPROVE PERFORMANCE OF VAR

The methodology to improve COP of VAR system involves optimization of temperatures using second law analysis and components with higher irreversibilities are identified using MATLAB script and the temperature of each component is iterated by keeping remaining component temperatures constant. Upon completion of this process in all the components of VAR cycle the temperature that produces minimum irreversibilities were identified as optimum temperatures for the VAR cycle. And MATLAB script itself identifies the component that produces higher irreversibilities. Since higher irreversibilities are indication of heat exchange through finite temperature gradient script automatically run a Organic Rankine Cycle (ORC) at that component to recover some of exergy destruction as work.

V.SIMULATION OF VAPOUR ABSORPTION REFRIGERATION SYSTEM

The VAR system is simulated for various values of evaporator, absorber, generator and condenser temperatures to obtain optimum temperatures the optimum temperatures are obtained as follows
Evaporator operating temperature = 10ºC
Condenser operating temperature = 35 ºC
Generator operating temperature = 85 ºC
Absorber operating temperature = 30 ºC
Chilled water entering temperature = 30 ºC
Chilled water cooling temperature = 10 ºC
Absorber Cooling water entering temperature = 25 ºC
Absorber Cooling water leaving temperature = 30 ºC
Generator hot water temperature at entering = 130 ºC (vapour)
Generator hot water leaving temperature = 130 ºC (liquid)
After finding optimum temperatures the optimum values are given to the MATLAB script coefficient of performance of VAR and irreversibilities are obtained as follows.

COP = 0.867
İtotal = 1.94170 kW
second law efficiency of system = 0.50435

VI.INCORPORATION OF ORGANIC RANKINE CYCLE AT CONDENSER

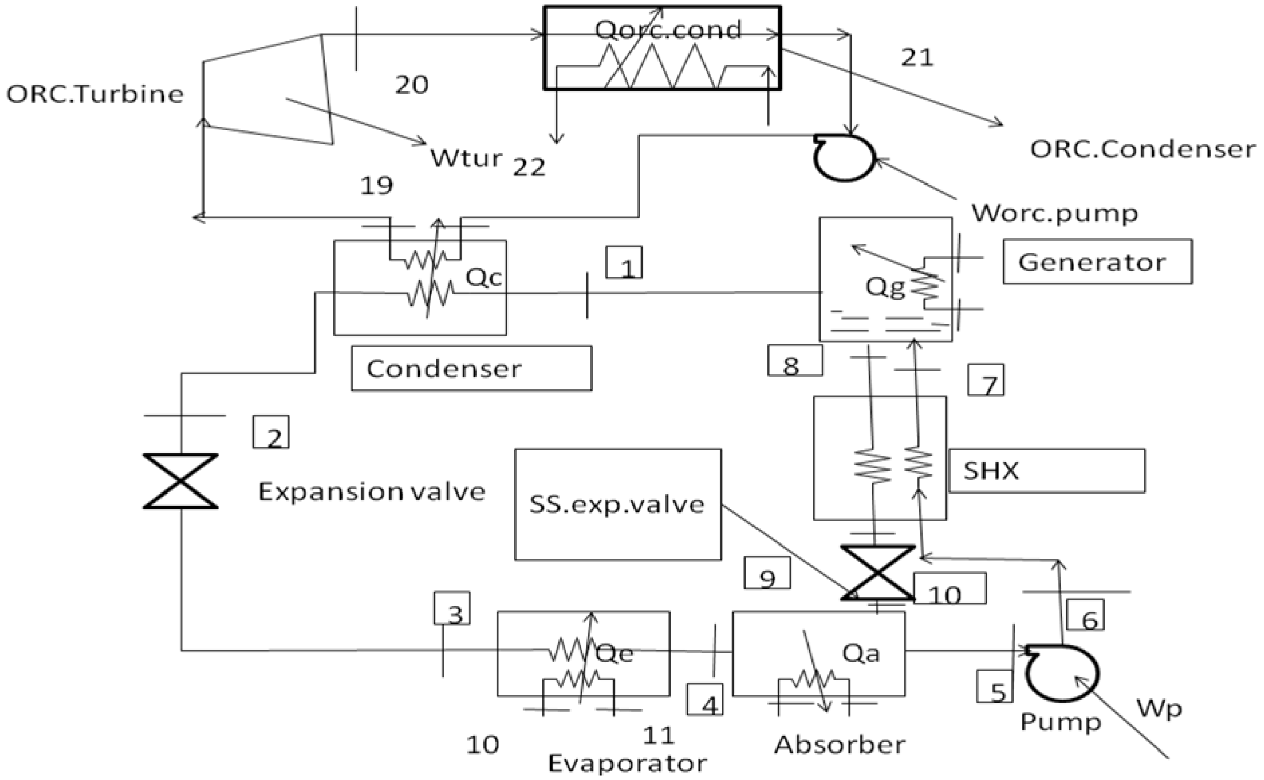

Figure.2. Proposed VAR system with Organic Rankine Cycle at condenser

From obtained performance parameters though there is decrease in irreversibilities but irreversibilities at condenser are not decreasing considerably due finite temperature difference. So to conserve some exergy destruction a heat engine can be placed. If there is no chance of optimizing temperatures in a cycle by installing heat engine the finite temperature difference between cooling water and vapour rejecting heat in condenser is causing so much entropy generation due to lack of reversible heat transfer so between these temperature limits heat engine can be placed to extract work. which ultimately decreases irreversibilities generated at condenser. By applying both methods the COP of system can be increased.

6.1. Designing of Organic Rankine Cycle at condenser

Working fluid = R-134a
Refrigerant leaving Temperature from gaining heat from condenser = 70 ºC(v)
Refrigerant Entering Temperature from pump = 35 ºC(l)
Refrigerant leaving from turbine = 35 ºC(v)
Organic Rankine cycle condenser Refrigerant leaving temperature = 35 ºC(l)
Cooling Water entering into Organic Rankine cycle condenser = 25ºC
Cooling Water leaving Organic Rankine cycle condenser = 30 ºC
With the following input parameters the ORC system extracted 0.504kw of energy from the turbine which increased the performance factor by 25%.

6.2. Results Obtained from MATLAB Script with optimized temperature and organic rankine cycle are obtained as follows

Work obtained from Organic Rankine cycle = 0.5124 kW
Refrigerant Effect = 6.18 kW
(COP)VAR = 0.8671
Organic Rankine Cycle Efficiency = 8.51%
Combined Performance Factor = 0.9259%
Irreversibilities associated with combined cycle = 1.77 kW

VII.CONCLUSION

From the above obtained results it can be concluded that after the installation of organic rankine cycle at the condenser the irreveribilities losses are minimized in condenser, in order to optimize the temperature at the condenser it is more efficient to place a heat engine cycle at the condenser. With installation of new proposed system and optimization of temperatures from second law analysis the Coefficient of Performance is increased to 8% and Irreversibilities are minimized by 25%. Since the VAR systems are not using high grade energy which is coming from the combustion of fossil fuels the attempts to increase the VAR system COP will encourages society to use VAR systems equipped with Organic Rankine cycles which will make a positive impact on global warming issues.

REFERENCES

[1] Lieb EH, Yngvason J. “A fresh look at entropy and the second law of thermodynamics”. PhysToday2000;53(4):32–6.

[2] Ogulata RT, Doba F. “Experiments and entropy generation minimization of across-flow heat exchanger”. Int.J.Mass.Transfer1998;41(2):373 -81.

[3] Vargas J, Bejan A, Siems D. “Integrative thermodynamic optimization of cross-flow heat exchanger for an aircraft environmental control system”. J Heat transfer 2001;128:760 -9.

[4] Adewusi S.A., Syed M. Zubair. “Second law based thermodynamic analysis of ammonia– water absorption systems. Energy Conversion and Management” 2004;45:2355–2369.

[5] Chen J, Schouten JA.” Optimum performance characteristics of an irreversible absorption refrigeration system”. . Energy Conversion and Management 1998;39:999–1007.

[6] Chua HT, Toh HK, Ng KC. “Thermodynamic modeling of an ammonia/water absorption chiller”. Int J Refrig 2002;25:896–906.

[7] Kececiler A, Acar HI, Dogan A. “Thermodynamic analysis of absorption refrigeration system with geothermal energy: an experimental study”. Energy Conversion and Management 2000;41:37–48.

[8]”Exergy calculation of lithium bromide–water solution and its application in the exergetic evaluation of absorption refrigeration systems LiBr-H2O” Reynaldo Palacios-Bereche1,2, R. Gonzales3 and S. A. Nebra2,, h.

