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Conference Title

Modeling of Energy Extraction in Vapor Absorption Refrigeration System

R.Shankar[a],T.Srinivas [b]a*

[a]*VIT University,Vellore-632014,Tamil Nadu,India*
[b]*VIT University,Vellore-632014,Tamil Nadu,India*

Abstract

There is energy, where the weak solution flows form generator to condenser and it is extracted by implementing the turbine. The super heater is used to make the ammonia vapor to superheated state to run the turbine and exit is still saturated vapor. Additional super heater and turbine is used to recover more energy from the integrated power and cooling cycle. The mass separation is made after the first turbine for cooling and power and extracted heat from solar exit temperature. The single generator plays a role for both cooling and power cycle. The maximum power of 25.52 kW from first turbine and 23.68 kW from second turbine with cooling of 142.68 kW are obtained, at solar exit temperature of 443.16 K with weak and strong solution concentration of 0.45 and 0.95 respectively. For weak solution concentration of 0.99 to the inlet of the turbine, the power produced is less because of mass difference.

Keywords : energy extraction,aqua-ammonia,combined power etc

1. Introduction

The cooling cycle is used all over the world for refrigeration and air conditioning whether it may be vapor compression cooling or vapor absorption cooling.

* Corresponding author. Tel.: +919788197582.
E-mail address: gentlewise26@yahoo.com.

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Nomenclature

h	Enthalpy (kJ/kg)
m	Mass (kg)
P	Pressure (bar)
Q_E	Cooling Output (kW)
T	Temperature (K)
x	Concentration (kg/kg)
$W1$	Power from turbine1 (kW)
$W2$	Power from turbine2 (kW)
G	Generator
HE	Heat exchanger
RC	Reflux condenser/ dephlegmator
SH	Super heater

For modeling the engineering circuit, the confirmation is done by using first and second law of thermodynamics. Here the circuit is designed and conformed by using the same. Manufacturing an experimental setup of an innovative idea, the basic process of mathematic modeling and simulation is required. The modeling is done for aqua-ammonia vapor absorption and refrigeration system with suitable energy extraction material. It helps for finding out the changes in the system by changing the design parameters like ammonia concentrations, solar exit temperature etc. The thermodynamic modeling and MATLAB programming are done for extraction of energy from vapor absorption refrigeration system. The alteration is made in the refrigeration cycle by including turbine and super heater.

The ammonia is suitable for heat recovery and power production proposed by Kalina. [1-2]. The refrigeration cycle with single turbine for energy extraction is done by Goswami[5-8] and concluded power production and exit of turbine has cooling. The exit of turbine is saturated vapor after extraction of energy by the turbine, when inlet is superheated vapor. The energy required is less for making saturated vapor to superheated vapor, so the additional super heater and turbine is added in the system. The properties of aqua-ammonia are predicted by using the equation given by Goswami[13], Ziegler & Trepp[13].

2. Modeling of the system

The system is designed for all condition but the analysis is made for Indian condition. The absorber exit temperature is maintained as 303.16 K, and evaporator exit as 283.16 K. The exit pressure of first turbine is maintained half of the vapor pressure. The exit pressure of first turbine goes to the inlet pressure of the second turbine but with superheated vapor. Turbine2 exit pressure is always maintained with sink pressure, so the cooling is happened. The degree of super heater is 5 K for turbine2 and 10 K for turbine1 because of mass difference. The mass of 1kg/s of strong solution concentration from absorber are flows to the generator via heat exchanger. The vapor pressure formula is used to find the generator pressure $P(T,x)$ [13]. The weak solution concentration is assumed to be x=0.08 less than the turbine inlet concentration. The solar exit temperature is decreases step by step from super heater to generator. The weak solution from generator is superheated to run the turbine, the energy is extracted and exit is still vapor [5-8]. The mass of ammonia vapor is separated (m_8 is separated as m_{16} and m_{20}) after the energy extracted form turbine1 for additional power and cooling cycle. The saturated ammonia vapor is condensed as liquid and pressure is reduced in the expansion process for continuing the cooling cycle.

The remaining separated mass moves to the turbine2 after getting superheated, the energy is again extracted by the turbine and the exit is saturated vapor. The ammonia vapor is mixed to the returning strong solution concentration and moves to the absorber. The mass and energy balance equation are used to find mass and concentration at various points of the system.

For generator:

$$F_g = \frac{m_5}{m_3} = \frac{(x_{10} - x_3)}{(x_{10} - x_5)} \quad (1)$$

For dephlegmator:

$$F_{deh} = \frac{m_6}{m_5} = \frac{(x_9 - x_5)}{(x_9 - x_6)} \quad (2)$$

The equation (2) is used to find the temperature and concentration values at the point 9. To find out the value for the point 9 $T(x_9, P_9)$ is equal to $T(x_6, P_6)$. The inlet of reflux condenser as some water and it is removed. The above mass balance equation is used to predict the mass at concentration at respective points along with energy equation.

For power & cooling:

$$W_1 = m_7(h_7 - h_8) \quad (3)$$

$$W_2 = m_{17}(h_{17} - h_{18}) \quad (4)$$

$$Q_E = m_{22}(h_{23} - h_{22}) \quad (5)$$

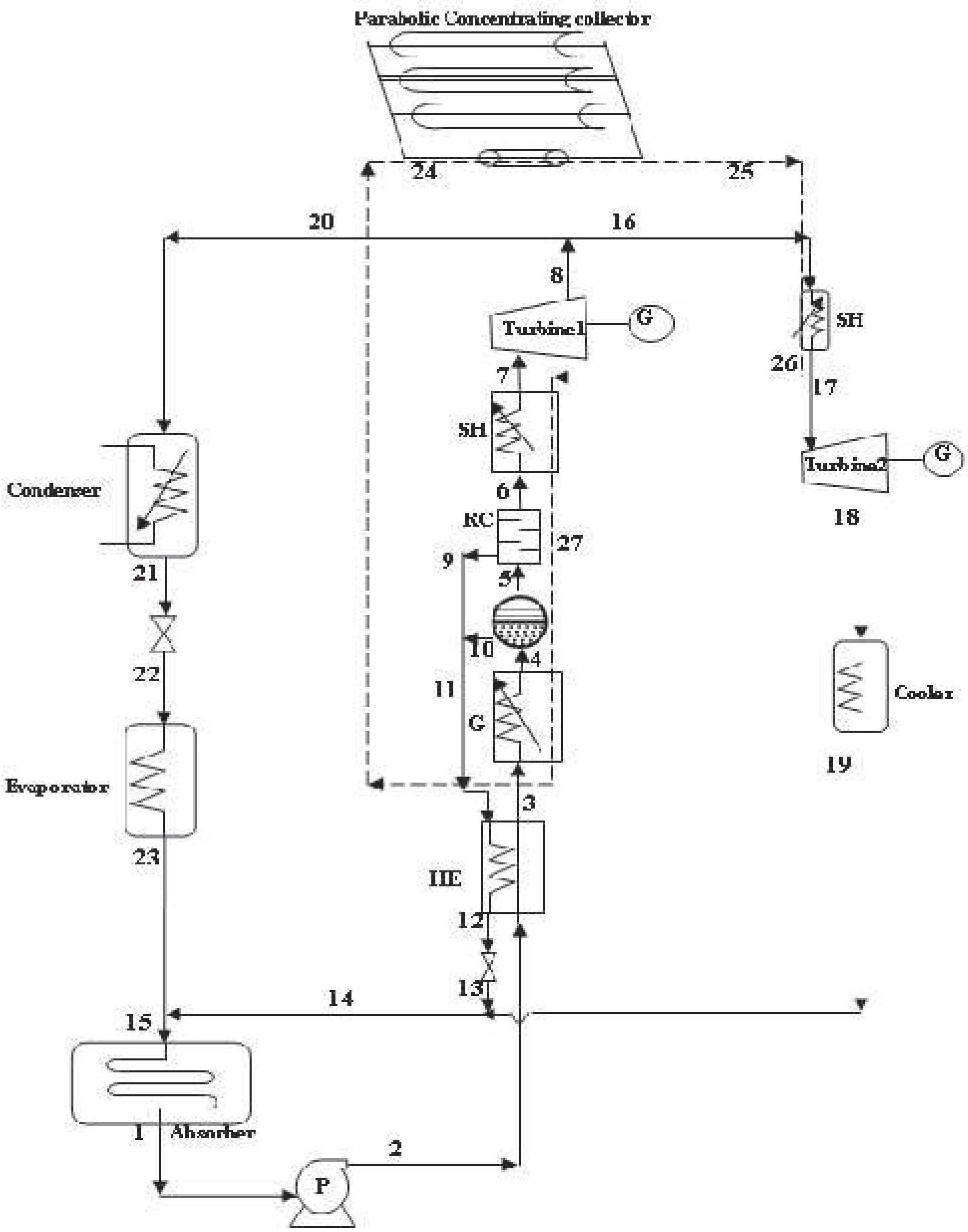

Fig .1.Diagram for extraction of energy from vapour absorption refrigeration system

3. Results and discussion

3.1. Cooling

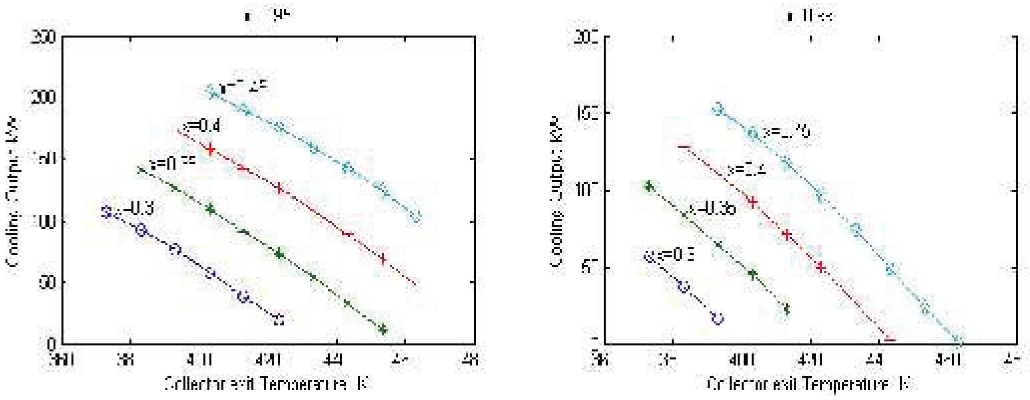

Fig.2.Comparision of cooling output with solar exit temperature

Goswami conducted the experiment based on the combined power and cooling system using aqua-ammonia vapor absorption refrigeration system. And gives the statement cooling is achieved at the exit of turbine, when high pressure and weak solution concentration is maintained. Less cooling is achieved as result. Here the system design is altered to get both cooling and power to overcome the wastage of energy. The cooling output of the modified system is given in the Fig.2, at various concentrations of weak and strong solution with respect to the solar exit temperature. The cooling obtained in the strong solution concentration of 0.45 and weak solution concentration of 0.5 is high compared to the weak solution concentration of 0.99. The reason for getting more cooling in 0.95 weak solution concentration is the difference in mass flow rate. I.e. the mass flow rate decreases at point 22.

3.2. Double power

The refrigerant ammonia is well suited for attaining maximum cooling and mostly used in vapor absorption refrigeration system. As same as cooling ammonia is also suitable for power proposed by Kalina and it is used for heat recovery system. Analysis part is most important before manufacturing the system to meet our needs. The analysis of power at various solar exit temperatures is given in the Fig.3. Higher the vapor pressure in the generator lower the mass of ammonia vapor in the turbine, because of increase in bubble point temperature. [12]. One of the main motives of aqua ammonia refrigeration is to reduce the amount water vapor content in the weak solution else ice blockage problem will occur, problem solved by dephlegmator. So more the amount we can not decrease the amount of weak solution concentration to attain maximum power. The double turbine plays a role to meet the need of power as well as cooling. The power produced in the turbine 1 is simultaneously decreasing with temperature due to increase in vapor pressure and maintaining the exit of turbine pressure as half of the turbine inlet pressure.

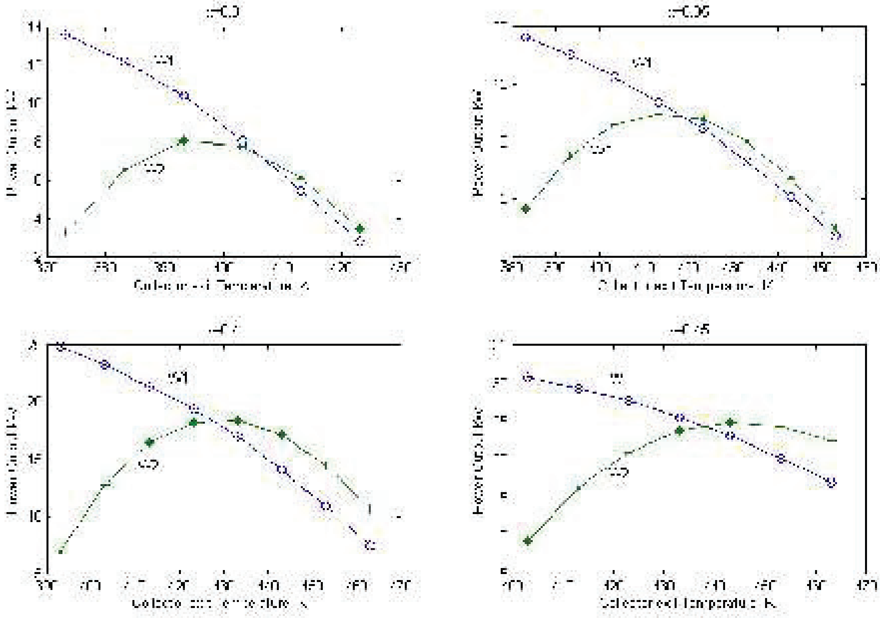

Fig.3.comparision of power output for turbine inlet concentration of 0.95

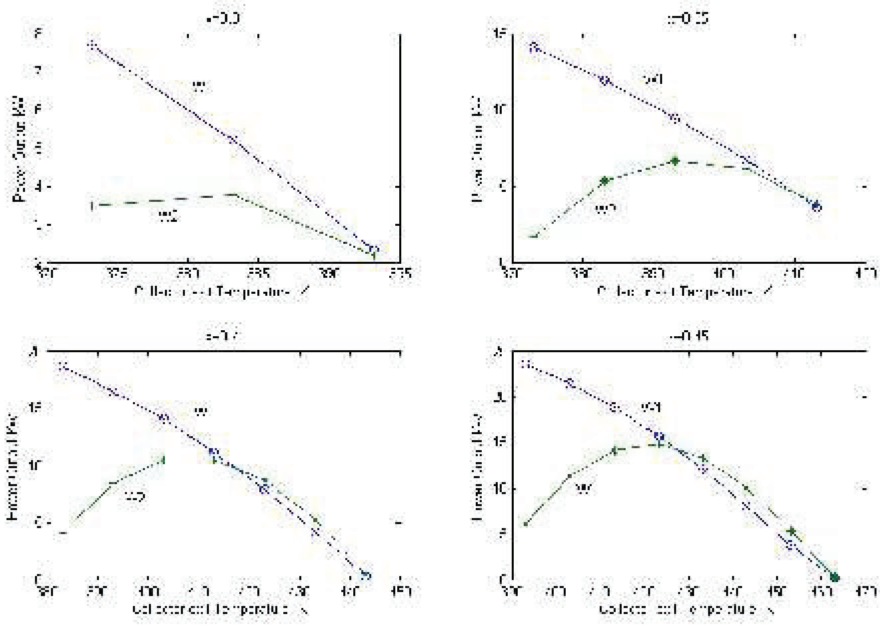

Fig.4.comparision of power output for turbine inlet concentration of 0.99

But for case of turbine 2, the exit pressure of the turbine is respect to the absorber pressure. It attains the optimum power and then decreases shown in the Fig .3 & 4.At low temperature the system unable to work more over the vapor pressure is less than absorber pressure. The strong solution of 0.3 concentrations works in the range of 373.16-423.16 k of solar exit temperature when weak solution concentration maintained at 0.95, but for 0.99 weak solution concentration working temperature range is low. The optimum working condition depends on the weak and strong solution concentration.

4. Conclusions

The maximum energy is extracted from the vapor absorption refrigeration system. For absorption concentration of 0.45 and temperature of 443.16 K, the maximum power obtained is 25.52 kW and 23.68 kW from first and second turbine respectively at turbine inlet concentration of 0.95. For same absorber concentration and turbine inlet concentration of 0.99, the power is less and shows optimum temperature of 393.16 K. Similarly for cooling at 0.95 concentration gives maximum of 142.68 kW and 0.99 concentrations gives 110.49kW but works at low temperature.

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