Thermal Design Calculations for Single Effect Vapour Absorption Machine (VAM) using LiBr-H_2O

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Abstract:

In this article, single effect Vapour Absorption Machine (VAM) using LiBr-H_2O focused for the study. This thermal design considered mass flow rate of each fluid flowing through the system and operating temperatures of them. By the use of graphical and numerical calculations, enthalpy of each state has been carried out. During a thermal design, it is concluded that the concentration ratio of LiBr-H_2O in absorber and generator played a major role during the operation of generator and absorber. Crystallization zone is also the factor to be taken care in operation of vapour absorption system which also effect on the concentration ratio. Finally COP has been calculated. To validate method data is taken of 15 TR VAM for thermal design.

Keywords:- Refrigeration; Absorption; Water/lithium bromide

Introduction:

In current era, Vapour Absorption Machine (VAM) technology is the most preferable for the field of cooling effect for industrial aspects. VAM is technology that can be used waste heat of industry to achieve cooling water and cooled air for various purposes. So, VAM is simply called as Cooling from Heating. Since past few decades, Vapour compression machines (VCM) are widely used but because of harmful refrigerants and global warming effects to environment, it is a challengeable to find out new options of cooling and refrigeration.

P.S. Arshi Banu, N.M. Sudharsan done the detailed thermodynamic analysis of the half-effect,single-effect,1.5-effect,double-effect,triple-effect Vapour absorption system using different working fluids. Main aim behind this analysis is analysis the different parameter effect on the system and choose the right parameter for enhancement of the system in comparison of the conventional system [1].A simple theoretical analysis based on Energy and Exergy calculations shown very effectively by Akhilesh Arora, S. C. Kaushik. Various parametric effects on COP explained [2]. T. Avanessiana, M. Ameria explain the different water cooled LiBr-H2O absorption system with different operating conditions and compared it, also they did the economic analysis of the system [3]. G. A. Florides, S. A. Kalogirou, S. A. Tassou, L. C. Wrobel model and simulate the solar operated absorption cooling system [4]. The system is modelled with the TRNSYS simulation program and the typical meteorological year file containing the weather parameters. A method to evaluate the characteristics and performance of a single stage lithium bromide (LiBr)–water absorption machine. The necessary heat and mass transfer equations and appropriate equations describing the properties of the working fluids are specified. These equations are employed in a computer program, and a sensitivity analysis is performed. The difference between the absorber LiBr inlet and outlet percentage ratio, the coefficient of performance of the unit in relation to the generator temperature, the efficiency of the unit in relation to the solution heat exchanger area and the solution strength effectiveness in relation to the absorber solution outlet temperature are examined [5]. Author proposed a systematic mathematical programme for environmentally conscious absorption cooling systems. Aim of this analysis is do the multi-dimensional analysis of the system at the design stage, and minimize the cost and environment impact of the system[6].A experimental analysis of solar powered single and double effect system is carried out in this paper. In this system parabolic through collector is used and COP of single effect and double effect is measured experimentally. Adsorption chiller are more bulky and expensive than absorption chiller. In double effect chiller high operational cost and investment is required. In this analysis many parameters like solar beam radiation, ambient temperature, inlet and outlet temperature of parabolic through collector and energy losses from pipe and hot water storage tank is investigated. Results show that performance if a system is increased by increasing hot water temperature and temperature of chilled water is also more influenced on performance of system [7]. Y. Fan, L. Luo_, B. Souyri study the recent development in the area of solar sorption technologies. In this adsorption and absorption technologies are discussed with basic principles. This paper provides the operating temperature of different system and range of the COP of the system [8]. Francis Agyenim , Ian Knight , Michael Rhodes performs the experimental investigation of outdoor LiBr/H20 solar operated vapour absorption system with cold store. In this system vaccum tube collector is used with cold storage tank and fan coil unit. This paper check the feasibility of new concept of cold store in this system. Results show that in hot sunny day when the solar insolation is very high than they achieved a COP of 0.64 very near to optimum value of 0.7 and average cop of system with the ambient temperature 24 ℃ is 0.58. Results show that new concept of cold store is feasible for this system[9]. M.I. Karamangil a, S. Coskun b, O. Kaynakli a,*, N. Yamankaradeniz b done the literature review on the vapour absorption refrigeration system and refrigerant-absorbent pair and recent year and also done the thermodynamic analysis of the system. Results show that LiBr-H2o pair is higher COP value but the it operates with narrow temperature range as compare to ammonia- water pair because of the possibility of crystallization. NH3–LiNO3 pair is best suited for low generator temperature. Effectiveness of solution heat exchanger have a much more effect on the performance of the system than the effectiveness of refrigerant heat exchanger [10]. K.E. N'Tsoukpoe, N. Le Pierrès, L. Luo study the LiBr-h2o absorption process with thermal storage system. In this study detailed analysis of absorption process is carried out by 20 test on experimental setup which contains two storage tank and two faaling film heat exchanger. Problem in this study is crystallization occurs in the storage tank because of inadequate design of the absorber, for this problem they suggest investigation of various additives in the storage tank[11]. Kokouvi Edem N'Tsoukpoe a,1, Maxime Perier-Muzet a, Nolwenn Le Pierre`s a,⇑,Lingai Luo a,2, Denis Mangin b, done the thermodynamic analysis of the absorption process with the help of solar thermal collector and the storage tank with the crystallization of the solution. This analysis done for system in which there is two tank and one heat exchanger. Results show that with the increase in the crystallization storage density of the tank increases and charging process is more efficient process than discharging, for this improvement in design of the desorber is suggested [12]. Ming Qu a,*, Hongxi Yin b,1, David H. Archer c,2 sytudied the experimentally solar thermal heating and cooling technologies. This system contain parabolic through collector for conversion of the solar energy and this model is smallest double-effect model in the world. After the analysis of the system in TRANSYS author suggested some design parameters for the solar heating and cooling system for the buildings[13].

METHDOLOGY

❖ THERMODYNAMIC ANALYSIS OF VAPOUR ABSORPTION SYSTEM:-

- Schematic diagram of the vapour absorption system is as shown in figure 1

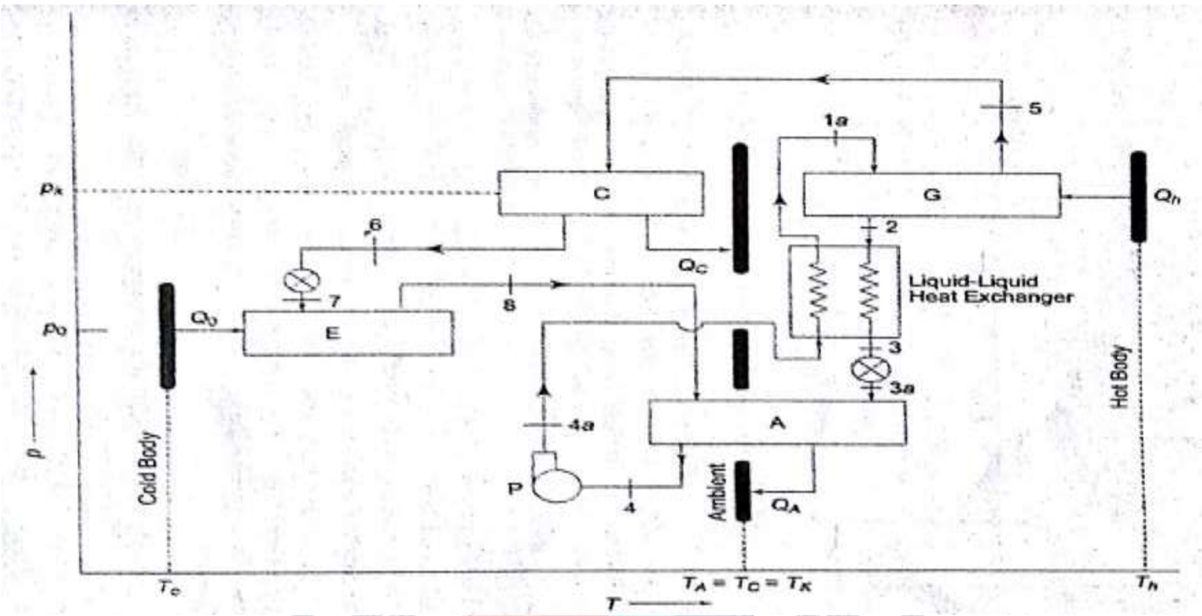

Figure 1:- Schematic of vapour absorption system.

- The system consists, basically, of a generator, absorber, condenser, evaporator, pump,expansion valves, solution heat exchanger (SHE) .The cycle efficiency of the vapour absorption system is depend on temperatures of the component, working fluid, concentration ratio and effectiveness of solution heat exchanger.
- The SHE heats the cool solution from the absorber on its way to the generator and cools the solution returning from the generator to the absorber. Thus, the heat load decreases in the generator, and the COP increases.
- Now , first from temperature values of condenser and evaporator find the values of pressure at higher and lower side of refrigeration system.
- To find out enthalpy at point 4, first find out the concentration of LiBr in absorber from ln p vs T graph, then using this value of concentration find out enthalpy of state point 4 from h- ξ graph.
- To find out enthalpy at point 2, first find out the concentration of LiBr in absorber from ln p vs T graph, then using this value of concentration find out enthalpy of state point 2 from h- ξ graph.
- To find out enthalpy at point 1, first find out temperature at point 1, then using this temperature value and concentration value of LiBr in absorber find the enthalpy at point 1 using h- ξ graph.
- To find out enthalpy at point 3, first find out temperature at point 3, then using this temperature value and concentration value of LiBr in generator find the enthalpy at point 3 using h- ξ graph.
- State 3 has the same enthalpy, temperature and composition as state 3, at generator pressure.

- By using the values of condenser temperature and concentration of LiBr in absorber we can find out the enthalpy at state point 4a using h- ξ graph.
- To find out enthalpy at state point 1a, first find out the specific solution circulation rate using this equation:- $f = (1 - X_{w2}) / (X_{w1} - X_{w2})$, then do energy balance at solution heat exchanger.
- Enthalpy at state point 5 can be found by this equation :- $h_5 = (2501 + 1.88t)$ at generator temperature.
- At point 6 there is saturated liquid so find out enthalpy at this point use this equation:- $h_6 = 4.1868 * t$ at condenser temperature. (enthalpy of point 6 & 7 are same).
- To find out enthalpy at point 8 use this equation:- $h_5 = (2501 + 1.88t)$at evaporator temperature.
- At last using the values of enthalpy find out the COP and do the heat balance of the system.
- We apply this methodology to above data and we get the results as below:-

Table 1:-Operating Conditions for Different Cases

Component Name	Operating Temperature (℃) (Case 1)	Operating Temperature (℃) (Case 2)	Operating Temperature (℃) (Case 3)	Operating Temperature (℃) (Case 4)
Evaporator	8	10	10	8
Generator	87	97	97	87
Condenser	34	40	34	40
Absorber	34	40	34	40

Table 2:- Results of Analysis

X_{LiBr}(Generator)	**63.5%**	**65%**	**68.36%**	**61.31%**
X_{H2o} (Generator)	**36.5%**	**35%**	**31.64%**	**38.69%**
X_{LiBr} (Absorber)	**54%**	**55%**	**52%**	**56.54%**
X_{H2o} (Absorber)	**46%**	**45%**	**48%**	**43.46%**
h_1	**143.5KJ/Kg**	**166KJ/Kg**	**130.2KJ/Kg**	**173.4KJ/Kg**

h_{1a}	127.89KJ/Kg	151KJ/Kg	112.1038KJ/Kg	164.98249 KJ/Kg
h_2	222.952KJ/Kg	248KJ/Kg	265.5KJ/Kg	211.9KJ/Kg
$h_3 = h_{3a}$	165.774KJ/Kg	180KJ/Kg	213.5KJ/Kg	141KJ/Kg
$h_4 = h_{4a}$	79.276 KJ/Kg	93.5KJ/Kg	72.55KJ/Kg	99.6KJ/Kg
h_5	2664.56KJ/Kg	2683KJ/Kg	2683.36KJ/Kg	2664.56KJ/Kg
h_6	141.712KJ/Kg	167.5KJ/Kg	141.712KJ/Kg	166.72KJ/Kg
h_7	141.712KJ/Kg	167.5KJ/Kg	141.712KJ/Kg	166.72KJ/Kg
h_8	2516.04 KJ/Kg	2520KJ/Kg	2519.8KJ/Kg	2516.04 KJ/Kg
f (Specific solution circulation rates)	6.6842105 Kg/Kg of vapour	6.5Kg/Kg vapour	4.178Kg/Kg vapour	12.85325Kg/Kg vapour
Heat supplied	3077.0224KJ/Kg	3066KJ/Kg	3058.75KJ/Kg	3055.55KJ/Kg
Refrigerant Effect	2374.328KJ/Kg	2352.5KJ/Kg	2378.088KJ/Kg	2349.32KJ/Kg
COP	0.7716	0.7672	0.7774	0.7688

Conclusion and Results:-

- From the above calculation we concluded that if increasing the all operating temperature of the system so there is small decrease is specific solution circulation rate and the COP, and on the side if we increase the generator and evaporator temperature than the COP will increase and specific solution circulation rate decrease and if we increase the temperature of the absorber and condenser than the specific solution circulation rate increases and COP will decrease.

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