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Methods for improving thermal performances of vapour absorption system using heat pipes

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Abstract

Several types of types of VAR systems such as single effect, double effect, triple effect etc. Energy-exergy analysis have been performed in the literature so far. The heat pipes can be made an integral part of the system and these valuable thermodynamic analyses can be executed for improving its thermal performances. In terms of energy efficiency (COP) and exergetic efficiency. Another problems is the waste heat going to the environment from condenser has never been used, which can be supplied back to the generator is required low grade energy for its operation can be used for improving its thermal performances.

The VAR system can be coupled with other systems may be refrigerating or power generating in which heat is released in the loop heat pipes will make the system compact, and that effect must be studied to optimize the performance of the VAR systems. It was observed that intra-Cycle heat exchange in the VAR system reduces heat input thus improved in the thermal performance in terms of first law efficiency(Energy-Efficiency) and second law efficiency (Exergetic efficiency) of the VAR system and highly effective heat exchange through the heat pipe due to removal of condenser exergetic losses improved second law performances. Similarly the gas power plant coupled with modified vapour absorption refrigeration improves the first law efficiency in terms energy-efficiency (COP) and second law efficiency in terms of exergetic efficiency with reduction in system exergy destruction ratio.

Keywords: Thermodynamic analysis, Heat Pipes, Vapour Absorption Refrigeration Systems, Exergy-Energy Analysis

1. Introduction

Vapour Absorption Refrigeration Systems (VARS) belong to the class of vapour cycles similar to vapour compression refrigeration systems. However, unlike vapour compression refrigeration systems, the required input to absorption systems is in the form of heat. Hence these systems are also called as heat operated or thermal energy driven systems. Since conventional absorption systems use liquids for absorption of refrigerant, these are also sometimes called as wet absorption systems. Similar to vapour compression refrigeration systems, vapour absorption refrigeration systems have also been commercialized and are widely used in various refrigeration and air conditioning applications. Since these systems run on low-grade thermal energy, they are preferred when low-grade energy such as waste heat or solar energy is available. Since conventional absorption systems use natural refrigerants such as water or ammonia they are environment friendly.

Condenser

Just like in the traditional condenser of the vapor compression cycle, the refrigerant enters the condenser at high pressure and temperature and gets condensed. The condenser is of water cooled type.

Expansion valve or restriction

When the refrigerant passes through the expansion valve, its pressure and temperature reduces suddenly. This

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refrigerant (ammonia in this case) then enters the evaporator.

Evaporator

The refrigerant at very low pressure and temperature enters the evaporator and produces the cooling effect. In the vapor compression cycle this refrigerant is sucked by the compressor, but in the vapor absorption cycle, this refrigerant flows to the absorber that acts as the suction part of the refrigeration cycle.

Absorber

The absorber is a sort of vessel consisting of water that acts as the absorbent, and the previous absorbed refrigerant. Thus the absorber consists of the weak solution of the refrigerant (ammonia in this case) and absorbent (water in this case).

When ammonia from the evaporator enters the absorber, it is absorbed by the absorbent due to which the pressure inside the absorber reduces further leading to more flow of the refrigerant from the evaporator to the absorber. At high temperature water absorbs lesser ammonia, hence it is cooled by the external coolant to increase it ammonia absorption capacity.

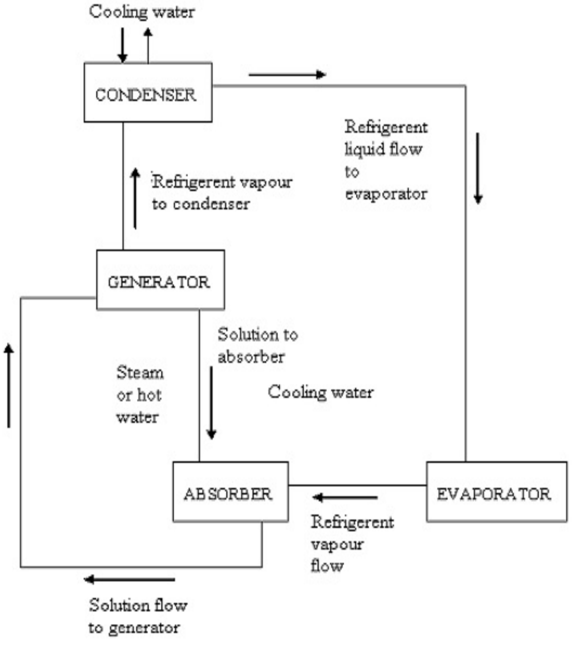

Figure.1: Vapor Absorption Refrigeration System

The absorption refrigeration system comprises of condenser, expansion valve, evaporator, absorber, pump and generator. The refrigerant leaving the evaporator enter the absorber, where it is absorbed by the absorbent. The strong solution of refrigerant-absorber enters the generator with the help of the pump. The refrigerant then enters the condenser while the remaining weak solution enters back to the absorber and the cycle is repeated.

The initial flow of the refrigerant from the evaporator to the absorber occurs because the vapor pressure of the refrigerant-absorbent in the absorber is lower than the vapor pressure of the refrigerant in the evaporator. The vapor pressure of the refrigerant-absorbent inside the absorbent determines the pressure on low-pressure side of the system and also the vaporizing temperature of the refrigerant inside the evaporator. The vapor pressure of the refrigerant-absorbent solution depends on the nature of the absorbent, its temperature and concentration.

When the refrigerant entering in the absorber is absorbed by the absorbent its volume decreases, thus the compression of the refrigerant occurs. Thus absorber acts as the suction part of the compressor. The heat of absorption is also released in the absorber, which is removed by the external coolant.

Pump

When the absorbent absorbs the refrigerant strong solution of refrigerant absorbent (ammonia-water) is formed. This solution is pumped by the pump at high pressure to the generator. Thus pump increases the pressure of the solution to about 10bar.

Generator

The refrigerant-ammonia solution in the generator is heated by the external source of heat. This is can be steam, hot water or any other suitable source. Due to heating the temperature of the solution increases. The refrigerant in the solution gets vaporized and it leaves the solution at high pressure. The high pressure and the high temperature refrigerant then enters the condenser, where it is cooled by the coolant, and it then enters the expansion valve and then finally into the evaporator where it produces the cooling effect. This refrigerant is then again absorbed by the weak solution in the absorber.

When the vaporized refrigerant leaves the generator weak solution is left in it. This solution enters the pressure reducing valve and then back to the absorber, where it is ready to absorb fresh refrigerant. In this way, the refrigerant keeps on repeating the cycle.

The pressure of the refrigerant is increased in the generator, hence it is considered to be equivalent to the compression part of the compressor.

1.1 Loop Heat Pipe

Loop heat pipes (LHPs) are two-phase heat transfer devices. It uses the evaporation and condensation of a working fluid to transfer the heat from one point to other. Capillary forces are developed in the fine porous wicks which helps to circulate the fluid. It does not require electrical power because they have no moving mechanical parts.

The pressure loss at the wick in the Loop Heat Pipes can be kept lower than in the conventional HPs. The wick is made of copper instead of PTFE (polytetrafluoroethylene) and has pores of size 0.3mm. Loop Heat Pipes are similar to heat pipes but have the advantage of being able to provide reliable operation over long distance. They can transport a large heat load over a long distance with a small temperature difference.

Different designs of Loop Heat Pipes ranging from powerful, large size LHPs to miniature LHPs (micro loop heat pipe) have also been developed and successfully employed in a wide sphere of applications both ground based as well as space applications. Compared with conventional Heat Pipes (HPs), which also use capillary forces to circulate the working fluid, the LHPs can transport heat over longer distances.

In the conventional Heat pipes, vapour flows through the center of the pipe from an evaporation area to a condensation area, while liquid flows through the wick, which is located in the inner surface of the entire pipe, from the condensation area back to the evaporation area. Therefore, if the distance needed for heat transport becomes longer, the length of the wick and the entire pipe also become longer.

In contrast, in the LHPs, the wick is located only in the evaporator. Therefore, if the distance needed for the heat transport becomes longer, the length of the wick does not change. Because of this difference, the pressure loss at the wick in the LHPs can be kept lower than in the conventional HPs.

The wicks in the LHPs develop high capillary pressures that are used to operate against gravity and can also be used to increase the horizontal distance for heat transport. The heat losses from vapor and liquid lines to ambient air and due to the pressure losses in the single-and two-phase fluids in the vapor and liquid lines. Figure shows the layout of loop heat pipe.

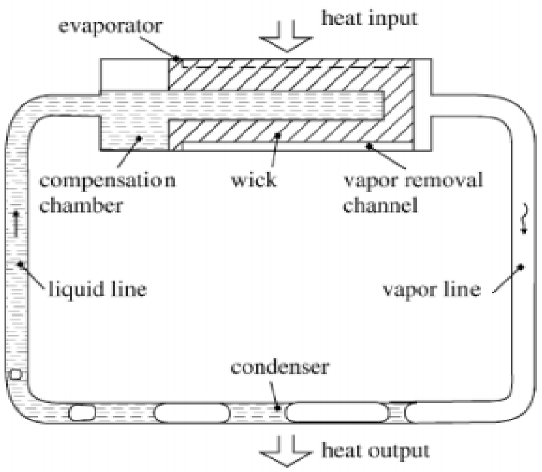

Figure.2: Loop Heat pipe [20]

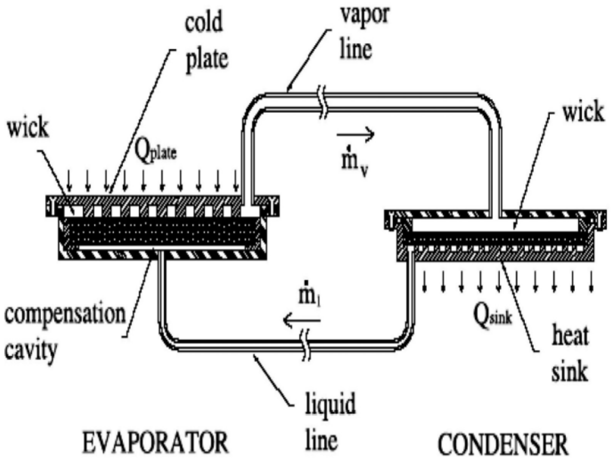

Figure 3: Loop Heat pipe [20]

Qualities of LHP

- High heat flux capability
- Capability to transport energy over long distances without restriction on therouting of the liquid and vapour lines
- Ability to operate over a range of 'g' environments.
- No wick within the transport lines
- Vapour and liquid flows separated, therefore no entrainment
- May be adapted to allow temperature control.

1.2 Use of exergy method for finding irreversibility in the system

Whole part of heat energy can never be converted completely into work, there some part of energy which used and second which get waste, the useful part of energy that is able to convert into heat is called available energy or exergy and unavailable part which get destroyed is called unavailable energy. As the first law of thermodynamics state that the energy is always conserved but the content of that energy wihic is capable of producing useful work is not constant that is exergy. The maximum useful work or exergy at a particular state is a composite property depending upon the state of system and surrounding. A dead state having Zero exergy that is equilibrium state.

1.3 Literature Review

Da-Wen Sun [1] (1996) performed a detailed thermodynamic analysis of the properties of these binary fluids and expressed in polynomial equations. The performances of three cycles were compared. It was found that ammonia-lithium nitrate and ammonia-sodium thiocyanate cycles are suitable alternatives to ammonia-water absorption systems. The performance of the ammonia-sodium thiocyanate cycle is slightly better than that of the ammonia-lithium nitrate cycle.

M.M. Talbiet et al.[2] (2000)carried out an exergy analysis on a single-effect absorption refrigeration cycle with lithium-bromide±water as the working Fuid pair. A design procedure has been applied to a lithium-bromide absorption cycle and an optimisation procedure that consists of determining the enthalpy, entropy, temperature, mass Fow rate, heat rate in each component, and coefficient of performance has been performed.

E. Kuremet et al [3] (2001)analyzed the Absorption Heat Pump (AHP) and Absorption Heat Transformers (AHT) using ammonia-water and water-lithium bromide solutions. A fundamental AHP and AHT systems was described and explained the operating sequence. Since the AHT systems widely uses ammonia-water solution with ammonia as the refrigerant and water-lithium bromide solution with water as the refrigerant, the comparison of the two was presented in respect of the coefficient of performance (COP), the flow ratio (FR) and the maximum system pressure. They concluded that the AHT system using water-lithium bromide solution provided better performance than the system using ammonia-water.

R.D. Misraet et al [4] (2002) applied the thermo-economic theory is to the economic optimization of a single effect water/LiBr vapour absorption refrigeration system for air-conditioning application. They applied a simplified cost minimization methodology to evaluate the economic costs of all the internal flows and products of the system by formulating exerg-o-economic cost equations. Having determined these costs, they evaluated the system therm-o-economically to identify the effects of design variables on costs and enabled to suggest values of design variables that made the overall system cost effective. An approximate optimum design configuration was obtained by means of sequential local optimization of the system, carried out unit by unit.

S.A. Adewusi et al [5](2004). studied the performance of single-stage and two-stage ammonia–water absorption refrigeration systems (ARSs).They calculated entropy generation of each component and the total entropy generation of all the system components as well as COP of the ARSs .The results showed that the two stage system had a higher S_ tot and COP, while the single-stage system has a lower S_ tot and COP. They investigated trend in COP and S_ tot with the change in heat exchangers effectiveness, absorbers temperatures and condenser and evaporator temperatures for both systems and found that an increase in COP corresponds to a decrease in S_ tot.

S. Arivazhagan et al. [6] (2006) investigated experimentally on the performance of a two-stage half effect vapour absorption cooling system .The prototype is designed for 1 kW cooling capacity using HFC based working fluids (R134a as refrigerant and DMAC as absorbent). The performance of the system in terms of degassing range, coefficient of performance and second law efficiency had been obtained. The system was capable of producing evaporating temperature as low as 7°C with generator temperatures ranging from 55 to 75 °C. The degassing range is 40% more in high absorber than in low absorber as the high absorber is operated at optimum intermediate pressure. The optimum generator temperature is found to be in the range of 65–70 °C at which the coefficient of performance is 0.36.

Rabah Gomri et al [7] (2008) performed exergy analysis of double effect lithium bromide/water absorption refrigeration system. The system consisted of a second effect generator between the generator and condenser of the single effect absorption refrigeration system, including two solution heat exchangers between the absorber and the two generators. They used a new set of computationally efficient formulations of thermodynamic properties of lithium bromide/water solution. In addition to the coefficient of performance and the exergetic efficiency of the system, the number of exergy of each component of the system is also estimated. The results showed that the performance of the system increased with increasing low pressure generator (LPG) temperature, but decreased with increasing high pressure generator (HPG) temperature. The highest exergy loss occurred in the absorber and in the HPG, which therefore makes the absorber and HPG the most important components of the double effect refrigeration system. In another comparative study between single effect and double effect absorption refrigeration systems with identical cold output was carried out. Results were used to study the influence of the various operating parameters on the performance coefficient, the thermal loads of the components, exergetic efficiency (rational efficiency) and the total change in exergy of the two systems. They concluded that the COP of double effect system was approximately twice the COP of single effect system but the exergetic efficiency of double effect system increased slightly compared to the exergetic efficiency of single effect system. They recorded that for each condenser and evaporator temperature, there was an optimum generator temperature where the total change in exergy of the single effect and double effect absorption refrigeration systems was minimum. At this point the COP and exergetic efficiency of the systems become maximum.

S.C. Kaushiket al [8] (2009) presented the energy and exergy analysis of single effect and series flow double effect water–lithium bromide absorption systems. They developed a computational model for the parametric investigation of the systems. Newly developed computationally efficient property equations of water–lithium bromide solution have been used in the computer code. The analysis involves the determination of effects temperatures and pressure drop on the energetic and exegetic performance of these systems. The performance parameters are computed. The results indicated that coefficient of performance of the single effect system lies in range of 0.6–0.75 and the coefficient of performance for the series flow double effect system lies in the range of 1–1.28. Irreversibility is highest in the absorber in both systems when compared to other system components.

Saeed. Sedigh et al.[9](2011)analyzedthe performancesof half-effect, single-effect and double-effect H2O/LiBr absorption cycles and it was found that there is an obvious blank for generation temperature between the maximum generation temperature of the single-effect cycle and the minimum generation temperature of the double-effect cycle. It was proposed that the one and a half-effect cycle can fill up the blank perfectly. In this paper, the energy analysis of single effect and half effect water– lithium bromide absorption systems is presented. A computational model has been developed for the parametric investigation of these systems. The effect of various parameters has been presented. It is shown that an increase in the generator temperature increases the COP in both single and half effect systems up to an optimum generator temperature. It is also shown that increasing the absorber temperature reduces the system performance influentially as compared to increasing the condenser temperature.

Gulshan Sachdeva et al [10] (2014) performed the exergy analysis of vapor absorption refrigeration system using LiBr-H2O as working fluid with the modified Gouy-Stodola approach rather than the classical Gouy-Stodola equation. Mathematical expressions for effective temperature had been formulated and calculated for each component of the system. The main aim of this analysis had been to determine the performance of the system and the components having major irreversible loss. Results showed that exergy destruction rate is considerable in absorber and generator followed by evaporator and condenser. The value of exergy determined by the modified Gouy-Stodola equation deviates maximum i.e. 26% in the generator as compared to the exergy calculated by the classical Gouy-Stodola method.

Yu.F. Maydanik [11] (2004) in a review stated that Loop heat pipes (LHPs) are two-phase heat-transfer devices with capillary pumping of a working fluid. They possess all the main advantages of conventional heat pipes, but owing to the original design and special properties of the capillary structure are capable of transferring heat efficiency for distances up to several meters at any orientation in the gravity field, or to several tens of meters in a horizontal position. Besides, the LHP conception allows a wide variety of different design embodiments, which essentially extends the sphere of functional possibilities and practical application of these devices. The paper is a review of developments, results of theoretical analysis and tests of LHPs performed at the Institute of Thermal Physics and some other organizations. It gives examples of successful application of these highly efficient devices in space technology and electronics. Randeep Singh et al [12] (2007) addressed the thermal characteristics of the miniature Loop Heat Pipe (mLHP) with the flat disk shaped evaporator, 10 mm thick and 30 mm in diameter, for the thermal control of the compact electronic equipment. The loop was made of copper with nickel wick and water as the working fluid. It was found that the device was able to start-up at input power as low as 5 W, however the start-up time was very high at such heat loads. During the testing, the thermal response presented by the loop to achieve steady state was very short. Overall, the effect of these oscillations on the thermal performance of the mLHP was not very significant. In the horizontal orientation, the device was able to transfer maximum heat load of 70 W with evaporator temperature below 100 ± 5 ◦C limit. The thermal resistance (RmLHP) of the mLHP lies between 0.17 to 5.66 ◦C/W.

T.X. Li et al [13] (2007) designed an innovative dual-mode multifunction heat pipe type chemisorption ice maker was, in which the compound adsorbent of activated carbon–CaCl2 was used to improve the mass and heat transfer performance of adsorbent. The heating, cooling and heat recovery processes between two adsorbent beds were performed by multifunction heat pipes without additional power consumption. The first operation mode was a highly efficient mass and heat recovery sorption cycle where driving heat source temperature was about 145 °C. The second operation mode was a two-stage heat recovery sorption cycle in which available driving heat source temperature was about 103 °C. The results showed that the first operation mode cycle can increase the coefficient of performance (COP) by 69% when compared with basic cycle. The second operation mode cycle could operate effectively with relatively low-grade generation temperature, and the performance of the two-stage heat recovery cycle was improved by more than 23% when compared with conventional two stage cycle under the same generation temperature of 103 °C and cooling water temperature of 30 °C.

Behrooz M. Ziapour et. al [14] (2010) analysed a diffusion absorption refrigeration heat pipe (DARHP) cycle for an ammonia-water DARHP cycle with helium .In order to obtain characteristics of the DARHP system. The second law efficiency was examined parametrically by the computer simulation. They validated the model by comparing it with previously published experimental data for DARHP system. The cycle performance results under different conditions indicated that the best performance was obtained for the concentration rich solution of 0.35 ammonia mass fraction and the concentration of weak solution about 0.1. It showed that the exergy losses in the evaporator, condenser and dephlegmator were small. Also the second law efficiency increases with increasing evaporator temperature; and decreases with increasing thermosyphon temperature.

Z.S. Lu et al [15] (2011) proposed and investigated a heat pipe type adsorption refrigerator system which can be powered by solar energy or waste heat of engine. They studied the performance of compound adsorbent (CaCl2 and activated carbon)–ammonia adsorption refrigeration cycle with different orifice sets and different mass and heat recovery processes by experimental prototype machine. Specific cooling power (SCP) and coefficient of performance (COP) were calculated with experimental data to analyze the influences of operating condition. The results showed that the jaw opening of the hand needle nozzle can influence the adsorption performance obviously and the thermostatic expansion valve (TEV) is effective in the intermediate cycle time in the adsorption refrigeration system. The SCP of the cycle with the mass-heat recovery together (combined recovery process) is superior to that of the conventional cycles with mass recovery or heat recovery independently.

Basant K. Agrawal et al [16] (2011), proposed a triple effect refrigeration cycle, a natural refrigerant based N2O compression cycle employed to the combined absorption cycle with an ejector refrigeration cycle. This triple effect cycle combines the advantages of absorption cycle, ejector cycle and low temperature N2O refrigerant based compression cycle. This combined cycle can produce refrigeration output of different magnitude at different temperature simultaneously and can be driven by the waste heat which is available abundantly in different form. System performance and exergy destruction on each component of combined cycle are evaluated based on parametric, energetic and exergetic analysis. The results showed that the waste flue gas temperature, turbine inlet pressure, turbine outlet pressure, ejector evaporator temperature and compressor discharge pressure have significant effects on the refrigeration outputs, exergy efficiency and thermal efficiency.

L. Garousi Farshiet al [17] (2013) compared Ammonia /$LiNO_3$ and ammonia/NaSCN absorption refrigeration cycles as alternatives to ammonia/water cycles for refrigeration applications at temperatures below 0 °C. They are found to have higher coefficient of performance (COP) and purification of the refrigerant vapour is not required. Entropy data for such solutions are calculated using their most recently published thermophysical property data. They used simulation results to examine the influence of various operating parameters on performance and the possibility of crystallization. For low generator temperatures, ammonia/LiNO3 cycles have better performance and at high generator temperatures, ammonia/NaSCN cycles are with better performance, but the range of allowable generator temperatures is quite limited for this mixture

Yuan-Ching Chiang et al. [18](2014)thoroughly investigated the composition factors influencing thermal performance, such as wick structures, working fluids, the modulation fields of working fluids, and combinations of these factors, were. The evaluated materials comprised micro grooved, sintered, and wickless heat pipes; magnetic nano fluids exhibiting volumetric fractions (vol.) of 0.16%e3.20%; and de-ionized water. A strong magnetic field of 200 Oe was applied. The results indicated that combining grooved heat pipes and a 0.80% vol. of magnetic nano fluids or sintered heat pipes and a 0.16%vol. of magnetic nano-fluids yielded the optimal promotions: the thermal resistance was reduced by approximately 80%and the critical heat flux was enhanced 2.7-fold compared with general wickless heat pipes filled with de-ionized water.

T.S. Jadhav et al [19] (2015) in their literature review indicated that very limited information is available on annual energy saving analysis of air conditioning system with HPHX for Indian climatic zones. The possible energy savings using HPHX for heat recovery in air conditioning system for Indian climatic zones was studied. The analysis is carried out for total 25 Indian cities representing different climatic zones. The annual energy savings with HPHX for a particular city is calculated for number of hours when outdoor air dry bulb temperature exceeds 25 °C. The maximum energy saving potential is revealed for hot and dry, warm and humid and composite Indian climatic zones.

Chengchu Yan et al.[20] (2015) presented a seasonal cold storage system that uses separate type heat pipes to charge the cold energy from ambient air in winter automatically, without consuming any energy. The charged cold energy is stored in the form of ice in an insulated tank and is extracted as chilled water for cooling supply in summer, which help to reduce the chiller running time and reduce the associated electricity consumption and greenhouse gas emission significantly. They developed a quasi-steady two-dimensional mathematical model of the system for characterizing the dynamic performance of ice growth. The model was validated using the field measurement data from an ice charging experiment conducted in Beijing. Fabian Korn et al [21] [2012]performed several vital experiments on heat pipes to establish it to be one of the most effective procedures to transport thermal energy from one point to another, mostly used for cooling. It is based on a combination of conduction and convective heat transfer, what makes it to a complex heat transfer problem. In this report the main working principal and most important possibilities to calculate a heat pipe will be shown. All in all it is necessary to understand all the basic theories of heat and mass transfer to understand the working principle of a heat pipe. On a first look a heat pipe seemed to be a very easy tool to transport energy, but if one looks closer, it is a very complex heat and mass transfer process which takes place in a heat pipe. First of all one has convective heat transfer in the adiabatic transport range, and one has convection through porous materials also. The second major point is mass transfer due to vaporization and condensation, also through porous media. Furthermore there are capillary effects, pressure effects and heat conduction effects involved, which creates a complex structure of heat transfer, where a lot of knowledge is involved. And all of these points can be treated as one problem, from this follows that a complete understanding of all involved processes needs more time and space than it is available for this project report.

R. Rajashree et al.[22] [1990] went through a numerical analysis of an unsteady, viscous, laminar, incompressible, two dimensional heat and mass transfer, in the vapour gas region of gas loaded circular heat pipe . The governing equations of motion were solved using Dufort-Frankel finite difference scheme with appropriate initial and boundary conditions. Successive over relaxation technique has been adopted to solve Poisson equation. The analysis is restricted to the vapour space of the cylindrical heat pipe with evaporator, adiabatic and condenser sections and the qualitative behaviors of the start-up transient in the vapour gas region has been presented with sodium as vapour for different Reynolds Number. The study demonstrated the qualitative behavior of heat and mass transfer can be studied with the above method with precision.

2. Research gaps identified

Loop heat pipes are being used in Solar Plants, Cooling of Electronic devices, Cooling of Space Shuttles etc. In several researches performed they are being used directly to maintain temperature of several cold storages around the world. It has high heat flux capacity. After reading available research papers following gaps can be identified:

- There are types of VAR systems such as Single Effect, Double Effect, and Triple Effect etc. of which First Law, Second Law and Economic Analysis have been performed. But Heat Pipes can be made an integral part of the system and these valuable analyses can be executed on this new system and results can be studied deeply.
- Waste heat going to the environment from condenser has never been used, which can be supplied back to the generator which requires low grade energy for its operation.
- Also the VAR system can be coupled with other systems may be refrigerating or power generating in which heat is released.
- The Loop Heat Pipes will make the system compact, and that effect must be studied to optimize the performance of the VAR systems.

Studying the literature available on the selected field the main research work has to be done on followings.

1. Intra-cycle heat utilization in the VAR system with help of LHP.
2. Thermodynamic and Thermo-Economic analysis of different types VAR system with LHP for intra-cycle heat transfer e.g. single effect, half effect etc.
3. Study of suitability of Heat Pipes for connecting different heat sources with VAR systems.
4. Study of different fluids in the heat pipe working as a part of the VAR system.

3. Methodology

Compressor in the Vapour Absorption System is replaced by three devices namely Generator, Absorber and Pump and it produces refrigeration using Low Grade energy. In this research it is aimed to remove the condenser also and to use a flow condensation instead. The heat released during the condensation of the rich refrigerant is to be used to evaporate the working fluid in the LHP. The condenser of the LHP will be in contact with the solution leaving the absorber. Thus utilization of the waste heat in the condenser can be done. Other systems can also be connected with each other to have a combined effect. Through the various parametric studies with the help of EES, the optimization of this system can be executed. The primitive system can be explained in the term of the figure.

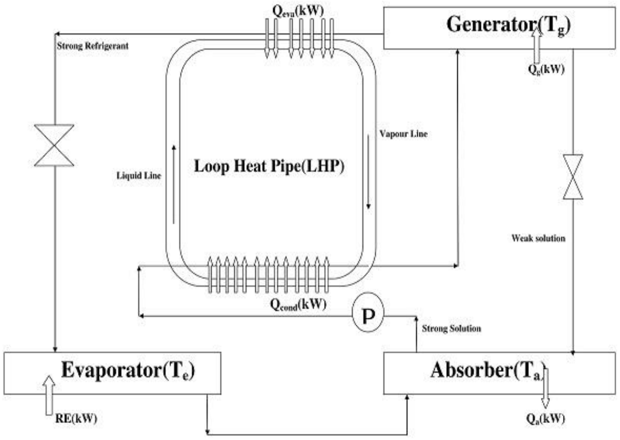

Figure 4: Modified VARS with a LHP

4. Results and Discussions

The VAR system uses low grade energy for its operation, which can be obtained from several cheaply available sources (solar, waste heat etc). The COP is low and irreversibilities related to heat transfer in the cycle are associated. With the use of a Loop Heat Pipe external heat sources can be connected which will increase the COP of the system. For optimizing a VAR system a LHP can be used to utilize the waste heat for intra-cycle heat exchange. Which will eventually increase the First Law COP, Second Law COP and will reduce the irreversibilities connected with the operation of a VAR system. The temperature variation can also be controlled by the use of heat pipe which will result in reduction of energy. The coupling of different cycles will not require complex heat exchangers but Simple LHPs which are available in different heat flux capacities. Thermal modelling of the VAR systems including a LHP for improving of First Law efficiency in terms of COP. And Thermal modelling of the VAR systems including a LHP for improving of Second Law in terms of exergetic efficiency by reducing irreversibilities in the system.

5. Conclusions & Recommendations

The Second Law analysis of the several systems which is possible in order to recover the waste heat is proposed in this paper. During which some combinations of parameter will be varied and following conclusions were made as follows:

1. Intra-Cycle heat exchange in the VAR system reduces heat input thus improved in the thermal performance in terms of first law efficiency (Energy-Efficiency) and second law efficiency (Exergetic efficiency) of the VAR system.

2. Highly effective heat exchange through the heat pipe due to removal of condenser exergetic losses improved second law performances
3. Gas power plant coupled with modified VAR improved first law efficiency(Energy-Efficiency) and second law efficiency(Exergetic efficiency)

References

[1] Da-Wen Sun," Comparison of the performances andNH3-H20, NH3-LiNO3 and NH3-NaSCN Vapor Absorption Refrigeration Systems" Energy Convers. MgmtVol. 39, No. 5/6, pp. 357-368, 1998.

[2] M.M. Talbi, B. Agnew," Exergy analysis: an absorption refrigerator using lithium bromide and water as the working Fuids" Applied Thermal EngineeringVol. 20 (2000) 619-630.

[3] E. Kurem,"A comparison betweenAmmonia-waterand Water-Lithium Bromidesolutionsin vapour absorption heat transformers "In. Comm. Heat Mass Transfer, Vol-28, No-3, pp-421-438 , (2001).

[4] R.D.Misra, P.K. Sahoo, S. Sahoo, A. Gupta,"Thermoeconomic optimization of a single effect water/LiBr vapour absorption refrigeration system" International Journal of Refrigeration Vol.26 (2003) 158–169.

[5] S.A. Adewusi, Syed M. Zubair," Second law based thermodynamic analysis of ammonia–water absorption systems" Energy Conversion and Management Vol. 45 (2004) 2355–2369.

[6] S. Arivazhagan , R. Saravanan , S. Renganarayanan ," Experimental studies on HFC based two-stagehalf effect vapour absorption cooling system" Applied Thermal EngineeringVol. 26 (2006) 1455–1462.

[7] RabahGomri ,RiadHakimi," Second law analysis of double effect vapour absorption cooler system" Energy Conversion and Management Vol.49 (2008) 3343–3348.

[8] S.C. Kaushika, Akhilesh Arora," Energy and exergy analysis of single effect and series flow double effect water–lithium bromide absorption refrigeration systems" internationaljournal of refrigeration Vol.32 (2009) 1247 – 1258.

[9] RabahGomri," Second law comparison of single effect and double effect vapour absorption refrigeration systems" Energy Conversion and Management Vol. 50 (2009) 1279–1287. refrigeration system" Int. J. Energy Res. 2008; Vol.32:161–174.

[10] M. Belghazi, A. Bontemps, C. Marvillet," Experimental study and modelling of heat transfer during condensation of pure fluid and binary mixture on a bundle of horizontal finned tubes" International Journal of Refrigeration Vol.26 (2003) 214–220.

[11] Yu.F. Maydanik," Review Loop heat pipes" Applied Thermal Engineering Vol.25 (2005) 635–657.

[12] Randeep Singh, AliakbarAkbarzadeh ,MasatakaMochizuk," Operational characteristics of a miniature loop heat pipe with flat evaporator" International Journal of Thermal Sciences Vol.47 (2008) 1504–1515.

[13] T.X. Li, R.Z. Wang , L.W. Wang, Z.S. Lu, C.J. Chen," Performance study of a high efficient multifunction heat pipe type adsorption ice making system with novel mass and heat recovery processes" International Journal of Thermal SciencesVol.46 (2007) 1267–1274.

[14] Behrooz M. Ziapour*, Mohsen Tavakoli," Performance study on a diffusion absorption refrigeration heat pipe cycle" International Journal of Thermal Sciences 50 (2011) 592-598.

[15] Z.S. Lu , L.W. Wang, R.Z. Wang," Experimental analysis of an adsorption refrigerator with mass and heat-pipe heat recovery process" Energy Conversion and ManagementVol. 53 (2012) 291–297.

[16] Basant K. Agrawal*, Munawar N. Karimi," Thermodynamic performance assessment of a novel waste heat based triple effect refrigeration cycle" International Journal of RefrigerationVol. 35 (2012) 1647-1656.

[17] L. GarousiFarshia,*, C.A. Infante Ferreira b, S.M.S. Mahmoudi a, M.A. Rosen," First and second law analysis of ammonia/salt absorption refrigeration systems" International Journal of Refrigeration Vol. 40 (2014) 111-121.

[18] T.X. Li, R.Z. Wang, L.W. Wang, Z.S. Lu," Experimental investigation of an innovative dual-mode chemisorption refrigeration system based on multifunction heat pipes" International Journal of Refrigeration 31 (2008) 1104 – 1112.

[19] T.S. Jadhav , M.M. Lele," Theoretical energy saving analysis of air conditioning system using heat pipe heat exchanger for Indian climatic zones" Engineering Science and Technology, an International JournalVol. 18 (2015) 669-673.

[20] ChengchuYan ,Wenxing Shi , Xianting Li , Shengwei Wang," A seasonal cold storage system based on separate type heat pipe for sustainable building cooling" Renewable Energy Vol.85 (2016) 880-889.

[21] Korn, F., "Heat Pipes and its Applications" Project Report 2008 MVK160 Heat and Mass Transport May 07, 2008, Lund, Sweden.

[22] Rajashree, R., Rao, K.S., "**A** Numerical Study of the Performance of Heat Pipe" Indian Journal of Pure and Applied Mathematics, 21 (1): 95-108, January 1990.