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Optimization of Vapour Absorption System Using Heat Pipes

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Abstract: Heat pipe was developed by NASA for space applications, and this device can be used in simple refrigeration systems, which will have a great impact on the size of the system. Multiple working fluids can be used in the heat pipe along with the different materials in the designs of the loop heat pipe (LHP). In this research it is aimed to remove the condenser of a Vapour Absorption Refrigeration System (VARS) and to use a flow condensation instead. The heat released during the condensation of the rich refrigerant is 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 have also been connected with each other to have a combined effect. The increase in COP will be recorded by simulation and the exergy loss can be reduced due to heat transfer while heat transfer if condenser. A large size condenser has also been replaced by a compact loop heat pipe.

I. INTRODUCTION: HEAT PIPES

A. History

Heat Pipes were developed mainly for space applications. One standard problem in space applications was transportation of heat from inside to the outside, and the heat conduction in a vacuum is restricted. So there was a requirement to create a quick and viable approach to transfer heat, without the impact of gravity. The mode of convection is used, in light of the fact that convective heat exchange is much quicker than conduction. Heat pipes are utilized in many applications nowadays, where space is restricted and high heat flux is to be dealt with.

B. Principle of Working

The fundamental of heat pipes is depends on evaporation and condensation. At the hot side, the working liquid evaporates and at the cool side it condenses. It's required to choose the set of material properly. At the source the cool fluid is evaporated, the hot vapour stream is a while later transported to the sink where the vapour condenses again and is transported back to the source. The low heat resistance is because of little effective length of heat exchange through strong porous wick walls.

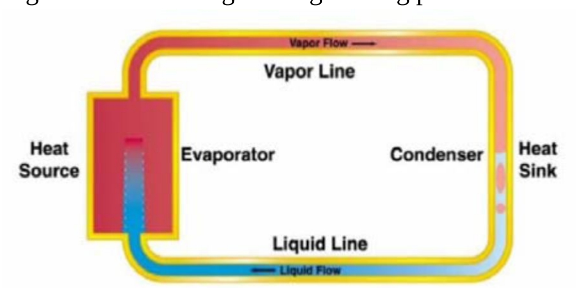

Fig 1: Circular process of a Loop heat pipe[30]

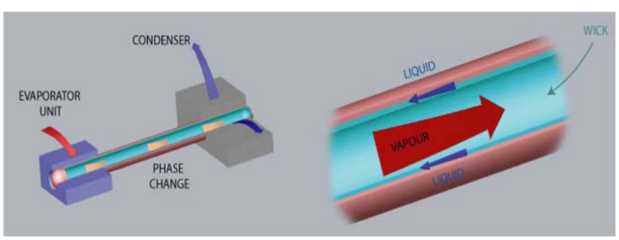

Fig 2: Concept of Heat Pipe[30]

C. Key Features of LHP

1) LHP has a High heat flux capability
2) Energy can be transported over long distances without restriction on the routing of the liquid and vapour lines.
3) It has the capability to operate over a range of 'g' environments
4) There is No wick within the transport lines.
5) Vapour and liquid flows are separate, therefore no entrainment problem
6) May be adapted to allow temperature control in various conditions.

D. Limitations

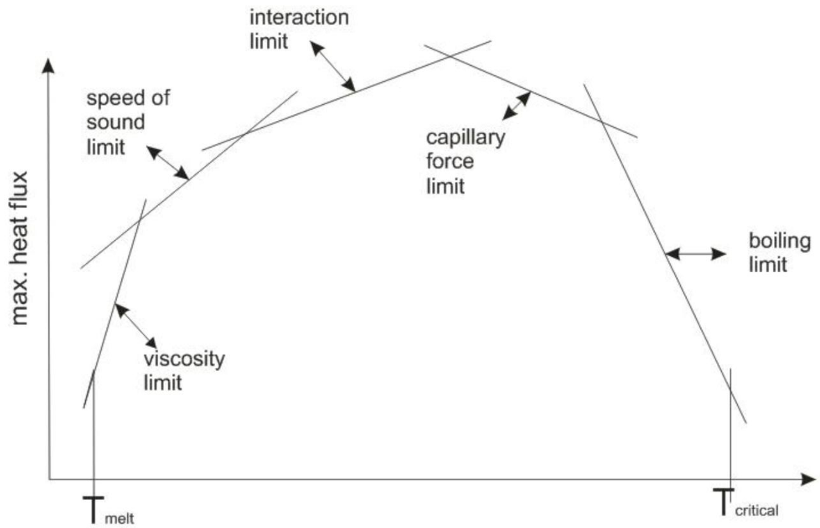

Fig 3: Limitations of a heat pipe [30]

1) *Melting temperature:* One can't utilize a heat pipe below the melting temperature.
2) *Viscosity Limit:* The viscosity of the liquid is too high for being transported at low temperatures and low pressures.
3) *Sonic Limit:* It is critical for high temperature, where the vapour could conceivably achieve the velocity of sound while leaving the source.
4) *Capillary limit:* When the capillary force is definitely not fulfilling the required force transport the fluid
5) *Interaction limit:* This breaking point is associated with open channels, where the vapour can be diverted by the vapour, because of high speed contacts.
6) *Boiling cut off:* The fluid forms bubbles which close the capillaries, it's not an issue for open channel structures
7) *Critical temperature***:** Beyond the critical temperature the concept of vapour and liquid seizes to exist.

II. LITERATURE REVIEW

Fabian Korn et al. [2012]performed several vitalexperiments 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[6].Sameer Khandekar et al.[2010]performed experiments on the global thermal performance modeling of Pulsating Heat Pipes (PHPs) requires local, spati-o-temporally coupled, flow and heat transfer information during the characteristic, self-sustained thermally driven oscillating Taylor bubble flow, under different operating conditions[7].JozefHužvár, PatrikNemec et al. [2007]used heat pipe, observed its basic principles and operating limits. High temperature heat pipes were evaluated for use in energy conversion applications such as fuel cells, gas turbine re-combustors, and Stirling cycle heat sources, with the resurgence of space nuclear power, additional applications include reactor heat removal elements and radiator elements[8].R.Z. Wang et al.[2008]added heat pipes in adsorption water chiller or ice maker initials. His work showed that the adsorption refrigerators are very efficient[10].]PrachaYeunyongkul et al.[2009] aimed at experimentally investigating the application of a closed loop oscillating heat pipe (CLOHP) as the condenser for a vapor compression refrigeration system[14].R. Rajashree et al.[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 [20]. Da-Wen Sun (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. M.M. Talbi et al.(2000) carried out an exergy analysis on a single-effect absorption refrigeration cycle with lithium-bromide±water as the working Fuid pair. E. Kurem et al.(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. R.D. Misra et al.(2002) applied the therm-o-economic theory is to the economic optimization of a single effect water/LiBr vapour absorption refrigeration system for air-conditioning application. S.A. Adewusi et al(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 . S. Arivazhagan et al. (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). Rabah Gomri et al.(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. S.C. Kaushik et al.(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. Berhane H. Gebreslassie et al. (2010) performed an exergy analysis, which only considered the unavoidable exergy destruction, conducted for single, double, triple and half effectWater–Lithium bromide absorption cycles. Gulshan Sachdeva et al.(2014) performed an exergy analysis of VAR system using LiBr-H_2O as working fluid with the modified Gouy-Stodola approach. Karl Ochsner (2008) et al. (2008) developed a new CO_2-heat pipe with high-grade steel corrugated pipe system, which – contrary to other pipe systems permits raw length up to 100 m. They also described the establishment of the heat pump system in general. Guilherme B. Ribeiro et al.(2010) investigated a novel evaporator design for a small-scale refrigeration system whose function is to assist the existing heat pipe technology currently used in chip cooling of portable computers. Chengchu Yan et al.(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. Dr. R.E. Critoph et al. observed carbon - ammonia refrigerators driven by the heat of steam condensing in a thermo-syphon heat pipe. The heat source can be such as solar energy, biomass, or combinations of the two.

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, 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 in a comprehensive manner. 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.

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 utilise 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 anergy. The coupling of different cycles will not require complex heat exchangers but Simple LHPs which are available in different heat flux capacities.

III. SYSTEMS DESCRIPTION

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 work, it will be aimed to remove the condenser also and to use a flow condensation instead. The heat released during the condensation of the rich refrigerant will 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 will also be connected with each other to have a combined effect. Through the various parametric studies, the optimization of this system will be executed. The primitive system can be explained in the Fig 3.

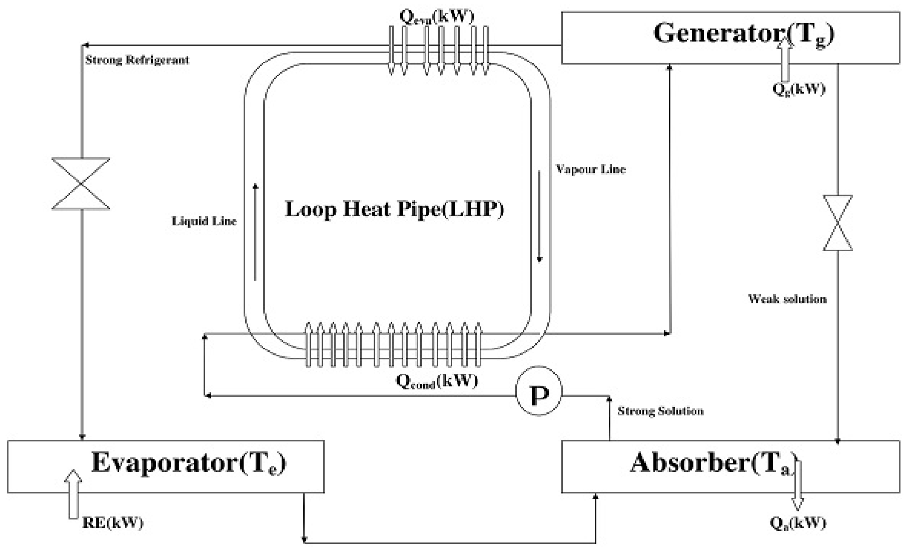

Fig.3: Modified VARS with a LHP.

Through such a modification in a system (VARS) thermal modelling of the VAR systems including a LHP for the computation of First Law COP will be taken care of. Thermal modelling of the VAR systems including a LHP for the computation of Second Law COP will also be done Numerical computation for finding various losses in the above system components will be done .Thermo-Economic Analysis of the system is to be done. Study of Various Fluids in the LHP is performed. Following abbreviations are used in the research work:

Terms	Abbreviations
Refrigeration Effect in kW	RE (kW)
Heat rejected in absorber in kW	Q_a (kW)
Heat supplied in generator in kW	Q_g (kW)
Heat rejected in condenser of LHP in kW	Q_{cond} (kW)
Heat absorbed in evaporator of LHP in kW	Q_{eva} (kW)

IV. RESULTS AND DICSUSSIONS

The far-reaching thermo-dynamic analysis of the several systems which is possible in order to recover the waste heat will be accomplished in this research work. During which some combinations of parameter will be varied and the possible outcomes may be as follows with the help software simulation.

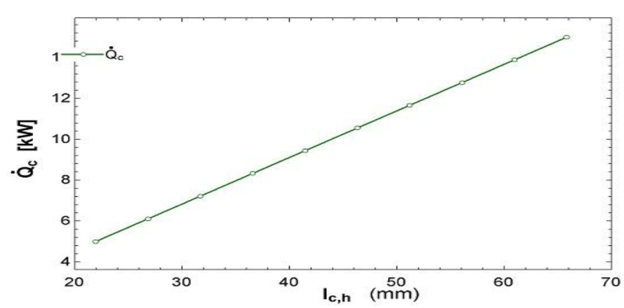

Fig 4: Plot between LHP Condenser Heat and LHP Condenser Length

The Fig. 4 shows the relationship between the length of the condenser of the LHP and heat that can be re-utilized for heating the mixture coming out of the absorber before entering the generator. It can be observed easily that for a very small sized LHP can high heat transfer be handled. Smaller the size, more economical the design will be developed.

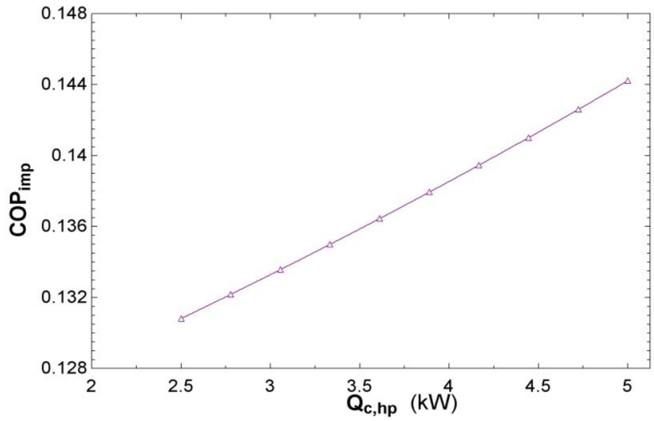

Fig 5: Plot between Improved COP and Heat Utilized by to LHP

Fig. 5 relates the improvement in the COP of the system with the total heat utilized by the LHP form the mixture leaving the generator. It shows that as the capability of heat removal increases and reutilized the COP will improve. The analysis is to be done whether the incorporation of a LHP is economically viable or not. And how complex the design will be?

The size of the entire system can be reduced by removing the condenser and replacing it by a LHP as the size of the condenser of the LHP is very small for its capability to transport heat.

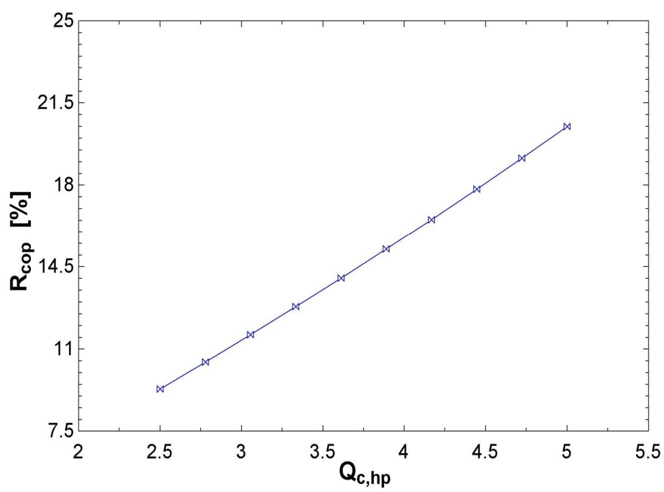

Fig 6: Plot between Improved COP and LHP condenser Heat

Similar to the Fig. 6 the increase in refrigerating efficiency is plotted against the heat reused by the LHP. It can be seen that may be the increase in COP is not that easily perceivable but the rise in efficiency say it all. From a value below 10 it moves to above 20 in a small utilization of heat.

V. CONCLUSIONS

Reading the results and inferring from them, the following conclusions can be made

The Second Law analysis of the several systems which is possible in order to recover the waste heat is proposed. During which some combinations of parameter will be varied and the outcomes are likely to be:

A. Intra-Cycle heat exchange in the VAR system. Improvements in the performance of the VAR system.

B. Highly effective heat exchange through the heat pipe. Different coupling combinations can be observed due to LHP.

C. Due to heat pipe Thermo-Economic Analysis commercial application of it in VAR system can be made possible. Optimized system can be developed.

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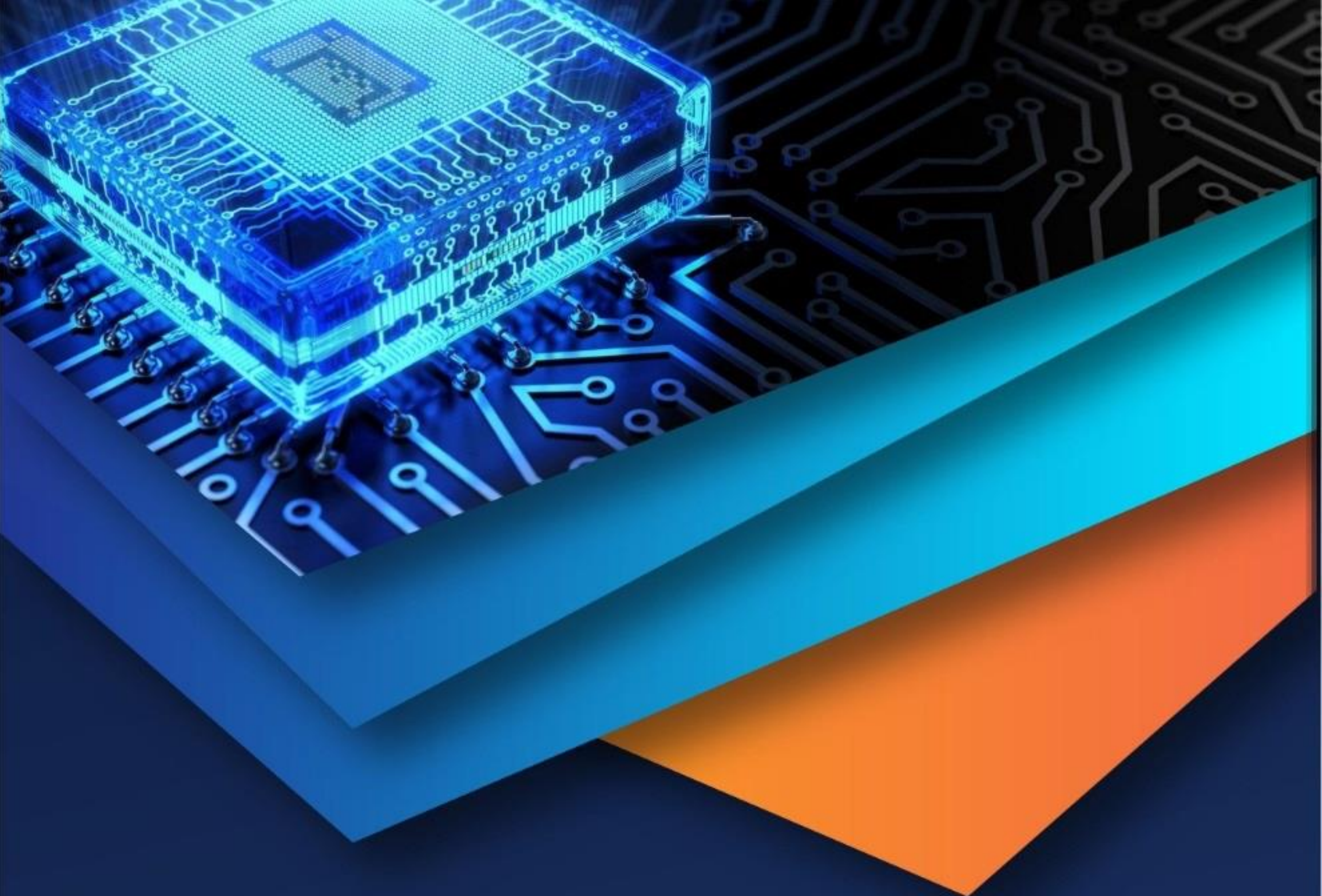

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