Review and Proposal of Compact Heat Pipe Based Liquid Cooled Heat Exchanger

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Abstract- *In compact electronic packages overheating is a persistent problem which leads to failure of electronic devices. So limitations of air cooling to liquid cooling in many demanding applications is making the liquid cooling of electronic devices more popular. So there is a need of critical thermal management. Conventional liquid cooling component cold plates include tube-in-plate, aluminium vacuum-brazed and copper brazed types for various applications. Tube-in plate cold plate materials consist of copper or stainless steel tubes pressed into a channelled aluminium or copper extrusion or machined plate. These devices show moderate performance with high gradient of temperature and poor performance with low gradient of temperature. A tower cooler using Heat pipe is the proposed solution to the above stated problem. It offers copper heat pipe tower that incorporate vertical radial spiral fin technology (e.g. micro-channel technology) or for higher performance, specialized powdered metal (sintered copper) heat pipe construction. The research work involves determination of heat load for application specific, selection of heat pipes, design and fabrication of heat pipe enclosure tower as to surface area and number of fins, steady state thermal analysis will be done using Ansys workbench 16.0. Test rig will be fabricated and testing will be done by varying flow rate of oil (medium for liquid heat load) and flow rate of air.*

Keywords- Cooling capacity, Energy consumption, Heat pipe, liquid cooled heat exchanger, sintered copper heat pipe, wick structure

I. INTRODUCTION

A heat pipe is a simple device that can quickly transfer heat from one point to another. They are often referred to as the "superconductors" of heat as they possess an extra ordinary heat transfer capacity & rate with almost no heat loss. It consists of a sealed aluminum or copper container whose inner surfaces have a capillary wicking material. A heat pipe is similar to a thermo-syphon. It differs from a thermo-syphon by virtue of its ability to transport heat against gravity by an evaporation-condensation cycle with the help of porous capillaries that form the wick. The wick provides the capillary driving force to return the condensate to the evaporator. The quality and type of wick usually determines the performance of the heat pipe, for this is the heart of the product. Different types of wicks are used depending on the application for which the heat pipe is being used.

The three basic components of a heat pipe are:

1. The container
2. The working fluid
3. The wick or capillary structure

Inside the container is a liquid under its own pressure, that enters the pores of the capillary material, wetting all internal surfaces. Applying heat at any point along the surface of the heat pipe causes the liquid at that point to boil and enter a vapor state. When that happens, the liquid picks up the latent heat of vaporization. The gas, which then has a higher pressure, moves inside the sealed container to a colder location where it condenses. Thus, the gas gives up the latent heat of vaporization and moves heat from the input to the output end of the heat pipe. Heat pipes have an effective thermal conductivity many thousands of times that of copper. The heat transfer or transport capacity of a heat pipe is specified by its " Axial Power Rating (APR)". It is the energy moving axially along the pipe. The larger the heat pipe diameter, greater is the APR. Similarly, longer the heat pipe lesser is the APR. Heat pipes can be built in almost any size and shape.

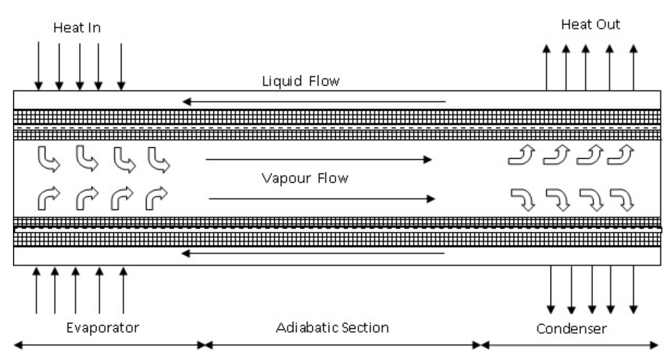

Fig: Working Principle of Heat Pipe

All electronic devices and circuitry generate excess heat and thus require thermal management to improve reliability and prevent premature failure. The amount of heat output is equal to the power input, if there are no other energy interactions. There are several techniques for cooling including various styles of heat sinks, thermoelectric coolers, forced air systems and fans, heat pipes, and others. In cases of extreme low environmental temperatures, it may actually be necessary to heat the electronic components to achieve satisfactory operation.

II. LITERATURE REVIEW

Randeep Singh, et al. (2007)

This paper presents an experimental investigation on a copper miniature loop heat pipe (mLHP) with a flat disk shaped evaporator, 30 mm in diameter and 10-mm thick, designed for thermal control of computer microprocessors. In the horizontal configuration, under air cooling, the minimum value for the mLHP thermal resistance is 0.17 C/W with the corresponding evaporator thermal resistance of 0.06 C/W. It is concluded from the outcomes of the current study that a mLHP with flat evaporator geometry can be effectively used for the thermal control of electronic equipment including notebooks with limited space and high heat flux chipsets. The results also confirm the superior heat transfer characteristics of the copper-water configuration in mLHPs.

Sumit Kumar Rai and K K Jain (2012)

The experiment will be conducted on the HPHE under natural convective condition at different tilt angles form the horizontal (150, 250, 300 and 900) and at various heating fluid temperatures (40 °C, 50 °C, 60 °C and 70 °C) at its evaporator inlet. The Reynolds numbers of heating fluid in the evaporator section will varies in the any range of Reynold Numbers. The variation of ambient surrounding temperature will also be considered. The heat transport rate of the HPHE should be increases marginally as the Reynolds number of heating fluid increases in the evaporator section because the condenser heat transfer coefficient does not increase significantly. The maximum heat transport rate from the HPHE will be obtained at any tilt angle and any heating fluid temperature.

Shailesh Prajapati, Prajesh Patel (2014)

In this paper study of heat pipe, copper pipe and stainless steel pipe is done using apparatus. The power is supplied to the all three pipes using suitable electric heater and change of heat is possible with Dimmer stat suitable heat is supplied and Temperatures were taken at certain length from temperature sensor and indicator results shows that the heat transfer is very good in case of the stainless steel heat pipe compare to rest two pipes and also computational analysis carried out in the ansys workbench and cfx module and the result from the experiment is validated from it.

Vishnu Agarwal, et al. (2015)

this paper presents a review on applications of heat pipes in different fields along with a brief introduction of these. Here mainly 8 applications are described in different fields which shows that the application field of heat pipes is vast . Need of this review is to make one familiar with the technology of heat pipes used for heat control in different devices and fields.

Lian Zhang and Yu Feng Zhang (2016)

In this research, the application of heat pipes in the air handler dedicated to decoupling dehumidification from cooling to reduce energy consumption was simulated and investigated by simulations and experimental studies. The cooling load profiles and heat pipes with effectiveness of 0.45 and 0.6, respectively, were evaluated in achieving the desired space conditions and calculated hour by hour. The results demonstrated that for all examined cases, a heat pipe heat exchanger (HPHX) can be used to save over 80% of the energy during the hours of operation of air conditioning. The overall energy reduction rate was from 3.2% to 4.5% under air conditioning system conditions. It was found that the energy saving potential of a laboratory was higher than for other kinds of buildings. Therefore, the dedicated ventilation system combined with heat recovery technology can be efficiently applied to buildings, especially for laboratories in subtropical areas.

Xiaoqin Sun, et al. (2016)

A thermoelectric cooling (TEC) system is proposed to remove the heat that is generated by electronic device in this paper. To improve the performance of this system, a gravity assistant heat pipe (GAHP) is attached on the hot side of the thermoelectric cooling module, serving as a heat sink. A mathematical model of heat transfer, based on the energy conservation, is established for the integrated system. A prototype is designed, built and tested in a climatic chamber under various conditions, comparing with a TEC system with air cooling heat sink. It is found that the cooling capacity is improved by approximately 73.54% and the electricity consumption was reduced by 42.20% to produce the same amount of cold energy.

III. LITERATURE GAP

After careful study of various papers and literature it is clear that liquid cooled heat exchangers using heat pipes are sparse and have being rarely researched. No specific research was found to be dedicated to study the effect of change in wick structures on the performance of liquid cooled heat exchangers. Given the specific applications in liquid cooling the heat pipe cooled devices are becoming increasingly popular research in this area is a must. The project work aims at design development and study of one such liquid cooled heat exchanger using heat pipes of two different wick structures namely sintered copper and woven mesh. The objective of research will be design and develop the system for liquid cooling system for application of electronic devices. The project work embodies the system development, thermal analysis using Ansys software and experimental performance evaluation and comparative evaluation of performances of the said devices.

This design permits to eliminate leakage problems and also reduces space required and cost of manufacture so there is a need to develop such a device.

IV. PROBLEM STATEMENT

The liquid cooling using extrusion of aluminium or copper on a cylindrical cavity and cooling fluid circulated through it is a common practice in industry, though the method is innovative and increases the surface area of the heat exchanger there are certain problems faced while using the device which are namely:

1. Very large foot print as the size of the plates is considerably large to increase the surface area the device. Hence occupies very large space making the equipment of application bulky and heavy.
2. Device is prone to leakages as large liquid volumes are needed to handle more heat flux.
3. Suitable to high heat gradients i.e. large temperature difference is desired for proper operation.
4. Relatively higher cost.

V. SOLUTION

Tower cooler using embedded heat pipes are a cost-effective solution, proven in rugged environments like computer components, computer electronics devices, transportation control systems and military and aerospace systems, among many other applications. Embedded heat pipes provide efficient thermal management for applications that are space-constrained (and redesigning a product to accommodate more volume for the heat sink would be impractical) and the need is to increase performance or upgrade their existing product with advanced electronics that generate more heat. Embedding heat pipes into the existing heat sink, or applying a spiral radial fin structure heat sink to increase its heat spreading and rejection efficiency, can do the job without a costly product redesign.

Two configurations are proposed for the tower cooler name:

1. Copper pipe with sintered powder metal wick structure
2. Copper heat pipe with copper wire mesh wick structure

This allows round, shaped, heat pipes configured to fit into the tightest of applications. For example, heat pipes can be held onto to mounting holes. For the best thermal contact, heat pipes are press fitted or adhesively bonded into the metallic heat sinks making them strong enough to withstand and survive the toughest temperature extremes and vibration environments.

Thus the System solves problem by

1. Increasing the heat transfer rate by extracting latent heat which is 100% more than the sensible heat extracted by previous system
2. Compact system, hence requires less space
3. Zero maintenance and no chances of leakage
4. Maximum surface in minimum space
5. Lower manufacturing cost

VI. PROPOSED TEST RIG

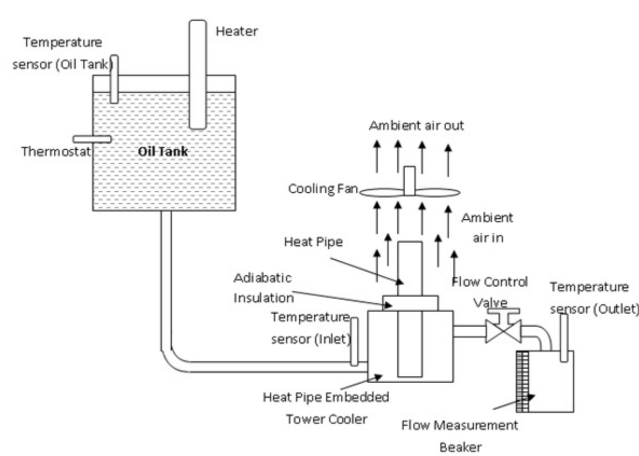

Fig: Experimental Setup

VII. METHODOLOGY

Designing and Developing an Innovative Cooling tower heat extraction system using heat pipes for determining the heat load (Application specific). Selection of heat pipe for given application load and Designing of Helical spiral radial fin enclosure tower heat sink. Designing and developing a test rig in order to evaluate and have comparison of performance and heat transfer ability of Copper heat pipe with wire mesh wick and Copper heat pipe with sintered copper wick. Hence heat transfer rate and heat transfer coefficient will be determined for individual cases and later compared. Steady state thermal analysis will be carried out using Ansys Workbench 16.0. Statistical analysis will be carried out using Taguchi method for Design of Experiment and Anova for 5% variance will be carried out using Minitab software to optimize the flow rates of air and oil in order to achieve maximum heat transfer.

A. Expected Outcome

a. LMTD
b. Capacity Ratio
c. Overall Heat transfer Coefficient
d. Optimal Flow rate of oil for maximum heat transfer
e. Optimal Flow rate of oil for maximum heat transfer
f. Effectiveness of device

VIII. CONCLUSION

As there is a need of critical thermal management in field of applications such as Medical science, laser technologies, aerospace, power electronics, military, unconventional energy, transportation sector, and many more due to persistent problem of overheating which leads to failure of devices.

A simple, compact, high efficiency, low cost device will be developed, so also a new technology of heat pipe embedded tower cooler will be learnt. The research will provide the industry with a new device to solve the problems of overheating in many types of machinery and electronic equipments in different areas of applications.

REFERENCES

[1] Randeep Singh, Aliakbar Akbarzadeh, Chris Dixon, Mastaka Mochizuki, and Roger R. Riehl, (2007). *"Miniature Loop Heat Pipe With Flat Evaporator for Cooling Computer CPU"*, IEEE Transactions On Components And Packaging Technologies, Vol. 30, No. 1, March 2007

[2] Sumit Kumar Rai and K K Jain (2012). *"Evaluation Of The Thermal Performance Of Heat Pipe Heat Exchanger Under Natural Convection"*, International Journal of Mechanical Engineering and Robotics Research, Vol. 1, No. 2, July 2012

[3] Shailesh Prajapati, Prajesh Patel (2014). *"Performance Behaviour of Copper Pipe, Stainless Steel pipe and Steel Heat Pipe"*, International Journal of Engineering and Management Research Volume-4, Issue-2, April-2014 Pn 277-281

[4] Vishnu Agarwal, Dr. Sudhir Jain, Keerti Vyas,Ginni Jain (2015). *"A Review Paper on Role of Heat Pipes in Cooling"*, International Journal of Emerging Trends in Electrical and Electronics,Vol. 11, Issue. 2, June 2015

[5] Lian Zhang and Yu Feng Zhang (2016). *"Research on Heat Recovery Technology for Reducing the Energy Consumption of Dedicated Ventilation Systems: An Application to the Operating Model of a Laboratory"*, Energies 2016, 9, 24; doi:10.3390/en9010024

[6] Xiaoqin Suna, Yanjia Yanga, Hongliang Zhanga, Huiwei Sia, Liang Huanga, Shuguang Liaob, Xiaosong Gua (2016). *"Experimental research of a thermoelectric cooling system integrated with gravity assistant heat pipe for cooling electronic devices"*, The 8th International Conference on Applied Energy – ICAE2016, Energy Procedia 105 (2017) 4909 – 4914