



A Review Of Heat Pipe With Nanofluid For Electronic Cooling

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Abstract: A heat pipe is an important tool for effective cooling performance of the electronic devices. The main focus of this paper is to review applications of heat pipe in electronic system. Miniaturization of chips and increasing processing speed decreases the heat transfer surface area and generates very high heat fluxes resulting in large temperature rise in electronics devices. Therefore, for an effective cooling heat pipe is a better selection because of its high efficiency and reliability. A major part of this review paper is allocated to applications of different types of heat pipe and modern trends in heat pipe technology. Nanofluids are dilute suspensions of nanoparticles composite materials with the specific aim of increasing the thermal conductivity of heat transfer fluids. Authors also analyzed some of the applications of heat pipes with nanofluid for electronic cooling.

Index Terms - heat pipe, effective cooling, nanofluids.

I. INTRODUCTION

Mobile electronic devices, such as wearable computers, mobile phones, personal digital assistants, mini-laptops, and others are becoming increasingly common and also getting smaller in sizes, but packed with higher power dissipation from their electronics components. The electrical resistance to the flow of electrical current during the operation of the electronic devices through the leads, poly-silicon layers and transistors will result in a significant internal heat generation and temperature rise, which if unchecked may lead to a deterioration in the device performance, and even lead to fracture, delamination, melting vaporization and combustion. Effective cooling is required to remove heat dissipation from wearable computers. Among all the cooling methods, heat pipe is a better selection because of its high efficiency and reliability.

High heat flux removal is a major challenge in the design of future electronic devices. Commonly, water is suggested to be used as a single-phase coolant in combination with microchannel heat sinks for cooling electronics, as it possesses the most adequate thermal and hydrodynamic transport properties in the required range of operating temperatures. However, the thermal conductivity of water is two to three orders of magnitude lower than of most metals and metal oxides. Therefore, an innovative way to elevate the thermal conductivity of fluids may be the addition of nanometer-sized metal or metal oxide particles into a base-fluid, most suitably water.

The main distinction of heat pipes, besides the working fluid and envelope material, is the wick structure. There are several types of wick structures: screen, grooves, felt, and sintered powder. Sintered powder metal wicks offer several advantages over other wick structures. An emerging advantage of the sintered powder wick is its ability to handle high heat fluxes with usually low thermal resistance. Since sintered powder wicks are generally more than 50% porous, there is, accordingly, a large surface area for evaporation.

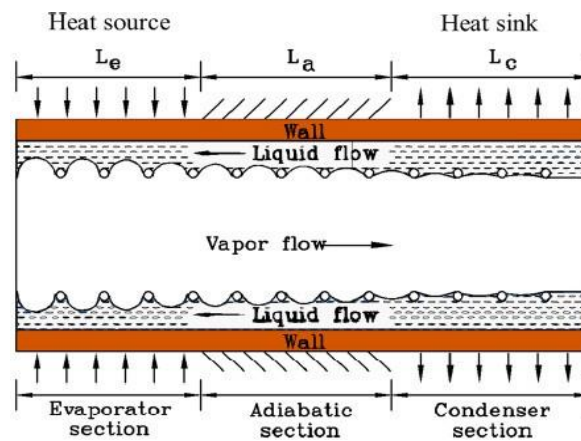


Fig. 1: Schematic representation of Heat Pipe.

II. HEAT PIPE AS A THERMAL SOLUTIONS FOR ELECTRONICS

In the early 1990's, heat pipe was gradually used as cooling device in the electronic thermal management. The first year a heat pipe was used in a notebook computer was 1994. Heat pipes were applied for desktop computer cooling in the early 2000s. From that time on as an efficient heat pipe has been increasingly used in the desktop computers and other electronic devices for an efficient cooling.

Heat pipe technology is emerging as a cost-effective thermal design solution for the desktop industry. The heat pipe applications for cooling computer CPU was started in the last decade and now 98% of notebooks CPU are cooled by using heat pipes. Different types of heat pipes are used for electronic cooling applications. Ahmed Imtiaz Uddin and Chowdhury Md. Feroz. investigated experimentally the heat transfer performance of copper parallel micro heat pipes with acetone as working fluid used for the cooling of desktop processor. They examined that with use of smaller diameter heat pipes reduces the maximum and steady state temperature of the processor surface significantly. Suggested an alternative low noise cooling system for personal computers using loop heat pipes. Presented study on the miniature heat pipe with circular cross-section was pressed and bent for packaging into a notebook PC with very limited space. Reviewed application of pulsating heat pipes in thermal management of electronic equipment. discussed an advanced heat pipe mechanism (pulsating heat pipe) that has the potential of achieving heat flux capabilities over 250 W/cm². Balewgize and demonstrated experimentally heat transport performance, transient responses and maximum heat capacity of flat heat pipe (FHP) for electronic cooling. studied FHP with screen mesh for electronic cooling. A hydrodynamic and thermal simulation shows that the ability of the FHP to cool several electronic components located on a printed circuit board. investigated experimentally the thermal performance of closed end oscillating heat pipe (CEOHP). They found that, the CEOHP cooling module had better thermal performance than conventional heat sink.

Presented an analytical solution for liquid and vapor flows as well as the temperature distribution inside a flat micro heat pipe, under the action of three electronic components. This model is devoted to the steady-state performance of FHP and is based on the coupling of the fluid flows and heat transfer processes. It was assumed that the liquid and vapour flows are governed by simplified transport equations as Darcy's law. The authors pointed out that conduction through the wall and wick is seen to play a significant role in determining the temperature distribution in FHP. Adopted the transient performance of a FHP, used to cool multiple electronics components. Performed experimental thermal analysis and FEM simulation of vertically oriented finned U-shape multi heat pipes under natural and forced convection conditions and showed that the air velocity, power input and heat pipe orientation have significant effects on the performance of finned heat pipes. The analysis shows that as the heat input and air velocity increase, total thermal resistance decreases. The lowest value of the total thermal resistance obtained was 0.181° C/W when heat input was 24W and air velocity 3 m/s.

A. Cooling methods in combination with heat pipe

Heat pipe is used with in combination with other cooling methods. Research is carried out on system that combined with the advantages of heat pipe for removal of dissipated heat. Focused on a system for removal of dissipated heat that combined the advantages of heat pipe and thermoelectric modules. Thermal cooling of central processing unit by using the vapour chamber (VC) with jet liquid impingement and found that the CPU temperatures obtained from the VC with jet liquid impingement cooling system are lower than those with conventional flow liquid system. proposed a novel heat pipe–heat sink with new wick structure, also conducted experimental investigation on its thermal performance and pressure drop. The heat pipe-heat sink reaches the performance of the thermal resistance 0.118 K/W for a total power of 420 W under the maximum temperature difference limit 50 K when the air flow rate was 71m³/h with pressure drop of 30 Pa.

III. MODERN TRENDS IN HEAT PIPE TECHNOLOGY

Since 2000, with regards to electronic applications, the main trend of heat pipe design has been focused on high performance, light weight and low cost . The investigations are still continuing, the people have made many improvements on traditional heat pipes and their assemblies. There are few modified version of heat pipes. In this paper, we have reviewed various latest technologies of heat pipes for cooling of high performance electronic devices.

A. Vapour Chamber

VC's are planar heat pipes used for cooling high heat flux electronics. Like conventional cylindrical heat pipes, VC's transport heat from a heat source to a heat sink with a very small temperature gradient. The main difference between FHP's and VC's is seen as their fabrication method. FHP's can be stamped from originally round material, while VC can be formed through welding or brazing operation and consists of separate evaporator and condenser where only the evaporator has wick structure. Fig. 2 shows schematic of VC.

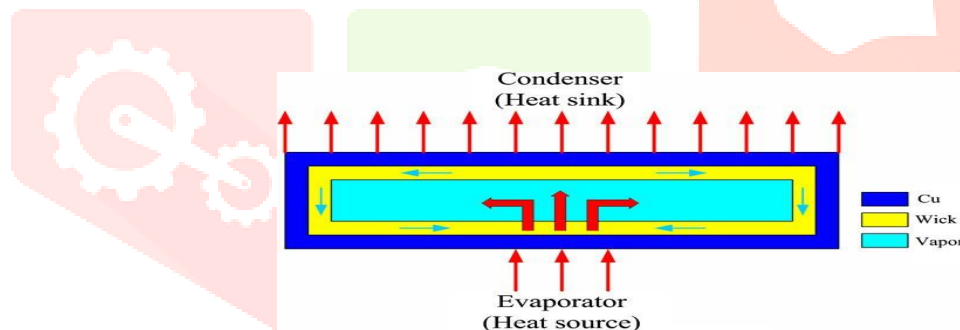


Fig. 2: Schematic of a Vapour Chamber.

B. Looped Heat Pipes

Loop heat pipes (LHP's) generally can transport higher heat flow rates compared to conventional heat pipes, since there is high hydraulic resistance in LHP for the liquid returning the evaporator. Here, heat is applied to the flattened evaporator and the working fluid vaporizes. It flows to the vapor line due to pressure difference and goes to condenser where heat is carried away by cooling fluid or fins with forced convection. Then the condensed fluid is then returned to the evaporator section by the liquid line. Fig. 3 shows the operating principle of loop heat pipe.

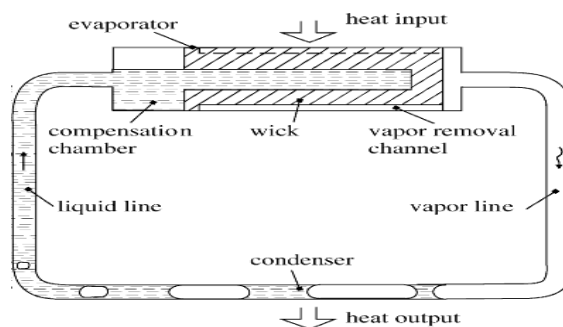


Fig. 3: Operating principle of loop heat pipe.

C. Embedded Heat Pipes

A popular heat pipe assembly method is to embed heat pipes into a metal block (normally aluminum or copper alloys). The evaporation section of heat pipes is embedded into a metal plate/block, and the condensation section connects with a cooling part, such as a fin stack or cooling material. Due to the metal block fully touching the heat source, it increases the heat dissipation surface area, so that the assembly enhances the heat transfer performance of heat pipes. The main advantage of embedded heat pipe assemblies is increasing the surface area of the heat transfer media, and then dissipating much more heat from the heat sources [24]. Embedding heat pipes into the heat sink is an effective cooling alternative to greatly enhance the performance of an existing heat sink with minimum design changes as shown in Fig.4.

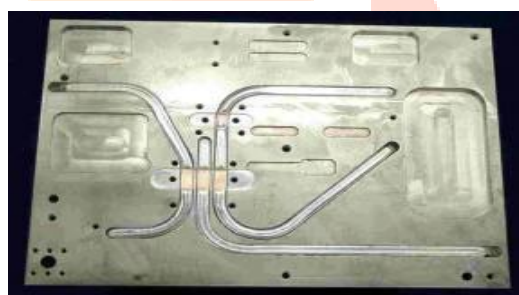


Fig. 4: Heat Sink Base with Embedded Heat Pipes

IV. COOLING OF ELECTRONICS WITH NANOFLUIDS

Due to higher density of chips, design of electronic components with more compact makes heat dissipation more difficult. Advanced electronic devices face thermal management challenges from the high level of heat generation and the reduction of available surface area for heat removal. In general, there are two approaches to improve the heat removal for electronic equipment. One is to find an optimum geometry of cooling devices; another is to increase the heat transfer capacity. Nanofluids with higher thermal conductivities are predicated convective heat transfer coefficients compared to those of base fluids.

Nanofluids are one of the potential technologies for heat transfer in future. The stable suspensions of nanoparticles (typically <100 nm) in liquids are called nanofluids; Nanofluids are found to have very stable suspensions, without substantial sedimentation for a long time. They are found to eliminate most of the problems arising with slurries like sedimentation, clogging of small channels, erosion, excessive pressure drop etc. Moreover, the heat transfer capabilities of nanofluids are much enhanced as compared to base fluids. This makes them suitable for use in cooling of electronic equipments. The selection criteria of nanoparticles for cooling systems are as follows.

- High stability in selected base fluid and lower tendency to agglomeration and settling;
- High thermal performance in suspension even at low concentrations;
- Availability and reasonable price;
- Non-toxic and environmental friendly.

In order to prepare the nanofluids by dispersing the nanoparticles in a base fluid, proper mixing and stabilization of the particles is required. Normally, there are three effective methods used to attain stability of the suspension against sedimentation of the nanoparticles,

which are summarized as follows

- (1) control of the pH value of the suspensions,
- (2) addition of surface activators or surfactants and
- (3) Use of ultrasonic vibration.

Some researchers have applied various nanofluids in heat pipes as the working fluids to enhance their heat transfer performance. Since heat pipes utilize the phase change of the working fluid to transport the heat, the selection of working fluid is of prime importance for enhancing their thermal performance. Investigated experimentally thermal performance of silver nano-fluid on heat pipe. Studied experimentally utilization of the water based Al_2O_3 nanofluids as the working fluid which enhances the thermal performance of the heat pipe. Reviewed the latest researches of heat pipes using nanofluids as working fluids in recent years.

The thermal efficiency enhancement of heat pipe with nanofluids (titanium nanoparticles, diameter of 21 nm) as shown in Fig.5. In general, the suspension of nanoparticles in the fluid has significant effect on the enhancement of heat transfer due to: higher heat capacity, higher thermal conductivity of working fluid and higher mixing fluctuation. Therefore, the heat pipe thermal efficiency increases with increasing nanoparticles concentrations. As the concentration of nanoparticles exceeds to a certain limit, the properties of the nanofluids seem to be a solid phase thereby lower evaporation rate of working fluid in the evaporator section. Therefore, the heat pipe thermal efficiency also decreases.

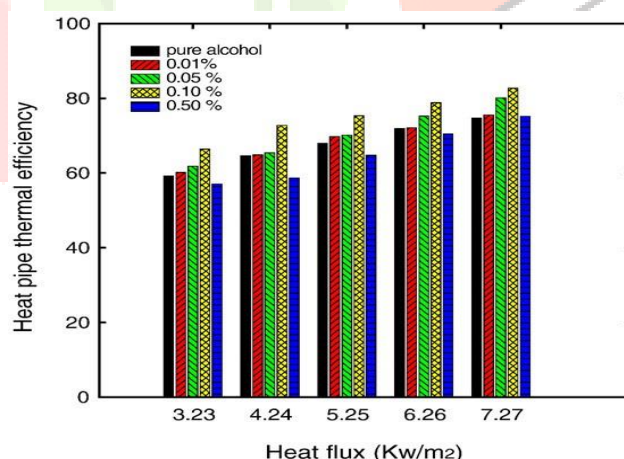


Fig. 5: Variation of heat pipe thermal efficiency with heat flux for different % nanoparticles volume concentrations

A. Heat pipe with Nanofluid

The novel technology for cooling devices such as combination of heat pipe with nanofluid for electronic cooling has emerged as current trend of development. However, there is no more published data on the use of nanofluids for enhancing the heat transfer of heat pipes used for CPU coolers. found first investigation on the effect of nanofluids in conjunction of heat pipes on the enhanced cooling of CPU as a function of gravity. Experiments with Al_2O_3 -water nanofluid, as the working medium, indicate that the thermal resistance can be decreased by 15% and 22%, when the heat generated at the CPU is at 10W and 25W respectively. Putra et al. [43] investigated the application of nanofluid as a working fluid on a heat pipe liquid block combined with thermoelectric cooling (TEC). The commercial sintered heat pipe liquid-block used was made of copper, alumina-water and titania-water nanofluids were used as the working fluids. Fig. 6 (a) shows the details of heat pipe liquid block. Using the design for personal computer for CPU cooling, the effect of various factors namely, nanofluid type, nanofluid concentration, coolant temperature, and thermoelectric system were investigated. Fig.6. (b) shows the comparison between the cooling system with and without the thermoelectric (TEC). The CPU temperature decreased considerably with the addition of the thermoelectric on the cooling system. Temperatures of CPU are approximately 26°C , 24.2°C , and 23.9°C , respectively for water, and TiO_2 , Al_2O_3 nanofluids have a 1% particle concentration. Thus, the higher thermal performance heat pipe liquid-block and thermoelectric cooled system with nanofluids proved its potential as a working fluid. discussed the thermal performance of the MPHP (micro pulsating heat pipe) in both the transient and steady conditions, also studied the effects of the working fluid (water, silver nanofluid, and ferrofluid), heating power, charging ratio, inclination angle and the application of magnetic field. The results show that the optimum charging ratio for water is 40%, while this optimum for nanofluids is 60%.



Fig. 6 (a): Heat pipe liquid-block.

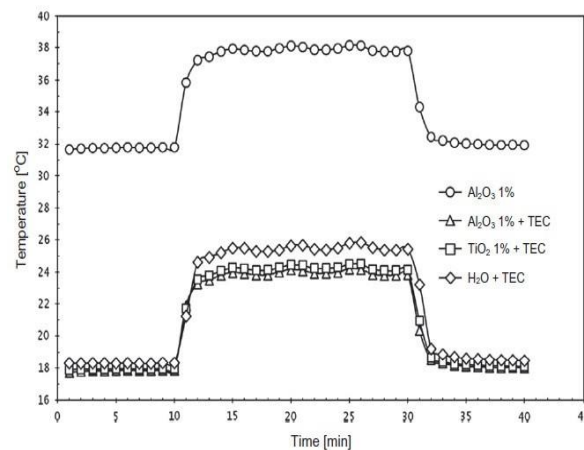


Fig. 6 (b): The CPU temperature obtained from the heat pipe liquid block with and without thermoelectric cooling system.

V. CURRENT & FUTURE DEVELOPMENTS

The above review shows that the application of heat pipes in electronic cooling is still in its infancy. Here, some suggestions are presented for future work along with recent work on heat pipe. The authors hope that these proposals will be helpful for the development on the use of heat pipes for cooling electronic devices. Nanofluids can be used in heat pipes. The majority of the experimental works carried out so far indicates a lowering of the thermal resistance and therewith a significant improvement of the thermal performance. Magnetic nanofluids and nanofluids with carbon nanotube are promising options because they allow the use of additional effects like the application of additional external forces or the extraordinary high thermal conductivity along the main axis of the CNT. In commercially available heat pipes used in electronic devices, the capillary radius is at an order of around hundred micrometers. Therefore, nanotechnology will be a choice to replace micro wick structures with nanostructures on the wall surface of heat pipe for raising both the capillary and boiling limits.

With the increase in processing power of computers a need has been identified for enhanced cooling techniques. The emerging design proposals of cooling components such as vapor chamber, loop heat pipe, embedded heat pipe and their combination with heat sink, other cooling methods have led the future developments of electronic cooling concepts toward the system development. Heat pipe assisted heat sink systems are still undergoing further developments and their applications in electronic cooling are limited primarily due to their costs. The increased power density for electronic chipsets and assemblies has urged the developments of cooling units for high power electronic components toward the two-phase systems which employ various heat transfer augmentation designs.

IV. CONCLUSION

The review reveals the applications of heat pipe in electronic cooling. Heat pipes are the one of the available technologies to deal with the high density electronic cooling problem due to their high thermal conductivity, reliability and low weight. Based on literatures, it has been found that different types of heat pipes are used for cooling electronic devices. Heat pipe with nanofluid for cooling of electronic devices is reported by few researchers. Heat pipe assisted heat sink systems are still undergoing further developments and their applications in electronic cooling are limited primarily due to their costs. This paper also reviewed modern trends in heat pipe technology. Nanofluids are advanced fluids containing nano sized particles that have emerged during the last two decades. Nanofluids, employed as working medium for conventional heat pipe, have shown higher thermal performances, having the potential as a substitute for conventional water in heat pipe. Some proposals are presented to develop use of heat pipe with nanofluid.

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