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Nano Fluid Based Investigation Study of Heat Transfer Enhancement Through Micro Heat Pipe

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Abstract— *Micro heat pipes are small and passive heat transfer devices. Research is going on in its applications ranging from using them in high powered electronic devices to using them during brain surgeries. A combination of silicon with many different liquids as working fluids is being investigated. This thesis investigates the fabrication of micro heat pipes arrays and the possibility of using mercury as one of the working fluids. Water was also tried on some of them. A new sealing technique was used to seal the micro heat pipes filled with mercury. Tests were carried out on these charged devices and silicon dummies under an infra-red camera. The results of the charged devices were compared with silicon dummy to check their working feasibility. The micro fabrication, charging, sealing and testing procedures are discussed in the following work. The results obtained from the tests conducted are also presented. Heat pipe is device working on two phase change of working fluid inside. This phase change of working fluid lead to increasing heat transport efficiency of heat pipe. The basic heat pipe working position is vertical position, when the heat pipe can transport maximal heat flow from evaporator to condensates. This article deals about wick heat pipe construction and propose device to identify thermal performance. The result of article is comparison of thermal performance transported by heat pipe from working positions.*

Keywords— *Heat Pipes, working fluids, mercury, infrared camera*

I. Introduction

Heat pipe is a heat transfer device with an extremely high effective thermal conductivity. Heat pipes are evacuated vessels, typically circular in cross sections, which are back-filled with a small quantity of a working fluid. They are totally passive and are used to transfer heat from a heat source to a heat sink with minimal temperature gradients, or to isotherm Alize surfaces. Heat removal is an important parameter while designing compact electronic components. Initially copper heat sinks were used to remove the heat from the mother board of desktop computers. Nowadays, to increase the heat transfer in electronic components, like laptops, note book computers etc., heat pipes have been used. Heat pipe is a device used to transfer the heat from one place to the other.

The heat pipe consists of evaporator section, adiabatic section and condenser section . Heat absorption takes place in the evaporator section and heat rejection at the condenser section. Adiabatic section is fully insulated. The heat pipe is evacuated using a vacuum pump and is filled up with the working fluid. The working fluid absorbs the heat at one end of the heat pipe called evaporator and releases the heat at the other end called condenser. Due to the capillary action, the condensed working fluid through the mesh wick structure returns to the evaporator, on the inside wall of the pipe. Normally conventional fluids are used in heat pipes to remove the heat. Nowadays, nano fluids play an important role in heat pipes to increase the heat transfer compared to conventional fluids.

Thermal conductivity is an important parameter in enhancing the heat transfer performance of a heat transfer fluid. A heat pipe is a heat-transfer device that combines the principles of both thermal conductivity and phase transition to effectively transfer heat between two solid interfaces. At the hot interface of a heat pipe a liquid in contact with a thermally conductive solid surface turns into a vapor by absorbing heat from that surface. The vapor then travels along the heat pipe to the cold interface and condenses back into a liquid – releasing the latent heat. The liquid then returns to the hot interface through either capillary action, centrifugal force, or gravity, and the cycle repeats. Due to the very high heat transfer coefficients for boiling and condensation, heat pipes are highly effective thermal conductors. The effective thermal conductivity varies with heat pipe length, and can approach 100 kW/(m·K) for long heat pipes, in comparison with approximately 0.4 kW/(m·K) for copper typical heat pipe consists of a sealed pipe or tube made of a material that is compatible with the working fluid such as copper for water heat pipes, or aluminum for ammonia heat pipes. Typically, a vacuum pump is used to remove the air from the empty heat pipe. The heat pipe is partially filled with a working fluid and then sealed. The working fluid mass is chosen so that the heat pipe contains both vapor and liquid over the operating temperature range. Below the operating temperature, the liquid is too cold and cannot vaporize into a gas. Above the operating temperature, all the liquid has turned to gas, and the environmental temperature is too high for any of the gas to condense.

In other words, whether too high or too low, thermal conduction is still possible through the walls of the heat pipe,

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but at a greatly reduced rate of thermal transfer. Working fluids are chosen according to the temperatures at which the heat pipe must operate, with examples ranging from liquid helium for extremely low temperature applications (2–4 K) to mercury (523–923 K), sodium (873–1473 K) and even indium (2000–3000 K) for extremely high temperatures. The vast majority of heat pipes for room temperature applications use ammonia (213–373 K), alcohol (methanol (283–403 K) or ethanol (273– 403 K)) or water (298–573 K) as the working fluid. Copper/water heat pipes have a copper envelope, use water as the working fluid and typically operate in the temperature range of 20 to 150 °C. Water heat pipes are sometimes filled by partially filling with water, heating until the water boils and displaces the air, and then sealed while hot. For the heat pipe to transfer heat, it must contain saturated liquid and its vapor (gas phase).

The saturated liquid vaporizes and travels to the condenser, where it is cooled and turned back to a saturated liquid. In a standard heat pipe, the condensed liquid is returned to the evaporator using a wick structure exerting a capillary action on the liquid phase of the working fluid. Wick structures used in heat pipes include sintered metal powder, screen, and grooved wicks, which have a series of grooves parallel to the pipe axis. When the condenser is located above the evaporator in a gravitational field, gravity can return the liquid. In this case, the heat pipe is a thermosiphon. Finally, rotating heat pipes use centrifugal forces to return liquid from the condenser to the evaporator. Heat pipes contain no mechanical moving parts and typically require no maintenance, though non-condensable gases that diffuse through the pipe's walls, resulting from breakdown of the working fluid or as impurities extant in the material, may eventually reduce the pipe's effectiveness at transferring heat.

The advantage of heat pipes over many other heat-dissipation mechanisms is their great efficiency in transferring heat. A pipe one inch in diameter and two feet long can transfer 3.7 kW (12.500 BTU per hour) at 1,800 °F (980 °C) with only 18 °F (10 °C) drop from end to end. Some heat pipes have demonstrated a heat flux of more than 23 kW/cm², about four times the heat flux through the surface of the sun.

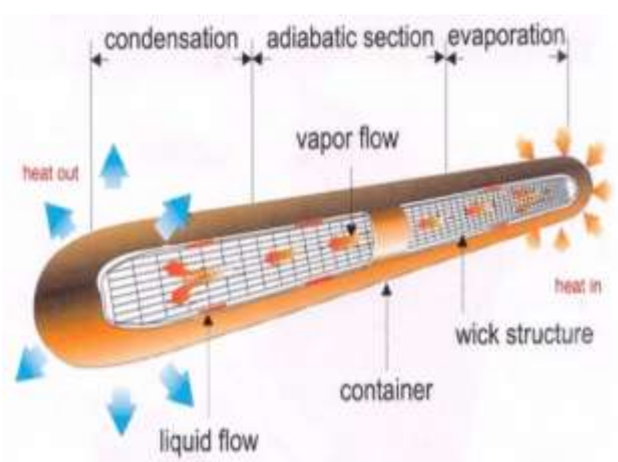

Fig 1.1 Heat pipe working principle.

II. LITERATURE REVIEW

Many researchers have presented the heat transfer characteristics of heat pipe using nanofluids. The nano meter sized particles have great potential in improving heat transfer of base fluids. The properties of nano particle of size lesser than 100 nm are different from conventional fluids and result show that there is an improvement in heat transfer.

Seok Hwan, Gunn hwang (2016) reported that operating temperature is 60- 90*c micro heat pipe is widely used in integrated electronics units as a cooling module to improve stability in operation and longtime of system. Working fluid is pure water container material oxygen free copper, filling ratio of working fluid is 20%

Fabian korn (2009) department of energy science, Lund university, swedon reported that complex heat transfer problem in heat pipe by possible calculating of operating temperature is 0 to 100*c. working fluid is ammonia, material is aluminum, steel, nickel.

Ramzi bey-oueslati (2011) said that heat pipe is used as heat spreaders to avoid hotspots, a major issue in electrical industry is direct wire assembly compatible with electronic fabrication.

Rojionium, Frederick (2013) department of nuclear engineering said that loop heat pipe with coherent micron porous evaporative wick is used to remove the heat and it achieve high heat removal capability material is copper working fluid is water.

CONSOL Inc. Research and development said that thermal based power plant heat pipe is used cooling system for flue gas. Xuan and Lihave studied the thermal conductivity and convective heat transfer of nanomaterials as substitutes to water and ethylene glycol.

Lin et al. have presented the experimental results of a two-phase heat transfer of R141b refrigerant in a 1 mm diameter tubulin et al. have developed a miniature heat pipe for heat removal of high heat flux electronics devices. Thermal performance of a solar cooking system using vacuum tube collectors with heat pipes and a refrigerant as working fluid has been experimentally investigated by Esen.Song et al. have experimentally investigated the heat transfer performance of axially rotating heat pipes by the effects of the rotational speed, heat pipe geometry, and working fluid loading under steady state.

Xuan et al. have investigated the effects of the different heat fluxes, orientations and amount of the working fluid on the performance of a flat plate heat pipe. Wen and Dinghave experimentally investigated the convective heat transfer of nanofluids in a copper tube at the entrance region under laminar flow conditions. Zhouhas investigated the improvement in heat transfer characteristics of copper nanofluids with and without acoustic cavitation‟s.

Bang and Changhave studied the boiling heat transfer characteristics of water with Al2O3 nanoparticles suspended by the effects of different volume concentrations of nanoparticles. The application of heat pipes in modern heat exchangers and the micro and miniature heat pipes used in cooling of electronic components has been studied.

Huang et al. have evaluated the performance of a heat pipe in the solar- assisted heat pump water heater system. Lin et al. have simulated numerically a heat pipe heat exchanger integrated with the dehumidification process and Kleinstreuerhave proposed the steady laminar flow of liquid nanofluids in micro channels.

Liu et al. have experimentally investigated the effects of thermal conductivity of nanofluids, ethylene glycol and synthetic engine oil on the multiwall carbon nanotubes. The convective heat transfer coefficient of nanofluids has been investigated under laminar flow in a horizontal tube heat exchanger by Yang et al.

Zenial Heirs et al. investigated the circular tube with the laminar flow convective heat transfer of oxide nanofluids under constant wall temperature boundary condition. Ang and Choihave numerically investigated the heat transfer characteristics of micro channel of heat sink with nanobuds‟ et al. have proposed the study of the heat and mass transfer properties of HFC134a gas hydrate in nano-copper suspension.

Palm et al. have numerically investigated a typical radial flow cooling system, an improvement in heat transfer characteristics of coolants with suspended metallic nanoparticles. Ang et al. have experimentally investigated on the heat transfer characteristics of heat pipe with silver nanofluid. Ding et al.have proposed a study on the heat transfer characteristics of aqueous suspensions of carbon nanotubes in pressure-driven laminar pipe flows of nanofluids. The effects of the length of the evaporator and vapor temperature on the critical values of the upper and lower boundaries of loop heat pipe were considered by Liu et al.

Vlassov et al.have investigated the characteristics of a heat pipe radiator assembly for space application filled with ammonia or acetone. He et al. have conducted study on the heat transfer and flow characteristics of aqueous suspensions of TiO2 nanoparticles flowing upward through a vertical pipe.

Nguyen et al.have experimentally investigated the heat transfer enhancement of an Al2O3–water nanofluid for cooling of electronic components.Trickeryand Wongwises summarized the recent developments in research on the heat transfer characteristics of nano fluids. The presence of suspended nanoparticles enhances the heat transfer characteristics of conventional fluids.Chein and Chuanghave studied the micro channel heat sink performance using nanofluids and compared the theoretical results with the measured data.

Mansour et al. have found the effect of uncertainties in physical properties on forced convection heat transfer with nanofluids.

A. PROPOSED HEAT PIPE

The basic idea of proposed system is originated from these existing systems. Majorly we are developing a system in a heat pipe is set to reduce a heat from the electronic device. nowadays the electronic device is used in industry. Our aim to design a heat pipe to reduce a heat from the device easily.

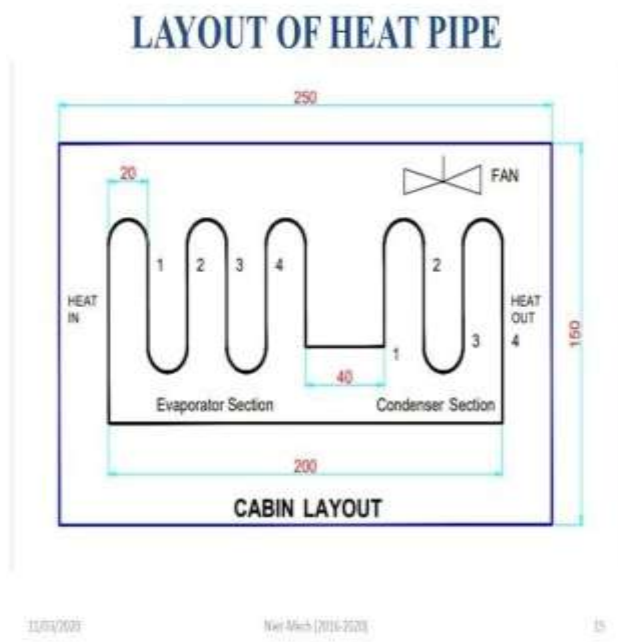

Figure 1. Layout of heat pipe

Heat pipe is working the principle of conduction and convection

- *Conduction will occur evaporator section*
- *Convection will occur condenser section*

B. Operation of heat pipe

The overall thermal resistance of a heat pipe, defined by equation, should be low, providing that it functions correctly.

In order for the heat pipe to operate the maximum capillary pumping pressure, ΔP_c, max must be greater than the total pressure drop in the pipe. This pressure drop is made up of three components. 1. The pressure drop ΔP_l required to return the liquid from the condenser to the evaporator. 2. The pressure drop ΔP_v necessary to cause the vapor to flow from the evaporator to the condenser. 3. The pressure due to the gravitational head, ΔP_g which may be zero, positive or negative, depending on the inclination of the heat pipe. For correct operation,

$$\Delta P_{c,max} \geq \Delta P_l + \Delta P_v + \Delta P_g$$

If this condition is not met, the wick will dry out in the evaporator region and the heat pipe will not operate. The maximum allowable heat flux for which equation 2 holds is referred to as the capillary limit. Typically, the capillary limit will determine the maximum heat flux over much of the operating range; however, the designer must check that a heat pipe is not required to function outside the envelope either at design conditions or at start-up. During start-up and with certain high-temperature liquid metal heat pipes, the vapor velocity may reach sonic values. The sonic velocity sets a limit on the heat pipe performance. At velocities approaching sonic, compressibility effects must be taken into account in the calculation of the vapor pressure drop. The viscous or vapor pressure limit is also generally the most important at start-up. At low temperature, the vapor pressure of the fluid in the evaporator is very low, and, since the condenser pressure cannot be less than zero, the maximum difference in vapor pressure is insufficient to overcome viscous and gravitational forces, thus preventing satisfactory operation. At high heat fluxes, the vapor velocity necessarily increases; if this velocity is sufficient to entrain liquid returning to the evaporator, then performance will decline, hence the existence of an entrainment limit. The above limits relate to axial flow through the heat pipe. The final operating limit discussed will be the boiling limit. The radial heat flux in the evaporator is accompanied by a temperature difference that is relatively small until a critical value of heat flux is reached above which vapor blankets the evaporator surface resulting in an excessive temperature difference [10]. Total heat flux may by readily be obtained if we assume: 1. the liquid properties do not vary along the pipe, 2. the wick is uniform along the pipe, 3.

C. THREE MAJOR SECTION IN HEAT PIPE

1) EVAPORATOR SECTION
2) ADIABATIC SECTION
3) CONDENSER SECTION

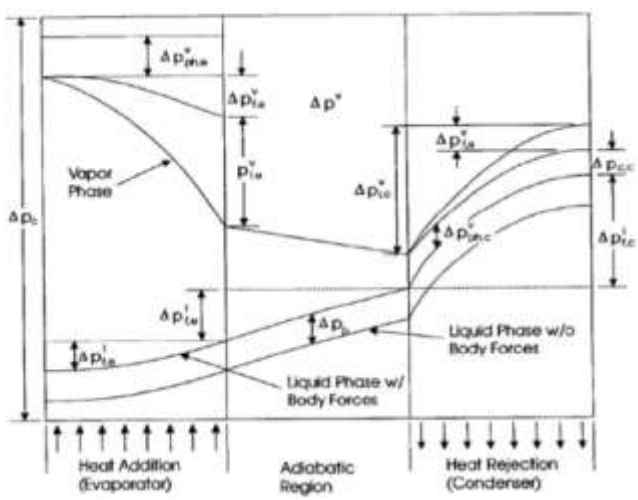

Figure 2 working of heat pipe

4) ADIABATIC

Vapor travels from the evaporator to the condenser through the adiabatic section. As the pressure drop is low, there is little temperature change in this area.

5) CONDENSER

Heat exits the heat pipe at the condenser where the working fluids condenser and releases its latent heat of vaporization. The condensed working fluids is drawn back in to the pores of the wick for return to the evaporator.

6) EVAPORATOR

Heat enters the heat pipe at its evaporator where it causes working fluid to vaporize. The vaporized fluid creates a pressure gradient which forces the vapor towards the condenser.

D. WORKING IMAGES

Figure 3Before sonicating Figure 4 After sonicating

Figure 5 Heat pipe finished model

E. FORMULAS AND CALCULATION

TO FIND VOLUME OF HEAT PIPE:

VOLUME = πdl

V=$(do - di)l$

- Inner diameter = 0.11cm
- Outer diameter = 0.16cm
- Length =10.16cm V=3.14*(0.16-0.11) *10.16

V=1.59512cc

- Heat energy q=mcpdt
- Heat transfer coefficient h=Q/Adt
- Heat flux q=Q/A

1) Volume of Filling of Nano Fluids

Total volume=1.59512cc

Filling volume (Vf) = 30% of total volume Vf= (30/100) *1.59512

Vf =0.4785cc

2) Specification

Evaporation section

Inner diameter: 1.1mm

Outer diameter: 1.6 mm Length: 101.6mm

Condenser section

Inner diameter: 1.3 mm Outer diameter: 1.7 mm Length : 76.2mm

Calculation:

Q= heat rate, watt

H=heat transfer coeffiecnt, w/m2k Dt=T2-T1

H=Q/dt

Operating temperature 60 deg to 120 deg Celsius

For Distilled water:

Q=167 W

Temp=68 to28 deg Celsius=341Kto 301K H=167/341-301

H=4.175W/m2 K

For Tetrahydrofuran:

Q=162w

Temp=335k to 308k H=162/335=308

H=6w/m2k For Acetone: Q=154 W

Temp=343K to300K H=154/343-300 H=3.58W/m2K

Figure 6 Distilled water

F. DISTILLED WATER

Definition

Distilled water is water that has been boiled into vapor and condensed back into liquid in a separate container. Impurities in the original water that do not boil below or near the boiling point of water remain in the original container. Thus, distilled water is one type of purified.

AAAAAA

1) PROPERTIES DISTILLED WATER

Chemical Formula H2O

Molecular Weight 18

Appearance White solid Or Almost Colorless, Transferant With A Slight Hint of Blue, Crystalline Solid or Liquid

Density 999.972

Melting Point 0°C (32°F,273.15K

Boiling point 99.98°C(211.96°F,373.13K)

Thermal conductivity 0.58W/mk-1

Refractive index 1.3325

Viscosity 1Cp

Specific heat capacity 75.375+_0.05j/Mol K-1

G. TABLE PROPERTIES OF DISTILLED WATER

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Thermal conductivity	0.58W/mk-1
Refractive index	1.3325
Viscosity	1Cp
Specific heat capacity	75.375+_0.05j/Mol K-1

III. RESULTS AND DISCUSSIONS

Name of the fluid	Evaporator temperature(K)	Condenser temperature(K)	Heat transfer coefficient (W/m2K)
Acetone	343	300	3.58
Tetrahydrofuran	335	308	6
Distilled water	341	301	4.175

IV. CONCLUSION

Many researches have focused on the heat pipe, loop heat pipe with various influence for the purpose of Cooling and heat transfer enhancement in different fluids.

In this project, it is proposed to carried out experimentation in the loop heat pipe and the results. i.e., energy efficiency, power consumption of the system may be the optimal.

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