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EFFECT OF ORIENTATION AND FILLING RATIO ON THERMAL PERFORMANCE FOR A CLOSED LOOP PULSATING HEAT PIPE USING DIFFERENT NANOFLUIDS

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ABSTRACT

One of the main problem faced in the thermal management of modern small-scale electronic devices such as microprocessors, microchips, hard disk drive is that they have very high power density resulting in higher heat dissipation rate. Configuration study suggests that the afore mentioned devices produce heat at a rate of 75W-85W. Traditional fan-cooling method can remove up to 50 W of the dissipated heat and thus is very inefficient. Pulsating heat pipes (PHP) can be installed inside the motherboard which can remove almost 100% of the dissipated heat. Using PHPs instead of fan not only make the motherboard more compact but also reduces noise. This study focuses on the effect of the inclination angle (gravity) and the filling ratio at different heat input levels on the heat transfer characteristics of a Closed Loop Pulsating Heat Pipe (CLPHP) using both conventional working fluids and nanofluids. In this investigation, seven different working fluids have been used namely distilled water, ethanol, methanol, Acetone, Zinc Oxide-Water, Copper Oxide-Water and Aluminum Oxide-water. The base fluid used to make all nanofluids is de-ionized water. A closed loop pulsating heat pipe is designed and fabricated with proper facility to change the angle of inclination (orientation), filling ratio and heat input. Experiments are then conducted with different filling ratios ranging from20%-80%, heat input ranging from 10W to 90W and angle of inclination varying between 30° to 90°. The main target of this study was to find out an optimum value for filling ratio and inclination angle for which heat transfer from evaporator section to condenser section is maximum. Heat transfer capability of different working fluids is also compared .Among all the fluids used, heat transfer capability of the nanofluids was better than the conventional heat transfer fluid and among the three nanofluids used, Aluminum Oxide-water based nanofluid showed the best performance. The optimum value for filling ratio is found to lie between 45%-50% and the optimum angle of inclination is within 40°-50°.

Keywords: Heat dissipation rate ,Closed loop pulsating heat pipe (CLPHP), Nanofluids , Filling ratio ,Angle of inclination.

1. INTRODUCTION

Due to continuous development of integrated circuit chips and semi-conductors, electronic devices are getting smaller day by day. Smaller components lead to higher power densities, that eventually result in higher heat release. This heat needs to be carried from the body to outside to ensure proper functioning of the device.Cooling such tiny components is not an easy task. The cooling technique also needs to be miniaturized. Heat pipes were introduced as the most appropriate, cost effective thermal design solution due to its excellent heat transfer capability, high efficiency, and structural simplicity. Due to their phase changing capability, they have a much higher capacity for transferring heat. The thermal performance of heat pipe depends on many physical parameter (orientation, filling ratio, heat input etc.) as well as on the property of the working fluid. The most common working fluid is water. Because of its low thermal conductivity, water sometime restrict the amount of heat absorbed by the heat pipe. Thermal conductivity of water can be increased by simply adding nano-sized metal particle to the water.

This study focuses on the combined effect of the inclination angle (gravity) and the filling ratio at different heat input levels on the heat transfer characteristics of a Closed Loop Pulsating Heat Pipe (CLPHP) using both conventional working fluids and nanofluids. In this investigation, we used seven different working fluids namely distilled water, ethanol, methanol, Acetone, Zinc Oxide nanofluid, Copper Oxide and Aluminum Oxide nanofluids. The base fluid used to make nanofluids is de-ionized water. A closed loop pulsating heat pipe is designed and fabricated with proper facility to change the angle of inclination (orientation), filling ratio and heat input. Experiments are then conducted with different filling ratios ranging from 20%-80%, heat input ranging from 10W to 90W and angle of inclination varying between 30° to 90°. The main target was to find out which working fluid performed best and to find out an optimum value of filling ratio and inclination angle for which heat transfer from is maximum.

2. PROBLEM STATEMENT:

Conventional cooling system for desktop PC has many problems, especially cooling performance. Lifespan of devices and reliable operation are largely dependent on junction temperature. Total power dissipation of recently introduced, new generation microprocessors had been increasing rapidly, pushing desktop system cooling technology close to its limits. Under conventional air-cooling at a speed of 2 m/s it can transfer up to 50 W. But for the case of a desktop PC, heat is generated at a rate about 50-100 W at temperatures of 80-90°C. To dissipate the extra heat, devices like heat pipes can be very useful. Using devices like heat pipe also increases the compactness of the electronic system. The most common fluid used in heat pipe is water, but the thermal conductivity of water is very low which creates a barrier to the heat transfer characteristics of heat pipe thus reducing its efficiency. By simple adding nano-sized metal particle, the heat transfer property of water can be enhanced.

3.DESIGN & FABRICATION:

The heat pipe under test is bought from manufacturer and is made into a pulsating loop with 10 turns.The evaporator section of the heat pipe is then wrapped with insulating cloth tape to prevent direct contact of heater with the pipe . The adibatic and the evaporative section is then insulated with asbestos,glass wool and two thick layers of wood to ensure proper insulation.Arrangments are made to rotate the heat pipe to the required angle.Required angles are marked on the side of the stand with the help of protractor.The rotating rods are rotated based on this marked angle .There are 12 different thermocouple points and each of Evaporator section ,Adiabatic section and Condenser section consists 3 thermocouple points . Figures of these experimental setup are given below .

Fig3.1:Experimental setup

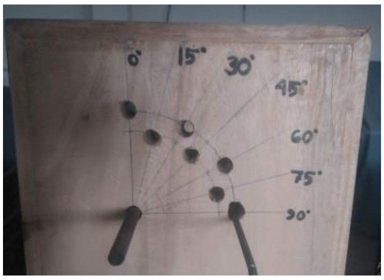


Fig3.2:Arrangement of the rotation of heat pipe.

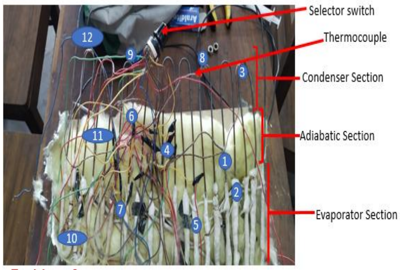


Fig3.3:Different sections of heat pipe.

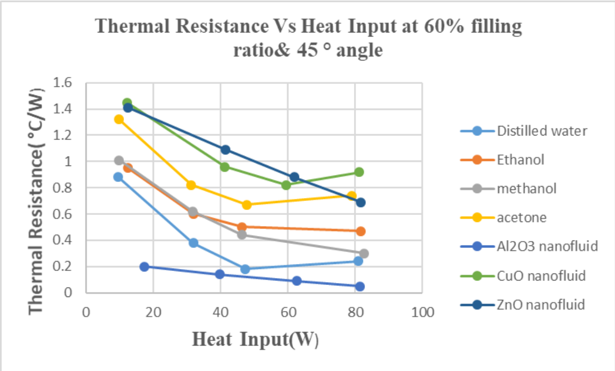
4.WORKING MECHANISM & EXPERIMENTAL PROCEDURE :

A pulsating heat pipe is a non-equilibrium heat transfer device. The liquid and vapor transport results in pressure pulsation in the system. As these pressure pulsations are fully thermal driven, due to the internal constructions of the device, there is no external mechanical power source required for the fluid transport. Bubbles are required for self-sustained thermally driven oscillations. lower heat input the size of the bubbles are very small but with the increase of heat input the size of bubbles increases by improving the heat transfer. If the temperature increases too much then dry out or burnout may occur in the evaporative section. At lower heat transfer there is no fixed flow pattern of bubbles within the PHP rather the bubbles result 'stable 'oscillations whose amplitude increases with the increase of overall fluid circulation in the device .In an actual working PHP, there exists temperature gradient between the evaporator and the condenser sections. At lower heat input there is no fixed flow pattern of bubbles within the PHP rather the bubbles oscillate inside the pipes but a further increase in heating power results in 'stable' oscillations whose amplitude increases with increase in input power. Eventually, the fluid oscillations in alternate tubes come in phase with each other thereby resulting in an overall fluid circulation in the device .

The Experiment was conducted in the room temperature. CLPHP was evacuated before charging with the working fluid using a bicycle pump and desired volume was measured with a syringe and then it was charged inside the heat pipe. The load was varied from 8/9 W to 80/85 W for each filling ratio and a desired angle. A digital thermometer and 12 K-type thermocouples placed at 12 different locations including 4 of the each in adiabatic, evaporative & condensation section were used to monitor and measure the temperature during tests. The temperature is recorded at an interval of 5 minutes. For each working fluid the stated process was repeated for 20% ,40% /50% ,60% & 80% filling ratio & inclination angle of 90° , 60° ,45° ,30° with respect to the horizontal. An interval of 12 minutes was given between two heat inputs.

5.RESULT AND DISCUSSION:

The general trend for conventional working fluid is that their thermal resistance decreases rapidly upto a heat input of 40-50W and then start increasing at a slower rate. But the trend is not same for nanofluids. For Nanofluids, the thermal resistance decreases continuously even for high heat input, though copper oxide was an exception. Decrease in thermal resistance means an increase in thermal conductivity. The optimum value of the angle of inclination is 45° and the optimum range of filling ratio is 50%-60%. The effect of angle of inclination is found to be less dominant than the filling ratio. The best working fluid was found to be Al_2O_3-water Nanofluid. These results are summarized in the graphs shown below:



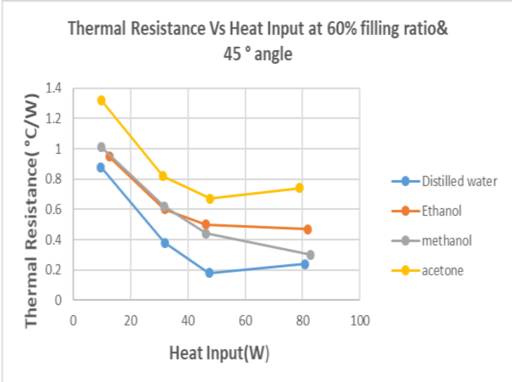
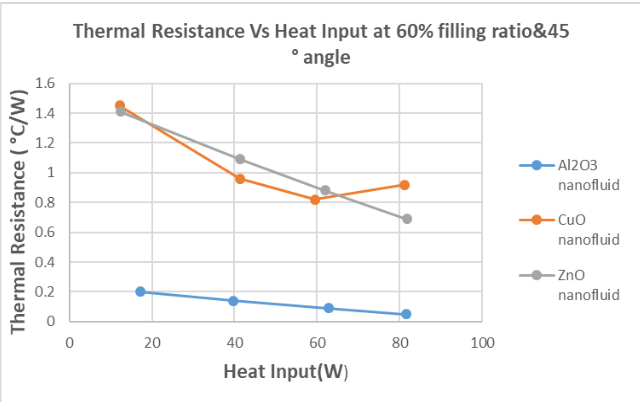


Fig: Variation of Thermal Resistance vs Heat input for all working fluids.

Fig: Variation of thermal resistance vs heat input for conventional working fluids.



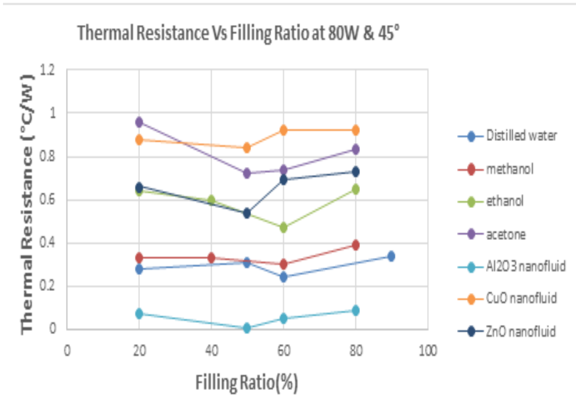
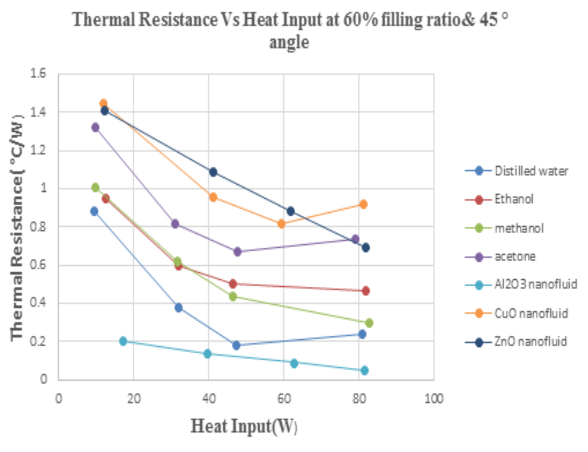


Fig: Variation of thermal resistance vs heat input for nano fluid

Fig: All Working fluids at 45° and high heat input(80W)



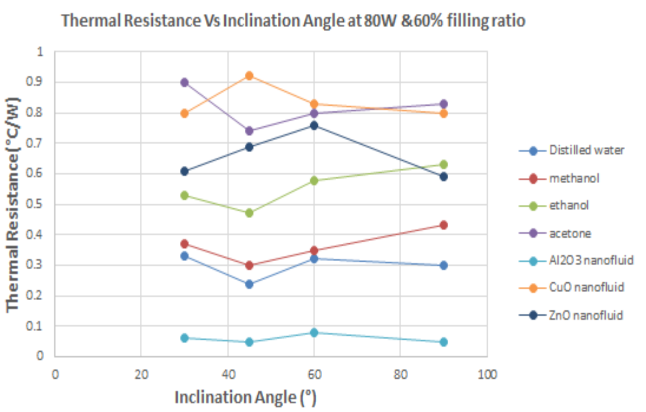


Fig: All Working fluids at 45° & 60% filling ratio

Fig: All working fluids at high heat input(80W) and 60 % filling ratio

6.CONCLUSION:

The following conclusions can be drawn from the investigation:

1.Al2O3-water nanofluid acts as the best working fluid at our required heat input (70W-80W) among all the fluids used due to its low density and cylindrical shape.
2. Among the conventional working fluid distilled water shows better performance due to its high boiling point and high specific heat capacity than other conventional working fluid.
3. The optimum filling ratio of the conventional working fluid varies between40%-60%. The variation is due to the interaction of the vapor slug and liquid plug inside the tube.
4. The optimum filling ratio of the 3 nanofluids are all 50%. This is partially due to the density of the fluid and partially due to their shape.
5. Nanofluids made up of heavier nanoparticle which shape are not suitable for proper agitation and disrupt conduction showed poor performance, in this case CuO and ZnO.
6. Angle of inclination and filling ratio both contributes to the heat transfer characteristics of conventional working fluids, though the effect of the orientation is less detectable.
7. Angle of inclination played a vital role in the heat transfer characteristics of nanofluids, specially which are made up of heavier particle like CuO and ZnO.Assistance of gravity helps partially to improve the heat transfercharacteristics of the nanofluid used.

7. REFERENCES

[1] Perkins, Jacob, “Perkins Tube”, April 1936 UK Patent 7059

[2] Gaugler, R. S., “Heat Transfer Device”, June 1944, U. S. Patent 2,350,348

[3] Wyatt, Theodore, “Satellite temperature stabilization system”, Oct 1964, U.S. Patent US3152774 A

[4] Grover, G. M., Cotter, T. P. and Erikson, G. F., “Structures of Very High Thermal Conductivity”, J. Appl. Phys., 35, 1990 (1964)

[5]] V.M. Patel, H.B. Mehta, Influence of gravity on the performance of the closed loop pulsating heat pipe, in: 18th International Conference on Fluid Mechanics and Thermal Engineering, Zurich Switzerland, 18 (2016) 1–6.

[6]https://www.researchgate.net/figure/A-schematic-of-heat-pipe-1_fig1_289686062

[7] https://www.omicsonline.org/articles-images/applied-mechanical-engineering-pipe-configurations-5-214-g006.png