International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2013): 6.14 | Impact Factor (2013): 4.438

Experimental Analysis on Thermal Performance ofClosed Loop Pulsating Heat Pipe Using Zno/Water Nanofluid

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Abstract: ***This research investigate the effect of concentration of water based zinc oxide nanofluid (i.e. ZnO/Water) on thermal resistance of closed Loop Pulsating Heat Pipe (CLPHP). CLPHPis made up of copper tubing with internal diameter of 3mm and outer diameter of 4mm. the tube had 2 meandering turns. The length of evaporator and condenser section was 380mm. Experiment was conducted in vertical orientation with having 50% filling ratio (FR). Heat load varied from 6 Watt to 72 Watt. The concentration of ZnO/Water nanofluid was 0.25%, 0.5%, 0.75% and 1% w/v.The various temperatures were recorded on the outer wall of the evaporator and condenser section and inlet & outlet of cooling water.Overall thermal resistance at different heat inputs was calculated. It is found that thermal resistance of CLPHP using ZnO/water nanofluid as working fluid was better than thermal resistance when pure water is used***

Keywords: Closed loop pulsating heat pipe (CLPHP), Nanofluid, ZnO/water nanofluid

1. Introduction

Due to huge development in electronic field, thermal management of high performance chips has become a challenging issue to direct heat transfer investigations. And again in industries, there had been always a great demand for having robust and promising cooling devices. For this reason pulsating heat pipe is best option due to simplicity of structure, reliability, and low manufacturing cost.

A heat pipe is simply a type of heat exchanger that is very simple in construction, easy and straight forward for use. Improvements have been done over time in Heat pipes used for heat transfer. Over the years, researchers have continuously search new methods of heat transfer augmentation. The results of employing different working fluid proved to be one effective way of improving the system's overall performance. Nanofluid is a new working fluid used in heat exchangers which is ecofriendly because it uses water as a base fluid. Nanofluids are prepared by suspending metallic or nonmetallic nanometer dimension particles in base fluids (water, oil, and ethylene glycol). So the nanofluid is used as working fluid in the pulsating heat pipe and analyzed the improvement of performance.

Phase changing phenomenon is used in heat pipe and the PHP to take away the heat. Because of the phase change, it will cause to absorb a large amount of latent heat. So the heat from the heat source can be rapidly extracted from the condenser.

The principal of pulsating heat pipe proposed and presented by Akachi H. [1], due to its excellent features the device used in many electronic cooling, heat exchanger, cell cryopreservation, the spacecraft thermal control system, etc.In order to improve the thermal performance of heat pipes, nanofluids have been proposed as working fluids

In 2008, Yu-Hsing Lin*et al.*[2] perform experiment with silver nanofluidhaving 20 nm size at different concentration (100 ppm and450 ppm) and various filled ratio (20%, 40%, 60%, 80%, respectively).60% filled ratio gives better result. At 100ppm concentration, heating power of 85 W and 60% FR, theaverage temperature difference of evaporator and condensercompared with the pure water is less than 7.79^{o}C,and the thermal resistance is also less than 0.092^{o}C/W.S. Wannapakhe*et al.* [3] in 2009 investigated the effect of aspect ratios (evaporator length to inner diameter of capillary tube), inclination angles, and concentrations of silver nanofluid on the heat transfer rate of a closed-loop oscillating heat pipe with check valves (CLOHP/CV).and he found that, CLPHP using silver nanofluid gives better performance than CLPHP using pure water, because silver nanofluid increases the heat flux by more than 10%. N. Bhuwakietkumjohn*et al.* [4] in 2010 investigate the internal flow patterns and heat transfer characteristics of a closed-loop oscillating heat-pipe with check valves (CLOHP/CV).Ethanol and a silver nano-ethanol mixture were used as working fluids with a filling ratio of 50%. Result shows that, when the velocity of slug increases, the length of vapor slug rapidly decreases and the heat flux rapidly increases. In addition, the silver nano-ethanol mixture gave higher heat flux than the ordinary ethanol.

Qu*et al.*[5] in 2010, performed an experiment using Al_2O_3nanofluid of 56 nm to investigate The effects of filling ratios, mass fractions of alumina particles, and power inputs on the total thermal resistance of the OHP. Result shows that, the maximal thermal resistance was decreased by 0.14 °C/W (or 32.5%) when the power input was 58.8Watt 70% filling ratio and 0.9% mass fraction. P.Gunnasegaran et al. [6] in 2104 work on impact of nanopartical concentration of Al_2O_3 on heat transfer characteristics of Loop heat pipe (LHP). 0% to 3% mass concentration is used. It is found that thermal resistance of LHP decreases when nanoparticles mass concentration of Al2O3-H2O nanofluid increases

V.K. Karthikeyan*et al*. [7] in 2014, describes the effect of copper and silver colloidal nanofluids on the closed loop pulsating heat pipe (CLPHP) performance. Experimental results show that the nanofluid charged CLPHPs enhance the heat transfer limit by 33.3% and have lower evaporator wall temperature compared to thatof DI water.

Rudresha S[8]in 2014, conducted an experiment as well as computational analysis on CLPHP using SiO2/DI Water and Al_2O_3/DI Water as the working fluids with concentrations by different mass 10g/lit, 20g/lit, 30g/lit.Experimental results show that at a heating power of 10w, 14w, 18w, 22w the Thermal resistance, Thermal heat transfer Co-efficient, Thermal conductivity and Efficiency for CLPHP SiO_2/DI Water and Al_2O_3/DI Water heat pipe are 69.37%, 75.99% and 11.98% respectively.

Md. RiyadTanshen*et al*. [9] in 2013, study an influence ofmulti-walled carbon nanotube (MWCNT) based aqueous nanofluids with different concentrationson the heat transport of oscillating heat pipe (OHP). 0.05 wt.%, 0.1 wt.%, 0.2 wt.% and 0.3 wt.%. Concentration was used. Result shows that, lowest thermal resistance has been achieved by 0.2 wt.%MWCNT based aqueous nanofluids.

Various nanofluids at different operating condition give different results. Until now, may nanofluids were used many researches having good thermal conductivity. But ZnO/water nanofluid is not used until now. No data is available related to ZnO/water nanofluid as working fluid in CLPHP. In addition double turn loop PHP also is not much used. Thus, in present work Zno/water nanofluid in double turn loop PHP is used to investigate the effect of concentration of nanofluid on thermal resistance

2. Experimentation

2.1 Preparation of nanofluid

Nanofluid is produced by metal or metal oxide nanoparticles suspended in base fluids such as oil or water. It involves many methods such as changing thepH value of the suspension, using surfactant activators,and using ultrasonic vibration. The nanoparticles suspended in base fluids are stable for a long time. For this research, nanofluid was prepared by a sonicator for one hour. The sonicator had a probe type, operating frequency, and power source of 20 kHz,AC100, and 120V/AC220~240V 50/60 Hz, respectively. Nanoparticles were purchased from D & D advance materials. The Znonano powder used in this study has a particle size of 100 nm and purity of 99.5%. The ZnO nanoparticles were suspended into DI water with concentrations of 0.25%, 0.5%,0.75%, and 1 %w/v. Stability was up to 48 hours. Fig shows the different concentration of Zno/water nanofluids

2.2 Experimental Setup

Figure 2 illustrates that, the schematic of experimental setup. The set-up comprises the CLPHP, cooling water unit, heater and a control panel. The CLPHP is divided in three main sections:

- The evaporator zone: - where the device receives a controlled heat input by means of oil bath.
- The adiabatic zone: - ideally insulated from the environment.
- The condenser zone: - where the PHP releases the heat by means of a liquid cooled heat sink.

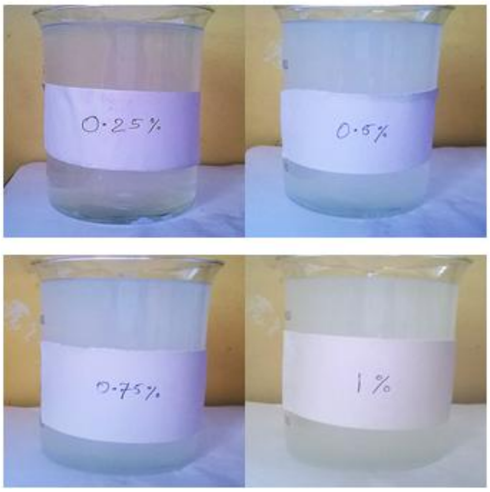

Figure 1: photograph of Different concentration of ZnO/water nanofluids

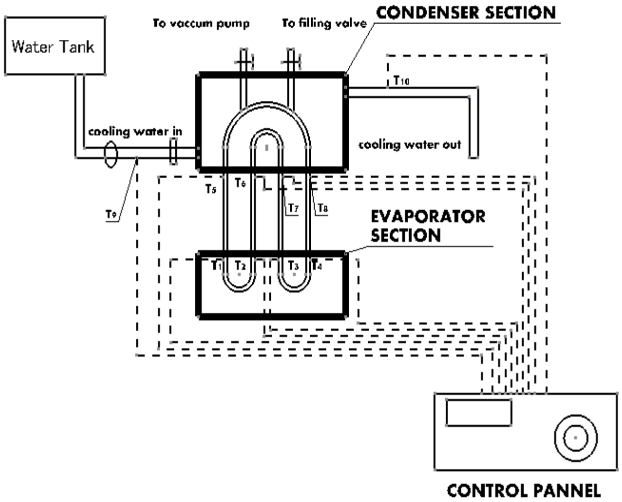

Figure 2: Schematic of Experimental setup

The tubes has three sections (i.e. evaporator, adiabatic and condenser) are made of copper in order to minimize the thermal resistance between the tube and the heat input/output zones while the straight tubes in the adiabatic section are covered with insulated material so that there should be no loss of heat with the environment. All tubes in evaporator and condenser section have inner diameter 3.0mm and outer diameter 4.0mm. The total length of evaporator section (L_e = 380mm), total length of condenser section (L_c = 380 mm) and total length of adiabatic section (L_a = 400mm). The central distance between two tubes (pitch) was maintained 20mm.

In the evaporator section oil bath is used. Oil bath is made of aluminum sheet having dimension 75×60×15 mm^3. It is heated with press coil of 600 Watt. This whole assembly is insulated with glass wool then it is enclosed with plywood structure. The condenser section was cooled by normal water through a cooling box of dimension 100×20×100 mm^3 with maintained flow rate of 50 ml/min and inlet and outlet temperature was measured. The control panel comprises of power measuring and temperature measuring equipment as shown in fig. 2. The heat input is measured in terms of electrical power supply through Dimmerstat (2Amp). The voltmeter (0 – 250V) and Ammeter (0 – 2 A) was connected in line for the input power measurement. The output of the experimental setup is calculated in terms of thermal resistance, for that, the various temperatures were recorded at different location by means of thermocouple wires (Chromel-Alumel, K-type, accuracy ± 0.20C). The position of the thermocouple wires are shown in fig. 2. With the help of knob ten different temperatures can be noted. Pure water and ZnO/water nanofluid are selected as working fluids for experimentation.

2.2 Experimental Procedure

1. The first step is to create a vacuum inside the tube. In order to create vacuum inside the PHP, a reciprocating vacuum pump is connected to the filling valve.
2. Thereafter the device is fill with the desired working fluids and closed the valve.
3. Water was supplied from storage tank to the condenser section. Wait till the condenser tank is completely filled. Then flow rate was measured with beaker and stop watch.
4. Switch on the control panel and set appropriate power supply for oil bath with the help of dimmerstat
5. Oil in oil bath starts heating. This in turn heats the evaporator section.
6. Provide a constant heat input to the oil bath up to steady state reached and temperature at different points of CLPHP note down between 10 minute intervals.
7. The heat input is increased with step of 10 W input powers after steady state reached. After a quasi-steady state was reached, note down the readings.
8. At steady state from the inlet - outlet temperature and mass flow rate of the coolant, the heat transfer could be calculated. Above procedure was repeated for the different working fluids.

3. Data Reduction

The heat output from condenser is calculated from the following equation:

$$Q_{out}=mC_p\,(T_{out}-T_{in}) \quad (1)$$

Where, m – mass flow rate
C_p - specific heat at constant pressure
T_{out} - outlet temperature of cooling water and
T_{in} - inlet temperature of cooling water
The total thermal resistance is obtained from the following equation:

$$R_{th} = \frac{T_e-T_c}{Q_{in}} \quad (2)$$

Where, R_{th} - Thermal resistance

T_e - Average temperature of evaporator

T_c - Average temperature of condenser

Q_{in} – Heat input (V×I)

4. Results and Discussion

From the experimental analysis, graphs are plotted showing effect of different concentration of ZnO/water nanofluid and pure water on average evaporator temperature, average condenser temperature, evaporator-condenser temperature difference and thermal resistance with different heat inputs as shown in figure 3, 4, 5 and 6 respectively.With increasing heat input to the device, the evaporator temperature rises resulting in a greater density gradient in the tubes. Simultaneously the liquid viscosity also drops diminishing the wall friction and it proportional to heat input therefore thermal resistance decrease with increase in heat input for all working fluids.

Figure 3 shows the change in average evaporator temperature of PHP for various heat inputs as well as different concentration values of ZnO/water nanofluids and pure water. Average evaporator temperature increases with increasing heat load and decreases as increase in mass concentration of nanofluid. It is due to the higher saturation temperature and high specific het of water. As concentration of nanoparticles in water increases saturation temperature and specific heat of water decreases tends to decrease in evaporator temperature. Minimum evaporator temp is obtained for 1%w/v ZnO/water nanofluid.

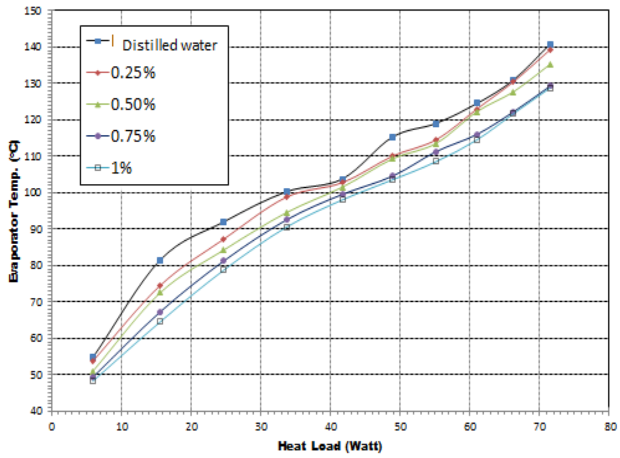

Figure 3: Average evaporator temperature of ZnO/water nanofluid

Figure 4 shows the change in average condenser temperature of PHP for various heat inputs as well as different concentration values of ZnO/water nanofluids and pure water. Average condenser temperature increases with increasing heat load and increase as increase in mass concentration of nanofluid. Because thermal conductivity of fluid is increases due to addition of ZnO nanoparticles, hence more heat is transported towards condenser section.

Figure 5 shows the change in evaporator-condenser temperature difference for various heat inputs as well as different concentration values of ZnO/water nanofluids and pure water. Evaporator-condenser temperature difference increases with increasing heat load and increases with increase in mass concentration of nanofluid. Minimum value is found for pure water and maximum value is found for 1% w/v concentration nanofluid.

Figure 6 shows the change in thermal resistance of PHP for various heat inputs as well as different concentration values of ZnO/water nanofluids and pure water. Thermal resistance decreases with increasing heat load and decreases with increase in mass concentration of nanofluid. It is due to the presence of nanoparticles in base fluid. This increases thermal conductivity of base fluid. Reason for enhancement of thermal conductivity is micro-convection between solid and liquid molecules, Brownian motion of nano size particles and clustering in nanofluids.

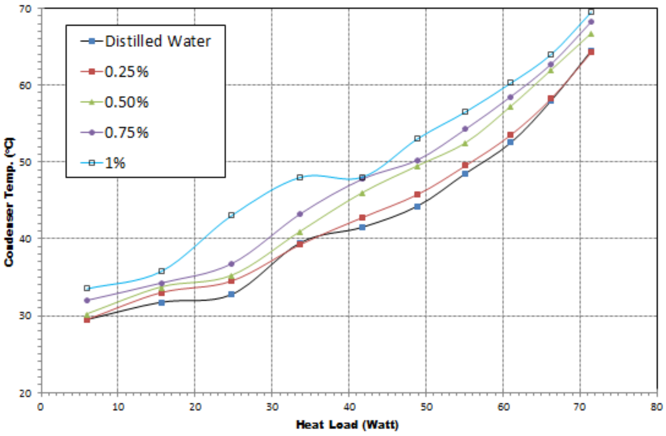

Figure 4: Average condenser temperature of ZnO/water nanofluid

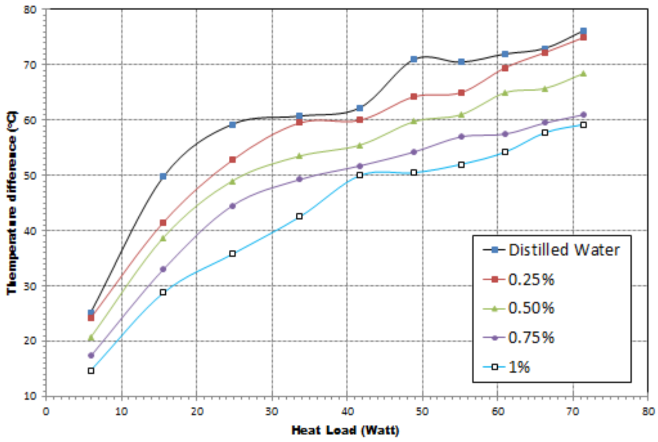

Figure 5: Evaporator-condenser temperature difference of ZnO/water nanofluid

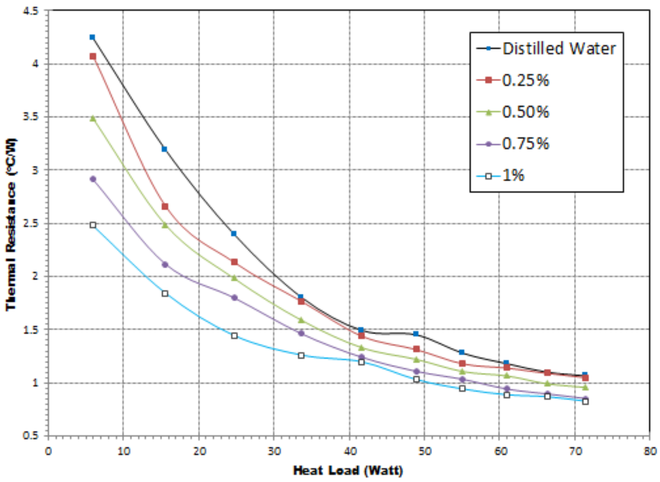

Figure 6: Thermal resistance of ZnO/water nanofluid

Minimum value thermal resistance0.829019169°C/W is obtained for 1%w/v concentration at 72W heat input.This is 77.7% less than pure water.

5. Conclusion

From these experimental studies, following conclusions are drawn:

- Thermal resistance decreases with increase heat input of PHP for both pure water and nanofluids.
- Thermal resistance decreases with increase in mass concentration of ZnO/water nanofluid.
- Minimum value thermal resistance0.829°C/W is obtained for 1%w/v concentration at 72W heat input.This is 77.7% less than pure water.
- Thermal performance of PHP strongly depends on thermo physical properties of working fluids.
- ZnO/water nanofluid PHP gives the good thermal performance than water PHP.

Nomenclature

Q Heating power input (W)
FR filling ratio
R thermal resistance (°C/W)
T temperature (°C)
$T_e$temperature of evaporation section (°C)
$T_c$temperature of evaporation section (°C)
$T_s$temperature of boiling point (°C)
$T_c$temperature of condenser section (°C)
C heat capacity (J/m³·K)
$C_p$specific heat (KJ/kg·K)
H_{fg}latent heat of evaporation (KJ/kg)
*t*time (s)

Greek Symbols
ρdensity (kg/m³)
σsurface tension(N/m)
υdynamic viscosity (Pa·s)
λthermal conductivity(W/m°C)

Subscripts
*l*liquid
*v*vapor
*sat*saturation state
*e*evaporation section
c condensation section

References

[1] Akachi, Structure of a heat pipe. US Patent No. 4921041, 1990.
[2] Yu-Hsing Lin, Shung-Wen Kang, Hui-Lun Chen.,2008, "Effect of silver nano-fluid on pulsating heat pipe thermal performance",Applied Thermal Engineering, vol. 28, pp.1312–1317.
[3] S. Wannapakhe, S. Rittidech, B. Bubphachot and O. Watanabe.,2009,"Heat transfer rate of a closed-loop oscillating heat pipe with check valves using silver nanofluid as working fluid",Journal of Mechanical Science and Technology, vol. 23,pp.1576-1582.
[4] N. Bhuwakietkumjohn, S. Rittidech.,2010,"Internal flow patterns on heat transfer characteristics of a closed-

loop oscillating heat-pipe with check valves using ethanol and a silver nano-ethanol mixture”.Experimental Thermal and Fluid Science, vol.34.pp.1000–1007.

[5] JianQu, Hui-ying Wu, Ping Cheng.,2010, “Thermal performance of an oscillating heat pipe with Al_2O_3water nanofluids”, International Communications in Heat and Mass Transfer. Vol. 37,pp. 111–115.

[6] P. Gunnasegaran, M.Z. Abdulah, M.Z. Yusoff, “Effect of Al2O3-H2O nanofluid concentration on hrat transfer in a loop heat pipe”, Procedia Material Science, vol. 5, pp.137-146.

[7] V.K. Karthikeyan, K. Ramachandran, B.C. Pillai, A. Brusly Solomon., 2014, “Effect of nanofluids on thermal performance of closed loop pulsating heat pipe”,Experimental Thermal and Fluid Science, vol. 54, pp.171–178.

[8] Rudresha S, Vijee Kumar.,2014, “CFD Analysis and Experimental Investigation on Thermal Performance of Closed loop Pulsating Heat pipe using different Nanofluids”,International Journal of Advanced Research, Vol. 2, Issue 8, pp. 753-760.

[9] Md. RiyadTanshen, B. Munkhbayar, Md. J. Nine, Hanshik Chung, HyominJeong., 2013, “Effect of functionalized MWCNTs/water nanofluids on thermal resistance and pressure fluctuation characteristics in oscillating heat pipe”,International Communications in Heat and Mass Transfer.

[10] Charoensawan P., Khandekar S., Groll M. and Terdtoom P., 2003, “Closed Loop Pulsating Heat Pipes Part A: parametric experimental investigations:” Applied Thermal Engineering, Vol. 23, pp.2021-2033.

[11] Mameli M., Khandekar S. and Marengo M., 2011, “An Exploratory Study Of a Pulsating heat pipe Operated With a Two Component Fluid Mixture”, Proceedings of the 21st National and 10th, ISHMT-ASME Heat andMass Transfer conference, December 27-30, IIT Madras, India, Paper ID: ISHMT-IND-16-033,2011.

[12] Pachghare P., Mahalle M., Khedkar S., 2012, “Effect of Working Fluid on Thermal Performance of Closed Loop Pulsating Heat Pipe: A Review,” International Journal of Computer Applications, pp. 27-31.

[13] Pachghare P., Mahalle M., 2012, “Thermal performance of closed loop pulsating heat pipe using pure and binary working fluids,” Frontiers in Heat Pipes (FHP), 3, 033002.

[14] NiloofarMohammadi, MaziarMohammadi, Mohammad BehshadShafii., 2012, “a review of nanofluidic pulsating heat pipes: suitable choices for thermal management of electronics”,Frontiers in Heat Pipes (FHP), 3, 033001.

[15] BhawnaVerma, V.L.Yadav, K.K.Srivastava., 2012, “Nano fluid- An alternative fluid in Pulsating Heat Pipe/Oscillating Heat Pipe”,Journal of Electronics and Communication Engineering (IOSR-JECE) ISSN: 2278-2834, ISBN: 2278-8735. Vol. 3, Issue 3, pp.28-37.