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Thermal Performance of Closed Loop Pulsating Heat Pipe with Titanium Oxide as Nanofluid

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***Abstract*—Closed loop pulsating heat pipe (CLPHP) are heat transfer devices having thermo hydrodynamic coupling governing the internal performance. A wide range of necessary characterization has been done for the internal diameter, number of turns, working fluid, and inclination angle of the device. The working fluid employed is Titanium oxide nanofluid. Silver coating is done on Evaporator and Condenser section to improve the heat transfer rate. The objective of this experiment is to increase the heat transfer rate of CLPHP and to find out the thermal performance of CLPHP.**

***Index Terms*—** Heat pipe, Nano Fluid, Titanium Oxide.

I. INTRODUCTION

The closed loop Pulsating Heat Pipes (CLPHPs) are heat transfer devices that increases amount of heat which works on the principle of evaporation and condensation [1]. CLPHP's are the heat transfer device that has been used for thermal management of electronic devices to remove heat without any external supply[1]. Heat pipe has the ability to dissipate more amount of heat with very less temperature drop. Closed loop pulsating heat pipe (CLPHP) is made from long capillary tube which is bent into many U-turns, it's both ends are connected to each other and forms loop, adiabatic section is optional depends on the locations of condenser and evaporator[2]. The inner diameter of the tube should be small enough in order to form the liquid vapour plugs and slugs exist.

The features of CLPHPs compared with the conventional heat pipe is that[3],

1Wickless Structure to return the condensate liquid to the heating section.

2. Easy to design and manufacturing

3. No counter current flow between the liquid and vapor spaces.

The closed pulsating heat pipe is evacuated and it is filled up partially with a desired working fluid. When heat is supplied to evaporator section the working fluid gets evaporated the working fluid inside the tube evaporates thus the vapour pressure in the tube get increased and due to this there is bubble formation takes place in the evaporator section[3]. This bubbles get formed and collapses due to this action the liquid get pushes towards the condenser section i.e. the liquid is supplied towards the low temperature region [4]. Due to this motion of the bubble the oscillating motion is generated within the tube Because of the low temperature in the condenser section the vapour pressure get reduced and the bubbles get condensed in the condenser section[5].

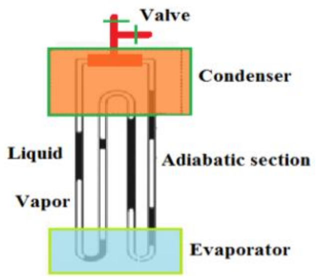

Fig 1. Schematic of Closed Loop Pulsating Heat Pipe

Through the heat pipe the thermo mechanical physics lies in the closed or constant volume, two phase, vapour liquid slug system generated inside the tubes of CLPHP due to the effect of surface tension forces [5]. This number of tube receives the heat at one end (evaporator section) and it cooled at the other section (condenser section) [5].

Due to the temperature difference occurs in the two section there is also change in pressure throughout the tube and due to this the phase change occurs. Due to generation and collapsing of bubbles it act as a pumping element for transporting the trapped liquid slug in a oscillating and translating fashion [6]. Due to this the direct consequence of pressure and temperature fluctuations with the fraction distribution. The causes of heat transfer are combination of sensible and latent heat transfer [6]. The sensible heat transfer has the major contribution in the overall heat exchange.

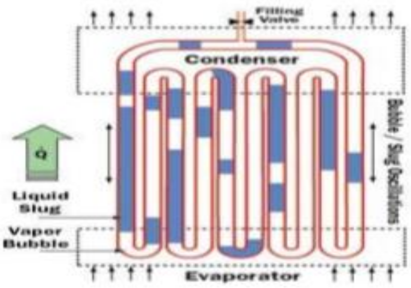

Fig 2. Internal working action of CLPHP

Further studies have indicated that after a certain input heat flux, the bubble–liquid slug flow may break down into annular flow regime [7]. The relative magnitude of sensible and latent heat portions thus changes and is dependent on the flow pattern existing inside the tubes.

A. Tube/channel cross sectional diameter

Heat pipe’s diameter depends on Bond number. The formula is shown below:

$$D_{crit} \approx 2 \cdot \sqrt{\frac{\sigma}{g \cdot (\rho_{liq} - \rho_{vap})}}$$

The undermentioned factors are important which affect the thermal performance.

- Working properties of fluid
- Internal and outer diameter
- Number of meandering turns or loops Filling ratio
- Inclination angle
- Heat flux Applied
- Latent Heat and Sensible Heat

Other conditions which influence the operation are: ·
Use of flow direction control check valves,
Tube cross sectional shape,
Tube material and fluid combination[10].

II. Experimental Setup

It consist of heating coil to the evaporator and cooling baths condensation, a temperature measuring thermocouples used to measure the temperature of the cooling solution, two each at the inlet and outlet sections of the condenser.

Fig 3. Experimental Setup of CLPHP

The heat throughput was thus measured by calorimetric method applied to the condenser-cooling jacket. In addition, two thermocouples on the evaporator tube sections, and two thermocouples on the condenser section completed the instrumentation. The tested CLPHPs were made of copper capillary tube [11]. Both ends of the tube were connected together to form a closed loop structure which was located in the condenser in all the experiments. The adiabatic section was well insulated with foam insulation. First, the CLPHP was evacuated and then filled with 50% of the total volume with the working fluid [12]. The inlet temperature of the hot and cold baths were set at the fixed values and the hot and cold fluids were supplied to the jackets of both the evaporator and condenser sections. After a quasi-steady-state was reached, the temperatures recorded [13].Thus for a given configuration the heat throughput could be evaluated. The value of calculated Q was subject to experimental uncertainties and errors that were later evaluated [14].

A. Hardware

The primary aim of this experiment is to study complex thermodynamic performance close loop pulsating tube pipe. Six parameter emerge as primary influence parameter affecting the system. These include,

1) Internal Diameter of tube = 2mm (1.78 mm)

2) Volumetric filling ratio = 50 FR

3) Input Heat flux =30 W to 100 W

4) Operating Orientation = 0 to 90

5) Total no. of turns = 10

B. *Readings from experimental setup*

TABLE 1

0 DEGREE ORIENTATION

Power in watt	Mean Evaporator Temperature	Mean Condenser Temperature
30	34.5	30
40	39	33
50	45.5	37
60	49	39
70	52	41
80	58	44
90	60	46
100	60.5	48

TABLE 2

30 DEGREE ORIENTATION

Power in watt	Mean Evaporator Temperature	Mean Condenser Temperature
30	35	30
40	38	33
50	42	34.5
60	45	37
70	47.5	38
80	50	40
90	50	41
100	52.5	41

TABLE 3

45 DEGREE ORIENTATION

Power in watt	Mean Evaporator Temperature	Mean Condenser Temperature
30	32.5	29
40	36.5	31
50	39.5	33
60	44	36
70	46	38
80	47.5	39
90	51.5	41
100	53	41

TABLE 4

60 DEGREE ORIENTATION

Power in watt	Mean Evaporator Temperature	Mean Condenser Temperature
30	34	30
40	38.5	33.5
50	42.5	36
60	46	38
70	47.5	40
80	51	43
90	52	44
100	55	46.5

TABLE 5

90 DEGREE ORIENTATION

Power in watt	Mean Evaporator Temperature	Mean Condenser Temperature
30	40	35
40	44	38
50	48	40
60	50	43.5
70	54	45.5
80	55.5	46.5
90	59	46.5
100	58.5	47

C. *Sample Calculation*

To find out resistance of the tube at different power input and different temperature in order to determine the suitable orientation and power input.

Power (watt)Q = Mean Evaporator Temp.- Mean Condenser Temp./ Resistance offered by tube material.

$$Q = \Delta T / R$$

$$30 = 5 / R$$

$$R = 0.166$$

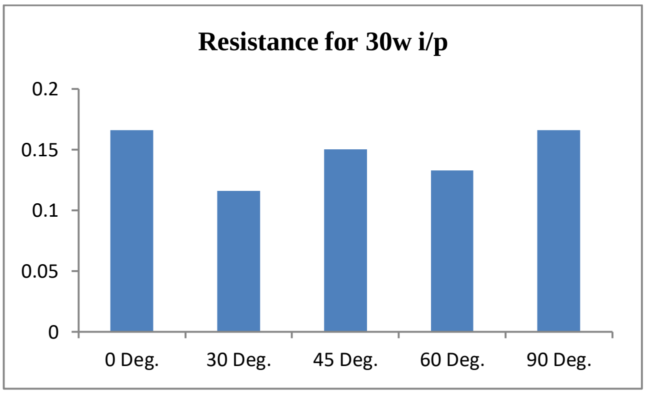

Fig 4. Resistance for 30w i/p

- At 30w input the value of thermal resistance is moderate which is average upto 0.15 ohm

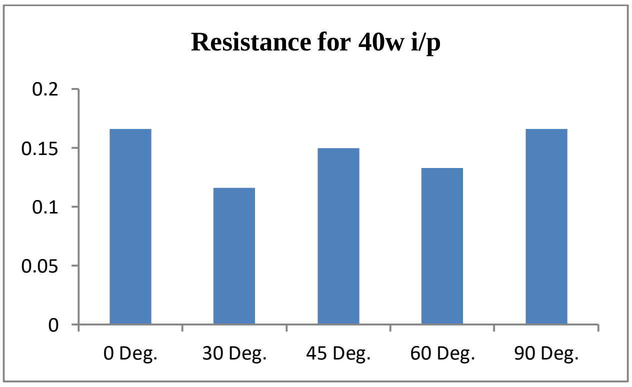

Fig 5. Resistance for 40w i/p

- At 40w input the value of thermal resistance is also moderate it is average less than 0.15 ohm.

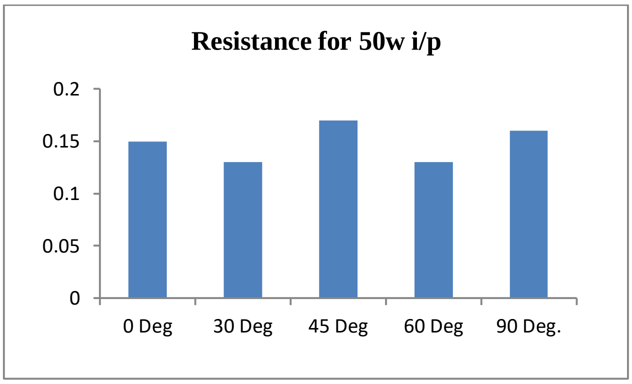

Fig 6. Resistance for 50w i/p

- At 50w input the thermal resistance is less at more only at the 45 deg. orientation at other orientation it is upto 0.15 ohm.

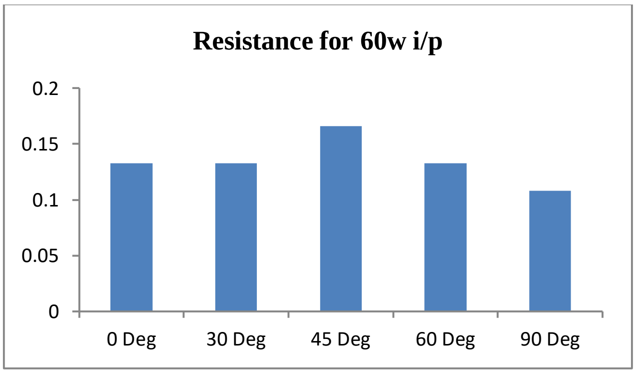

Fig 7. Resistance for 60w i/p

- At 60w input and 45 degree orientation the value of thermal resistance is more than the all other conditions.

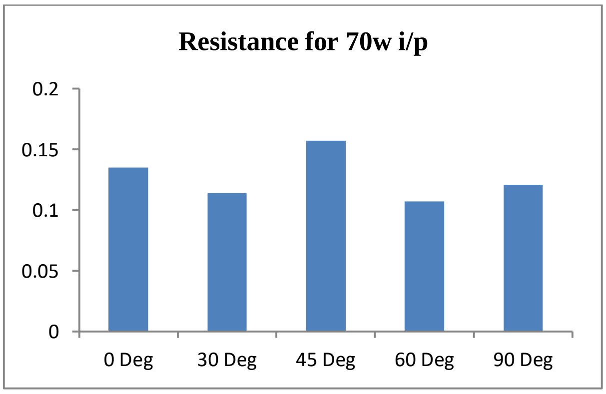

Fig 8. Resistance for 30w i/p

- At 70w input the value of thermal resistance is less.

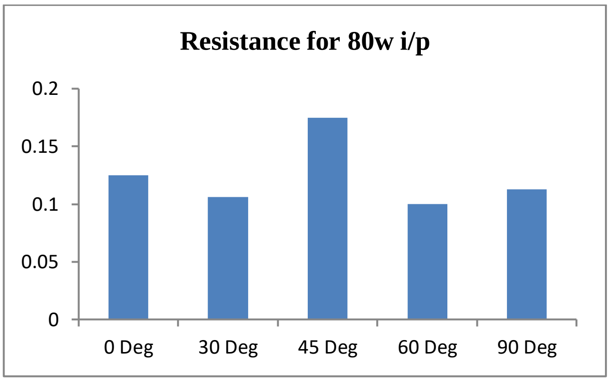

Fig 9. Resistance for 80w i/p

- At 80w input the value of thermal resistance is less at all the orientations except for the 45 deg orientation.

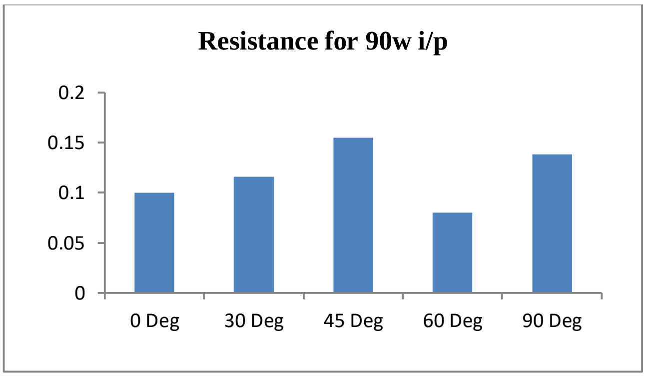

Fig 10. Resistance for 90w i/p

- At 90w input the value of thermal resistance is less at the 60 degorientation and the overall value of thermal resistance is also less than the other.

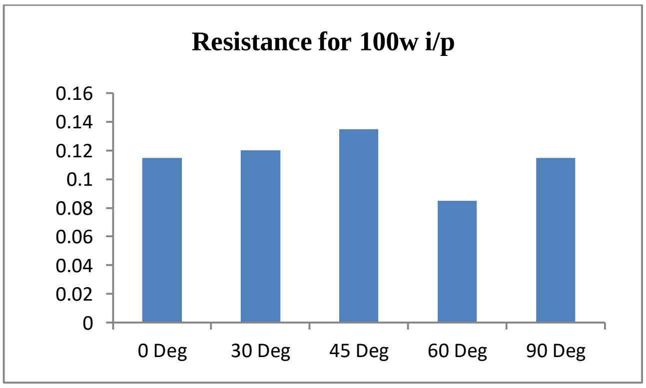

Fig 11. Resistance for 100w i/p

- At 100w input the overall value of thermal resistance is also less.

III. Conclusion

- For 60^0 orientation of CLPHP, it has been found that thermal resistance is less than the other orientation.
- Thermal resistance decreases as the heat input increases in all orientation.
- The evaporator and condenser wall temperature variation with respect to heat input is found to be acceding in order.
- Gravity certainly affects the heat throughput.
- As degree of orientation increases thermal performance increases.
- The CLPHP's gives the best thermal performance, when they operate in 60^0 orientation between 70w-100w heat input and 50% filling ratio, because it gives the minimum thermal resistance in this condition.
- In this case, we have used Titanium oxide as a nanofluid with a Ethanol as a base fluid as a working fluid. It has been observed that the heat transfer rate of the CLPHP is considerably increased because the nanofluid increases the heat transfer rate and other thermal properties of the CLPHP

References

[1] HimelBarua*, Mohammad Ali, Md. Nuruzzaman, M. Quamrul Islam, "Effect of filling ratio on heat transfer characteristics and performance of a closed loop pulsating heat pipe", *Procedia Engineering 56 (2013) 88 – 95*, 2013.

[2] Xiangdong Liu, Youngping Chen, Mingheng Shi "Dynamic performance analysis on start-up of closed-loop pulsating heat pipes(CLPHP)", *International Journal of Thermal Sciences 65 (2013) 224e233*, 15 October 2012

[3] Saiyan Shi, Xiaoyu Cui, Hua Han, Jianhua Weng, Zhihua Li, "A study of the heat transfer performance of a pulsating heat pipe with ethanol-based mixtures", *Applied Thermal Engineering 102 (2016) 1219–1227*, 3 April 2016.

[4] AkterJahan*, Mohammad Ali, Md.Quamrul Islam "Effect of inclination angles on heat transfer characteristics of a closed loop pulsating heat pipe (CLPHP)", *Procedia Engineering 56 (2013) 82 – 87, 5th BSME International Conference on Thermal Engineering*, 2013.

[5] Pramod R. Pachghare and Ashish M. Mahalle "Thermo-hydrodynamics of closed loop pulsating heat pipe: an experimental study", *Journal of Mechanical Science and Technology 28 (8) (2014) 3387-3394*, 21 March 2014.

[6] Mauro Mamelia, Vincenzo Manno , SauroFilippeschi , Marco Mareng "Thermal instability of a Closed Loop Pulsating Heat Pipe: Combined effect of orientation and filling ratio", *International Journal of Thermal Sciences* 75 (2014) 140e152, 23 July 2014.

[7] Pramod R. Pachghare ,Ashish M. Mahalle "Effect of pure and binary fluids on closed loop pulsating heat pipe thermal performance", *Procedia Engineering 51 (2013) 624 – 629*, 2012.

[8] Yu Wang "Experimental investigations on operating characteristics of a closed loop pulsating heat pipe", *Front. Energy 2015, 9(2): 134–141*, 12 June 2015.

[9] Xiaoyu , Cui ZiqianQiu, JianhuaWeng ,ZhihuaLi"Heat transfer performance of closed loop pulsating heat pipes with methanol-based binary mixtures", *Experimental Thermal and Fluid Science, 76 (2016) 253–263,* 6 April 2016 (13)

[10] D. A. Chavan* and V. M. Kale "Understanding Effect of Operating Parameters on Thermal Performance of Closed Loop Pulsating Heat Pipe: An Experimental Study", *International Journal of Current Engineering and Technology E-ISSN 2277 – 4106*, 15 June 2016.

[11] Sameer Khandekar, "Closed and open loop pulsating heat pipe", *13th International Heat Pipe Conference (13th IHPC), Shanghai*, China,September 21-25, 2004.

[12] Pankaj Sharma, Il-Hyun Baek, Taehyun Cho, Sangdo Park, Ki Bong Lee "Enhancement Of Thermal Conductivity Of Ethylene Glycol Based Silver Nanofluids", *Powder Technology 208 (2011)* 7–19, 23 November 2010

[13] X. Wang, X. Xu, and S.U.S. Choi, J. "Silver Nanofluids - Synthesis, Properties an Application", *International Journal of Current Engineering and Technology 2347 – 5161,* June 2016

[14] Ahmet Ozsoy, Vahit Corumlu, "Thermal performance of a thermosyphon heat pipe evacuated tube solar collector using silver-water nanofluid for commercial applications", *Renewable Energy 122 (2018) 26e34,* 28 December 2017.