Comparative Study of use of Different Working Fluids in the Performance of A Pulsating Heat Pipe

S. K. Jagadeesh, N. T. Nischith Gowda, K. Prateek
Department of Mechanical Engineering,
Dr. Ambedkar Institute of Technology
Bangalore, India.

***Abstract*— PHPs are two phase passive heat transfer device which do not require a pump or additional power to carry out any operations. A functional test rig is fabricated with well insulated evaporator and condenser. A detailed study of the performance of heat pipe is carried out with acetone, ethanol and methanol as working fluid. The fill ratios are varied (40%, 50%, 60%) for varying heat input (4W, 5W, 6W) for evaluation of the performance. A comparative study is done with the three working fluids and the variations and characteristic changes are determined by the thermal resistance and overall heat transfer coefficient.**

***Keywords*— Pulsating Heat Pipes (PHP); Heat Transfer Coefficient; Thermal Resistance**

I. INTRODUCTION

Modern day electronic circuits dissipate huge amount of heat that needs to be carried out of it. The incompactness of the conventional heat pipes led Akachi et al. [5] to propose the concept of PHPs in mid 1990s. PHP belongs to the group of wickless heat pipes which works on the principle of oscillation for the working fluid and a phase change phenomenon in a capillary tube [6].

The performance characteristics of pulsating heat pipes with certain thermo mechanical boundary conditions helps in determining how efficient the PHPs work as integral heat spreaders [2].

With different working fluids, the performance of PHP need to be carried out with constant fill ratio for varying heat input to determine the best working fluid amongst the acetone, ethanol, methanol and water[4].

For effective heat transfer to take place, many parameters are needed to be taken under consideration. With many varying parameters, it is difficult to draw the result from the put forth constraints. The variations can be observed by changing the respective parameters [1] [3].

For a defined geometry of device, the input heat flux is also directly responsible for the type of flow pattern which exist in the channel, thus affecting the fundamental relaxation instabilities. The operating heat flux will directly affect the level of perturbations inside a PHP, thereby affecting the thermal performance of the device. [7]

Taking horizontal orientation as the geometry, the heat transfer characteristics of the three working fluids are determined for the single loop pulsating heat loop. A detailed comparative study is done to determine the performance of the heat pipe and the performance is assessed using the thermal resistance and overall heat transfer coefficient.

II. FABRICATION OF THE EXPERIMENTAL SETUP

The heat pipe is fabricated using a copper tube of 700 mm length and 3 mm inner diameter and 4 mm outer diameter. Tape heater of 0-100W capacity was used for providing the required heat source at the evaporator. The evaporator and adiabatic section of the heat pipes are insulated using glass wool to minimize the heat loss through these portions. D.C. Regulated power supply was provided to control and measure the power input respectively. K-type thermocouples were used as temperature sensors.

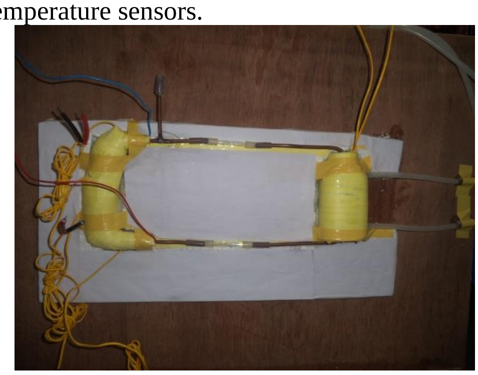

Fig. 1 Photograph of pulsating heat pipe experimental setup

A simple 8- channel temperature indicator is used to indicate the temperature measured. A rotor switch is used to change the channels of the indicator, so that temperature of each thermocouple can be observed. All the apparatus is mounted on to a wooden board with suitable fixtures.

Experiments were conducted to test the proper functioning of the fabricated test rig. The experiment was conducted with dry run to remove impurities. The dry run acts as a base for the evaluation of heat pipe.

The heater is put on and varied accordingly. The fill ratio of the working fluid is varied for each trial. The temperatures are noted down with 1 minute interval and the experimented its concluded after 12 minutes. Various plots were drawn to study the performance The experimental apparatus consists of three sections, evaporator, adiabatic and condenser sections. To have a base for comparison, a dry test (without working fluid) was carried out and it helps in nullifying any impurities present.

Ni-Cr wire (tape heater) was wound across the evaporator section. Power to the heater was provided from Regulated Power Supply (RPS) and the power input could be altered through a variac. Continuous circulated flow of water was established at the condenser section. Six thermocouples were fixed onto the body of the test apparatus i.e. four at the evaporator section and two at the condenser section. The other end of the thermocouples is soldered to a rotor switch. The output terminals of the rotor switch is given to the temperature indicator by using thermocouple wires.

III. EXPERIMENT DETAILS

The experiment was carried for constant heat inputs and varying fill ratios. The temperature rise was observed for regular intervals till steady state was achieved. After the steady state was achieved, the temperatures at the six points were noted down. The temperatures were for an interval of 1 minute and the test was conducted for 12 minutes to obtain sufficient data for evaluation.

The experiment was repeated for different working fluids and fill ratios. Fill ratio of fluid is the ratio of volume of working fluid charged inside the tube to total volume of oscillating heat pipe tubes. Various plots were drawn to study the performance of the heat pipe and optimize the working fluid. All the temperature readings for respective working fluid and fill ratios was recorded and tabulated after the steady state condition was achieved.

IV. RESULTS AND DISCUSSION

The experiment was conducted at steady state conditions using Acetone, methanol and ethanol as the working fluids with varying heat input and filling ratios. The heat input was varied between 4W to 6W in steps of 1W and the filling ratio was varied between 40% to 60% in steps of 10%. For each trial, the temperatures at the evaporator and condenser sections were recorded and performance of the heat pipe was evaluated in terms of thermal resistance. The thermal resistance is calculated using the equation [2]:

$$R = \frac{T_E - T_C}{Q} \quad ({}^0C/W)$$

where T_E = Evaporator temperature (^{0}C), T_C = Condenser temperature (^{0}C) and Q = Heat input (W).

The effect of heat input, filling ratio and working fluids on the performance of PHP is discussed in the following section.

A. *Effect of Heat Iinput*

Since a pulsating heat pipe (PHP) may be subjected to different heat-load conditions, it is very much important to study the performance behavior of a PHP subjected to the different heat input in the study. Heat input of 4W to 6W in steps of 1W has been considered in the present study for all the working fluids with all the filling ratios.

Fig.2 shows the variation of thermal resistance of the PHP with respect to the different heat input for FR60% of acetone, methanol and ethanol. It is observed that the thermal resistance of the PHP has decreased with increase in heat input at the given filling ratio of all the working fluids considered. The decreased thermal resistance represents the increased heat transfer coefficient and therefore indicates that the performance of the PHP increases with the increased heat input.

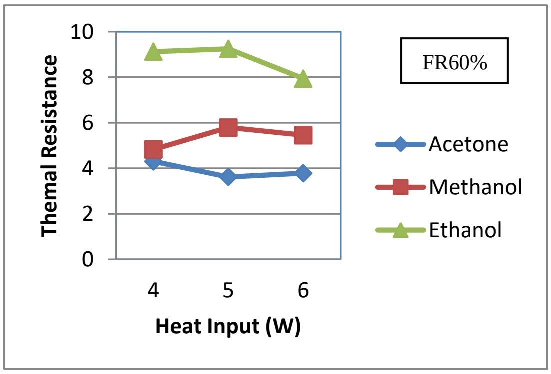

Fig. 2 Variation of thermal resistance with heat input

B. *Effect of Filling Ratio*

The ratio of the quantity of liquid (measured in volume) present in the heat pipe with respect to the total internal volume of the heat pipe is referred to as filling ratio (FR). It is normally expressed in percentage. For example, FR 0% indicates that the PHP does not contain any liquid and hence works in the pure conduction mode. FR100% indicates that the PHP is completely filled with liquid and hence works as thermosyphon. It is reported [7] that the PHP works as a true pulsating device when the filling ratio is maintained in the range of 20%-80%. However, the exact range varies with the working fluid, operating temperatures and construction.

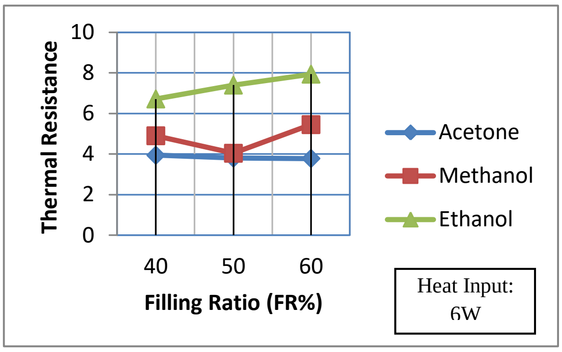

Fig. 3 Variation of thermal resistance with filling ratio

Fig.3 shows the effect of filling ratio on thermal resistance of PHP filled with different working fluids. It is observed that the thermal resistance has significantly changed with the change in filling ratio. Acetone has the lowest thermal resistance for all the percentage of filling ratio compared to methanol and ethanol.

C. *Effect of Working Fluid*

Since thermo physical properties such as surface tension, thermal conductivity, latent heat, specific heat and viscosity of the working fluid affect the performance of the PHP to a

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 8 Issue 10, October-2019

greater extent, it is very much essential to understand the role of a particular type of working fluid in the effective functioning of a pulsating heat pipe. Review of literature [1-6] suggested that acetone, methanol and ethanol are considered to be suitable working fluids for better performance of a PHP.

The variation of thermal resistance of the PHP filled with acetone, methanol and ethanol investigated with respect to different heat input and different filling ratio is shown in Fig. 2 and Fig. 3 It is observed that in both cases, of the three working fluids, the thermal resistance of acetone-filled PHP remained the lowest. This indicates that the performance of acetone-filled PHP is better than methanol or ethanol-filled PHP.

CONCLUSION

1. An experiment test rig for evaluating the performance of pulsating heat pipe has been fabricated.
2. Acetone, ethanol and methanol have been used as the working fluid.
3. Experiments were successfully conducted with fill ratios (40, 50, 60%) and with heat inputs (4W, 5W, 6W).
4. Heat transfer coefficients and thermal resistance were determined and tabulated.
5. The results were found to be fascinating and matched with literature [3]
6. Among the three working fluids, acetone showed best heat transfer characteristics.
7. The working fluids have varying characteristics and are sensitive to any change in parameters and holds good to literature [2].

REFERENCES

[1] S.Y. Nagvase and P.R. Pachghare, "*Parameters affecting the functioning of close loop pulsating heat pipe: A review*", Research Journal of Engineering Sciences, ISSN 2278 – 9472, Vol. 2(1), pp. 35-39, January 2013.

[2] H. Yang, S. Khandekar and M. Groll, "*Performance characteristics of pulsating heat pipes as integral thermal Spreaders*", Intl. J. Thermal Sciences, Vol. 48, pp. 815–824, 2009.

[3] P. Charoensawan, S. Khandekar, M. Groll, and P. Terdtoon, "*Closed loop pulsating heat pipes Part A: parametric experimental investigations*", Applied Thermal Engineering, Vol. 23, pp. 2009–2020, 2003.

[4] D. Wang and X. Cui, "Experiment Research On Pulsating Heat Pipe With Different Mixtures Working Fluids", 2002.

[5] H. Akachi, F. Polasek, and P. Stulc, "*Pulsating Heat Pipes*", Proc. 5th International Heat Pipe Symposium, Melbourne, Australia, pp.208–217, 1996.

[6] P. R. Pachgharea and A. M. Mahalleb, "Thermal performance of closed loop pulsating heat pipe using pure and binary working fluids", ISSN: 2155-658X, Frontiers in Heat Pipes (FHP), Vol. 3, 2012.

[7] S. Khandekar and M. Groll, "On the definition of pulsating heat pipes: Overview", Proc. 5th Minsk International Seminar (Heat Pipes, Heat Pumps and Refrigerators), Minsk, Belarus, 2003.