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Experimental Analysis of Closed Loop Pulsating Heat Pipe with Different Working Fluids at Different Inclination Angles

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Abstract
The intensity of heat rejected by the electronic components is very high. In order to avoid the damage of these components efficient thermal management systems are required. Pulsating Heat Pipes are one of the best suggested solution for rapid cooling of these electronic devices.Various parameters such as type of working fluid, inclination angles, filling ratio, number of turns etc. will affect the performance of Pulsating Heat Pipe. In 2014 Zhihu and Wei studied the thermal response of pulsating heat pipe by considering 2 mm inner and 6 mm outer diameter tube with ammonia as working fluid. The tests were conducted at 50% fill ratio for different inclinations and found that there is remarkable increase in thermal resistance for 0 degree inclination when compared to other angles of inclinations. The impact of inclination angle on thermal resistance is more when compared with other parameters and hence in the present study thermal resistance is calculated by varying the heat input and inclination angle. The dimensions of Closed Loop Pulsating Heat Pipe are 2.0 mm inner and 3.0 mm outer diameter and the material used is copper. From the previous study for copper material the fluids like water, Ethanol, Methanol and Acetone has given better performance and hence these fluids are used for experimentation. The experiments were conducted on 5-turn Pulsating Heat Pipe at 50% fill ratio and the results obtained are with the increase in heat input thermal resistance decreases irrespective of inclination and also fluid. And with the increase in inclination angle thermal resistance increases for all the fluids at lower heat input and at higher heat input thermal resistance decreases with increase in inclination angle.
Keywords:*Pulsating heat pipe, Heat Input, Thermal Resistance, Inclination Angle*

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I. INTRODUCTION

Electronic components are undergoing continual miniaturization which has resulted demand for smaller devices having higher heat flux dissipation. A Pulsating Heat Pipe (PHP) also called as Oscillating Heat Pipe (OHP) (since the working fluid oscillates inside the tube) introduced by Akachi [1] has proved one of the best substitute for conventional heat pipes. Unlike conventional heat pipes, the PHP does not have a wick structure and thus makes a promising technological application such as electronic cooling, heat exchanger, cryogenics, the spacecraft thermal management system, etc [2]. PHP is a passive device working on the principle of liquid evaporation in which the working fluid gets heated in evaporator and rejects heat in condenser. In general PHP consists of three sections namely evaporator, adiabatic and condenser. When heat is supplied to the evaporator the working fluid evaporates and increases the vapor pressure, thus causing the bubbles in the evaporator zone to grow. This pushes the liquid towards the low temperature section i.e., condenser and cooling of this condenser section results in a reduction of vapor pressure and condensation of bubbles in that section. There are basically three types of PHPs [3-4]. They are: Closed Loop Pulsating Heat Pipe (CLPHP), Open Loop System and Closed Loop Pulsating Heat Pipe with additional check valve. Fig.1(a) shows the Closed Loop Pulsating Heat Pipe (CLPHP), in which both ends of the tube are connected to form a closed loop. Fig.1(b) shows the CLPHP with a check valve in which the working fluid moves in a specific direction. Fig. 1(c) shows the representation of Open loop system whose ends of the tube are not connected.

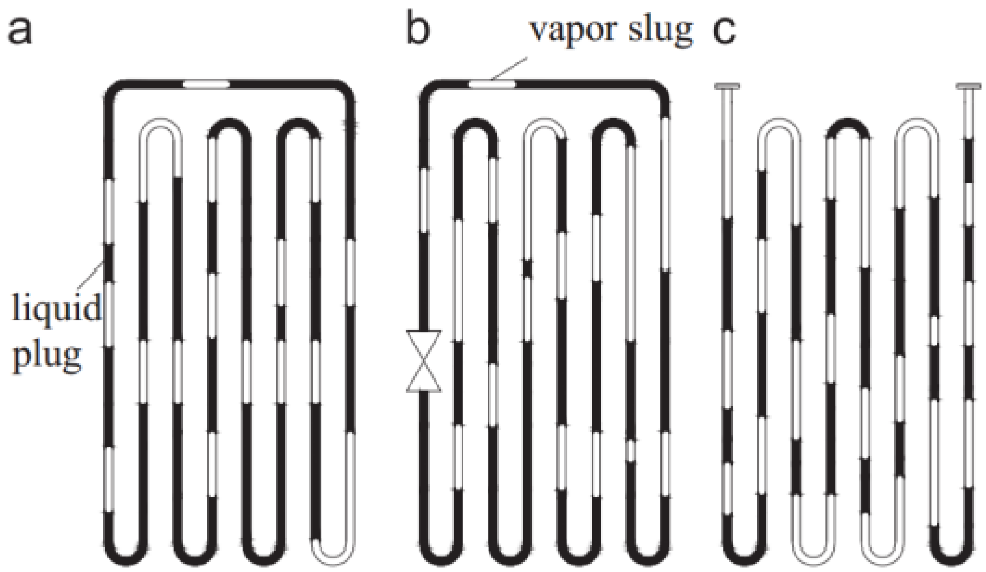

Fig:1. Types of Pulsating Heat Pipes: a. CLPHP; b. CLPHP with check valve; c. Open PHP[5]

Most of the researchers concluded that CLPHP is better than the other two types because of the fluid circulation within the pipe is faster [6]. In CLPHP, the heat transfer phenomenon is dominated by surface tension force in the constant volume of two-phase working fluid (bubble-liquid slug system) formed inside the partially filled capillary tubes.

II EXPERIMENTAL SETUP

The experimental setup was made up of copper with capillary dimensions 2mm and 3mm internal and external diameters respectively. Pulsating Heat Pipe consists of three sections namely evaporator of 42mm ,adiabatic of 170mm and condenser section of 50mm respectively. A transparent borosilicate tube is used for the visualization of pulsations inside the tube. Cooling water jacket was used for cooling of condenser section. Some thermocouples were used to measure the temperature of evaporator and condenser sections. The following figure gives us the schematic representation of closed loop pulsating heat pipe.

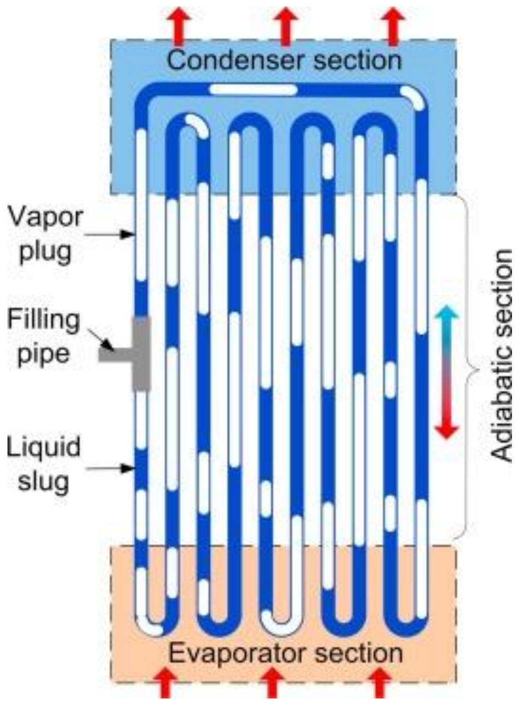

Fig: 2.Schematic Representation of 5- turn Closed Loop Pulsating Heat Pipe.

III EXPERIMENTAL PROCEDURE:

Step 1:
First the pulsating heat pipe is to be evacuated using vacuum pump to make sure that the tube is free from any kind of moisture and dust particles.
Step 2:
After the evacuation process the required fill ratio corresponding to the working fluid is to be filled using syringe.
Step 3:
Make sure that the connections of the setup are in proper manner to do the experiment.
Step 4:
The required heat input is to be given to the evaporator using the Heat variac.
Step 5:
Then the data logger is to be started to take the values for every 5 seconds of interval.
Step 6:
After the starting of the data logger, we have to wait for the required time period generally until the working fluid reaches the boiling point.
Step 7:
Then we have to press the stop button in data logger and has to transfer the data to the laptop that was connected.
Step 8:
Using this data, we will calculate the temperature difference between the water inlet and outlet of the condenser.
Step 9:
The values which are negative and very high temperature difference are to be removed and analyze the range from the data.
Step 10:
Then we will calculate the evaporator and condenser mean temperature.
Step 11:
Using the following formula, we will calculate the thermal resistance value for the particular heat input.

$$R_{th} = \frac{T_e - T_c}{Q}$$

Where T_e=average temperature of evaporator.
T_c= average temperature of condenser.
Q=heat input supplied to the evaporator.
R_{th}= thermal resistance.

IV RESULTS AND DISCUSSIONS

From the experimentations the data for the fluids water, ethanol, methanol and acetone at different inclinations like 0, 45 and 90 were recorded. The following figs are the graphical representation of different fluids at various inclinations.

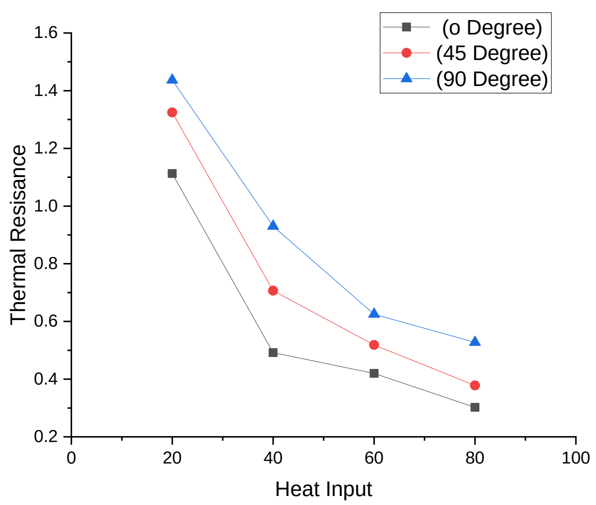

Fig: 3. Heat input (W) Vs thermal resistance (^{0}C/W) for different inclinations (working fluid water)

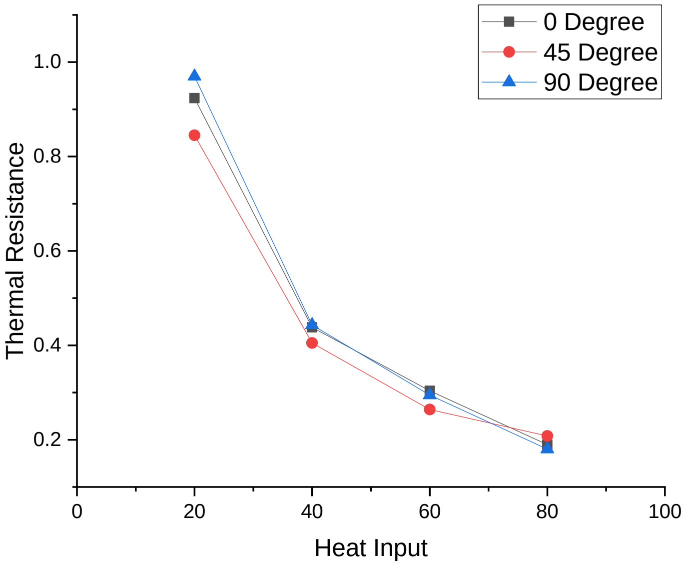

Fig: 4. . Heat input (W) Vs thermal resistance (^{0}C/W) for different inclinations (working fluid methanol)

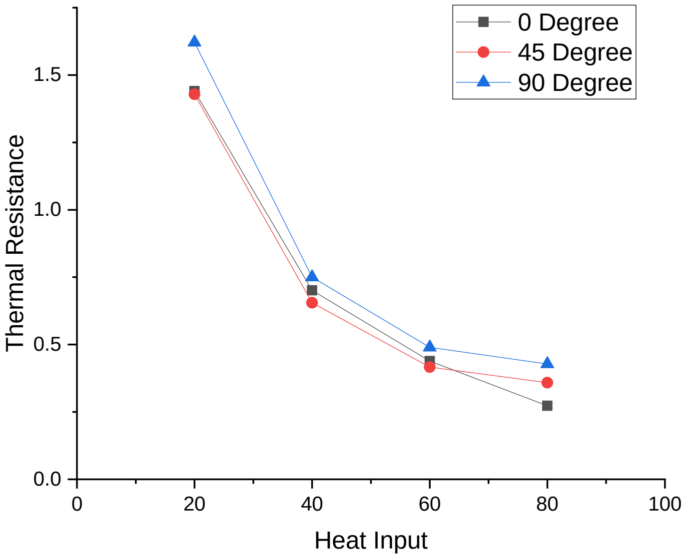

Fig: 5. Heat input (W) Vs thermal resistance (^{0}C/W) for different inclinations (working fluid ethanol)

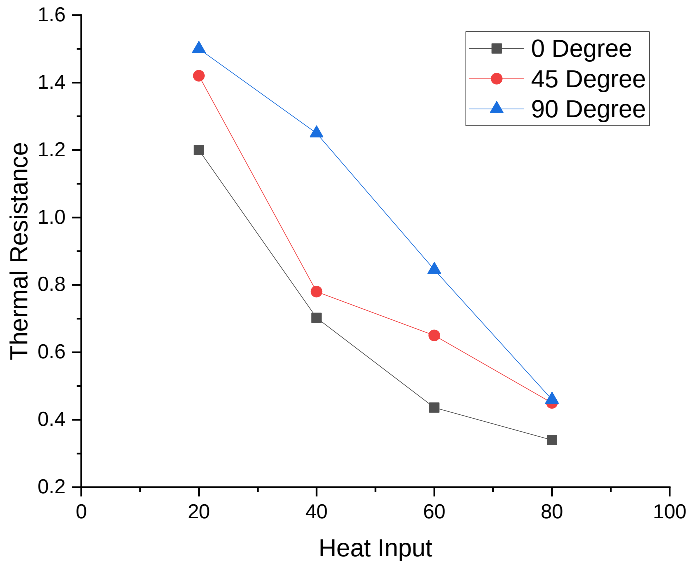

Fig: 4. Heat input (W) Vs thermal resistance (^{0}C/W) for different inclinations (working fluid acetone)

V CONCLUSIONS

From the experiments the following conclusions are drawn.

1. For all the working fluids as the heat input increases thermal resistance decreases.
2. The effect of inclination is always depends upon properties of working fluid.
3. As the inclination angle increases thermal resistance increases for most of the fluids at lower heat input.
4. Among all the fluids methanol has given better performance at all inclinations

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