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Effects of Filled Ratio, Heat Input and Orientation on Closed Loop Pulsating Heat Pipe

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ABSTRACT

This work presents an experimental study on pulsating heat pipe. A single CLPHP (closed loop pulsating heat pipe) with U turn is fabricated and tested. This experiment is carried out for different inner diameter, evacuation level, heat input and orientation. By varying these parameters optimization in PHP is possible. This optimization gives the condition for minimum thermal resistance or maximum heat transfer rate. Dimensions of three different inner diameters are 1 mm, 2mm and 3 mm, working fluid used as water and heat input range from 10 to 95 watt and orientation varying from 30 to 90°. Results from this study find out that

Keywords : Pulsating Heat Pipe, Data Acquisition System.

I. INTRODUCTION

Today's due to miniaturization of electronic component power input into the system getting increased so heat dissipation from a system for a thermal management is major problem. Chip heat flux a range from 40 to 120w/cm2 now a days, it becomes 200W/ cm2 in next few decades. To solve this problem lot of cooling devices developed and used now days, pulsating heat pipe is one of them and widely used now a days due to its low cost, less complexity, orientation independent operation and higher heat transfer rate is possible as compared to fin. Pulsating heat pipe is a tube of high thermal conductive material in which water is used as a working. Material used for heat pipe are copper, aluminium, nickel, stainless steel and molybdenum and working fluid chosen on the basis of its thermo-physical property can be taken as water, ammonia, ethanol, methanol, acetone R123 etc. complete length of tube divided into different sections are evaporator, adiabatic and condenser section. Evaporator section maintained at a higher temperature and condenser section maintained at lower temperature so due to this temperature difference pressure also exist between these two sections and this pressure difference acts as a driving potential. From evaporator to condenser combination of liquid slug and vapour plug moves towards condenser. At the condenser vapour and liquid slug gets condensed by transferring its latent and sensible heat transfer respectively. The amount of sensible heat transfer is much more than latent heat transfer. After condensation whole liquid return to evaporator due to gravitation al force when bottom heat mode is used and orientation independent operation is obtained more no. of turns is used in operation. Two type of arrangement are possible in pulsating heat pipe are

1. Open loop Heat pipe
2. Closed loop heat pipe

As shown below in figure 1 when meandering tube of capillary dimensions open at both the ends does not form a loop is called open loop pulsating heat pipe while when the ends.

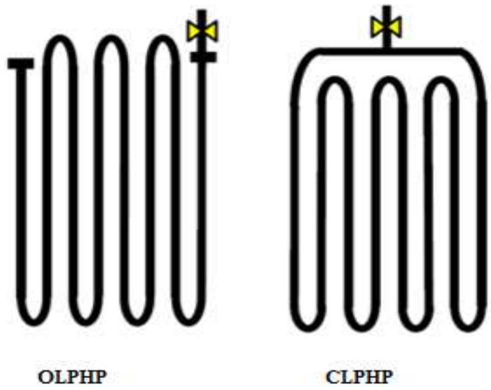

Figure 1.

II. METHODS AND MATERIAL

A. System Model

This work presents an experimental analysis of CLPHP by the use of visualization study. A single quartz tube of 2 mm ID is taken and uses water as a working fluid. Tube always filled with working fluid by some proportion of its total volume that is also called filled volume of tube. Influence of parameters like FR, heat input and orientation evaluated by visualizing the flow pattern of pulsating heat pipe. In present work filled ratio are 30, 40,50,60,70,80% of its total volume, heat input vary from 10 to 120 Watt and orientations are vertical bottom heat mode, 30 & 45° from vertical. With the variation in these parameters find out the operational limit of CLPHP.

Figure 2. Present work Set Up

B. Previous Work

Since 1990 Akachi developed a new type of Heat Pipe is known as Pulsating Heat Pipe [1]. Manfred Groll et.al. [2] Design a Pulsating Heat Pipe/ Oscillating Heat Pipe is a advanced cooling device in the family of Heat Pipe because of capability to transfer large amount of heat with small temperature difference. S.khandekar et.al. [3] In his experiment took initially tube is evacuated and filled partially with working fluid and then sealed it. After gain heat at evaporator working fluid gets evaporator and bubbles with liquid slug entrapped between them. S.Khandekar et.al. [4] In his another setup seen this liquid slug and vapour bubble combination obtained due to dominance of surface tension force. Temperature difference between evaporator and condenser creates pressure difference. This pressure difference drives the liquid slug along with vapour bubbles from evaporator to condenser. This mechanism is called thermo- mechanical physics. S.Khandekar et.al. [5] Made another setup of 10 glass tubes in no. of ID= 2 mm. and at the U end copper material is used. In this input parameters like filled ratio, heat input and tilt angle and cross section varied. He concluded that rectangular cross section with less than 10% FR in vertical orientation is best. P. Charoensawan et.al [6] experimentally analyze the thermal performance of CLPHP on the basis of parameters are internal diameter, working fluid, no. of turns, inclination angle. He concluded that performance improved by increasing no. of turns and inclination angle because gravitational force becomes inferior as compared to capillary force and different working fluid gives optimum performance under different working condition. Honghai Yang et.al [7] has done experimental study CLPHP. They investigated performance in different orientations are vertical bottom heat mode, horizontal orientation and vertical top heat mode. Also effect of inner diameter, filling ratio and heat input gives the operational limitation of CLPHP. He concluded that in vertical bottom heat mode with 50% FR gives the beat performance. P. Meena, et.al. [8] Has done experimental study to take the effects of evaporator section length, working fluid on CLPHP with check valve. With increases in evaporator length critical heat flux deceases. Working fluid from R 123, ethanol to water critical heat flux decreases. Working fluid having lower latent heat has higher heat flux. Stephan Lips Ahlem Bensalem et.al. [9] Has done experimental work on two full sizes PHP for different inner diameter, no. of turns and working fluid. He concluded that at lower heat flux heat transfer performance is sensitive for orientation but at higher heat input heat transfer rate independent from orientation. S. Rittidech et.al. [10] Has done visualization study of CLPHP to know the performance by internal flow dynamics of flow pattern with check valves. He conducted experiment for different evaporator length and ratio of check valves to no. of turns. He concluded that with decrease in evaporator length bubble flow with liquid slug disperse into bubbles and decrease in ratio of check valves with no. of turns changes disperse bubble flow with bubble into bubble with liquid slug.

C. Proposed Methodology

Experimental setup shown below -

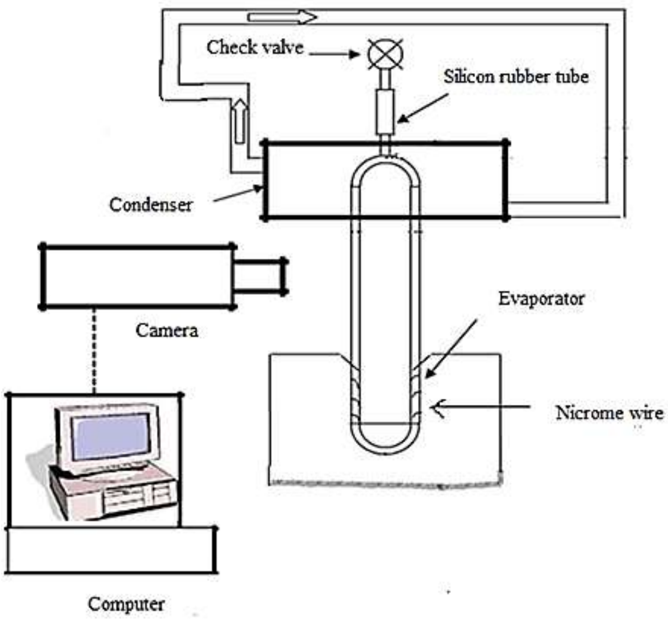

Figure 3. Experimental layout of CLPHP

A single tube of diameter ID 2 mm fabricated and tested. At first tube is evacuated and filled partially with working fluid then sealed it. This is a bottom heat mode so Nicrome wire wrapped at the lower end to make it evaporator and then connected it to variac by voltmeter, ammeter and Wattmeter. Upper end of the tube inserted into container which is filled with water. In condenser pump is used to circulate the working fluid for stirred it. High speed camera with high resolution used for visualization study. This camera connected to computer by 1 GPS LAN wire.

Difference in temperature creates pressure difference also. This pressure difference will derive the liquid slug along with vapour bubble from evaporator to condenser. At evaporator vapour bubbles gain heat and gets expanded and at condenser due to transfer its latent heat at condenser it gets contracted. Due to motion is obtained in left and right limb is known as pulsating or oscillating motion.

III. RESULTS AND DISCUSSION

A. Simulation/Experimental Results

Effect of 30% FR on D=2 mm- lower amplitude motion start at power input of 20 Watt due to less filled ratio but with increase in power input up to 50 Watt no movement is obtained due to vaporization. So 30% FR not suitable for high heat transformation.

Effect of 40% FR on D= 2 mm- Better than 30% FR but at higher heat input enough pumping action is not possible due to gravitational force predominance over gravitational force also due to less FR less bubble will formed.

Effect of 50% FR on D= 2 mm- At 50% FR pulsating motion start at 20 Watt of lower amplitude with increase in power input large amplitude pulsating motion is obtained. For true pulsating motion power input range from 20 to 80 Watt.

Effect of 60% FR on D= 2 mm- At 60% FR Motion start soon but less frequent in direction. Due to higher FR capillary force becomes inferior as compared to gravitational force. At higher heat input surface tension force decreases so liquid slug combination with vapour bubbles does not exist and this thing maintain the temperature and pressure in both the limbs approximately constant.

Effect of 70% FR on D= 2 mm- Initially process starts at lower power input due more FR more bubbles acts as a driving potential at the U bend but due to greater FR gravitational force restrict its motion. Pulsating motion is less frequent because of greater FR temperature and pressure difference is constant in limbs also gravitational effect predominant over capillary force. Vapour film formed on the right limb so it will reduce heat transfer rate because vapour has lower thermal conductivity as compared to liquid.

Effect of 80% FR on D= 2 mm- Initially at lower power input most of vapour form a film on surface due to film boiling but after increase in heat supply film vanishes because of large amplitude pulsating motion. More small size liquid slug formed in between the vapour plug due to surface tension but due to increase in heat supply temperature of surface also increase that will decrease surface tension force.

Figure 4. Pulsating Motion of 50% FR

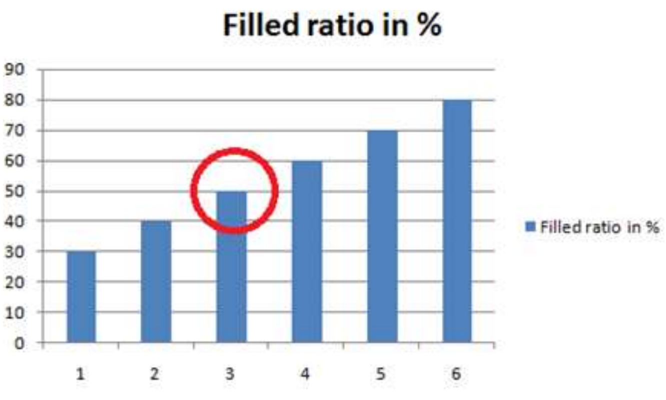

Figure 5. Influence of FR on CLPHP

When FR= 60% keep constant and orientation vary so as compared to vertical bottom heat mode inclination from vertical gives best result for pulsating motion. In vertical bottom heat mode with 60% FR gravitational force predominant but when take inclination of 30° from vertical start pulsating motion of large amplitude this is because of decrease in gravitational with increase in inclination. At 45° for 60% gives best performance with high heat transformation and with large amplitude. Also by taking inclination process start little earlier than then vertical orientation. This variation also shown in Fig. 4

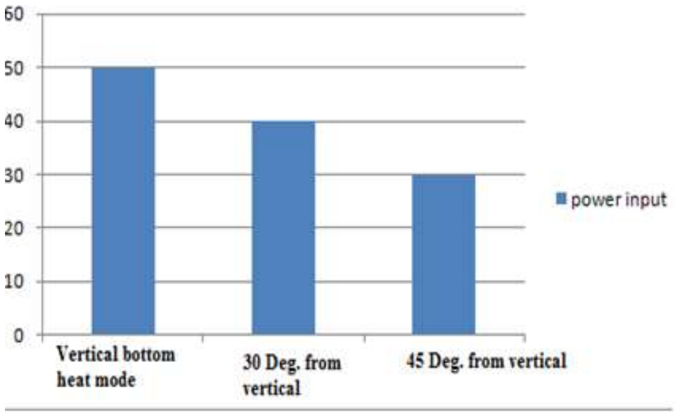

Figure 6. Influence of Orientation CLPHP performance

IV. CONCLUSION

30 & 40% FR not suitable to be used as a pulsating heat pipe due to less FR less bubbles formed so enough pumping action is not possible. At 50 % FR true pulsating motion from 20 to 80 Watt is obtained but at higher FR 60% less frequent motion is obtained due to surface force decrease with increase in heat input so liquid slug & vapour combination get affected. At 70 & 80% FR Process starts earlier then less FR from these but less frequent in direction also unstable film formation on the limbs appeared this will affect heat transfer performance adversely.

V. FUTURE SCOPES

Comparative study of different ID (1 mm, 2mm & 3 mm) of tube with different FR & Power input also possible.

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