ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
Available online at www.ijartet.com

International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 5, Special Issue 3, January 2018

EXPERIMENTAL AND NUMERICAL EVALUATION OF THERMAL PERFORMANCE OF CLOSED LOOP PULSATING HEAT PIPE

1. Dr. K Rama Narasimha PhD , Professor and Head,
Dept. of Mechanical Engineering, KSIT, Bangalore.

2. Mr. Pradeep G V, Assistant Professor,
Dept. ofMechanical Engineering, SET, Jain University, Bangalore.

3. Mr. T.Paramesh, Assistant Professor,
Dept. of Aeronautical engineering, SJCIT, Chickkaballapur.

Abstract

Thermal management is challenging day by day as the chip heat flux is increasing continually.. In order to satisfy the junction temperature requirements in terms of performance and reliability, improvements in cooling technology is required

There are several cooling methods for electronic devices. Heat pipe is being used to cool the electronic devices with promising results. The conventional heat pipes are good heat transfer devices but their applications are limited to small amount of heat transfers with short distances. Pulsating heat pipes are excellent heat transfer devises which transfer heat for longer distances. PHPs are simple tubes of small diameter extend from source to sink filled with certain working fluids in it. PHPs are working on the principle of pressure difference across liquid slugs and vapor plugs from evaporator and condenser and vice versa.

Although the PHP technology is well established, the open literature on PHPs is limited especially on the numerical investigation and mathematical modeling of a PHP. The use of dimensionless numbers were very limited hence, the above aspects motivate the present investigation.

In the present experiment on a multiloop PHP Acetone, Methanol, Ethanol, and Heptane as working fluids have been used for investigation of thermal performance of PHP. The experiments were carried out for different fill ratios. Also, the experiments were carried out for different heat inputs for acetone at 60% fill ratio. The thermal parameters evaluated were thermal resistance, convective heat transfer coefficient for different working fluids.

Numerical investigation is done with the different dimensionless numbers to determine the thermal performance of CLPHP

From the results it is observed that there is a significant change in the thermal performance at different fill ratios. The investigation shows that at higher heat inputs the performances of the PHPs are better. Also it is observed that the calculated thermal performance is nearly equal to the experimental thermal performance for ethanol.

Index Terms—Working fluid, Closed loop pulsating heat pipe, Fill ratio, Dimensionless numbers, Thermal performance

I. INTRODUCTION

HISPulsating heat pipes comprise of a tube, evacuated and partially filled with the working fluid. Typically, a Pulsating heat pipe comprises a serpentine channel of capillary dimension, which has been evacuated, and partially filled with the working fluid. Surface tension effects result in the formation of slugs of

ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
Available online at www.ijartet.com

International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 5, Special Issue 3, January 2018

liquid interspersed with bubbles of vapor. A PHP is a device consisting of a tube of small diameter. The device may be of single loop or with multiple loops.

A single loop PHP consists of a small diameter tube that crosses a condenser and evaporator region single time. The tube is filled with a working fluid such that only the fluid and its vapor

A single loop PHP consists of a small diameter tube that crosses a condenser and evaporator region only once. The tube is filled with a working fluid such that only the fluid and its vapor phase exist. The tube's inner diameter must also be small enough for the capillary forces of the fluid to create vapor bubbles (plugs) and liquid slugs. Thus the vapor plugs completely block the flow of the liquid. This keeps the plugs and slugs in a linear arrangement within the tube. Heat transfer in a PHP is associated with liquid and vapor motions induced by the pressure difference. Evaporation at a higher temperature in the evaporator produces a higher vapor pressure. The same is the case for the condenser where condensation and reduced temperature at the condenser cause a decrease in pressure. The increased pressure in the evaporator and decreased pressure within the condenser causes a pressure imbalance. Due to the random arrangement of liquid slugs and vapor plugs within PHP, this pressure imbalance forces the hot vapor and liquid from the evaporator to the condenser. Subsequently, the cool vapor and liquid flows from the condenser to the evaporator, resulting in a pulsating motion. The pulsating motion consists of small rapid movement within portions of the tube and in some cases bulk motion through the entire PHP. [1]

There general closed loop PHP is as shown in Fig. 1 The closed loop PHP is a continuous tube in which the fluid passes through the evaporator and condenser multiple times continuously. The open loop PHP is similar except that the two ends of the tube are sealed. Generally, close loop PHPs perform better than open loop PHP.

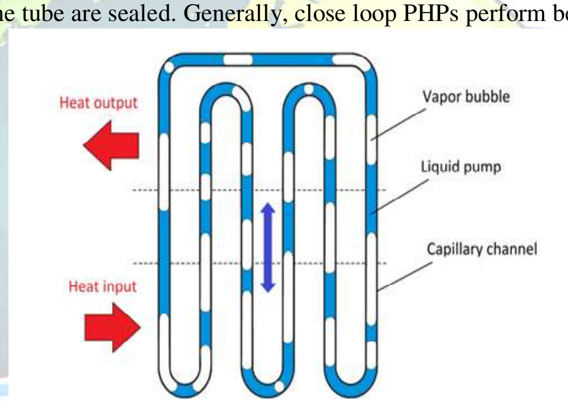

Fig.1 Closed Loop pulsating heat pipe

Most of the PHPs are made of copper, aluminum and/or glass. Copper and aluminum with their high thermal conductivity are better suited for PHP. Glass has been used in several experiments for flow visualization. [3] proposed a system, this fully automatic vehicle is equipped by micro controller, motor driving mechanism and battery. The power stored in the battery is used to drive the DC motor that causes the movement to AGV. The speed of rotation of DC motor i.e., velocity of AGV is controlled by the microprocessor controller.This is an era of automation where it is broadly defined as replacement of manual effort by mechanical power in all degrees of automation. The operation remains an essential part of the system although with changing demands on physical input as the degree of mechanization is increased.

The parameters affecting the performance of closed loop PHP have been summarized by

a. Working fluid
b. Internal tube diameter
c. Length of condenser, evaporator and adiabatic sections
d. Number of turns or loops
e. Orientation.
f. Fill Ratio

II. EXPERIMENTAL SETUP AND PROCEDURE

The performance of the PHP is dependent on many factors. The aim of this project is to test the effect of fill ratio of working fluid and the effect of working fluid on performance. Therefore the experiment was conducted to understand the operational phenomena under the influence of working fluids. The following section briefly describes the components used in the present experimental setup.

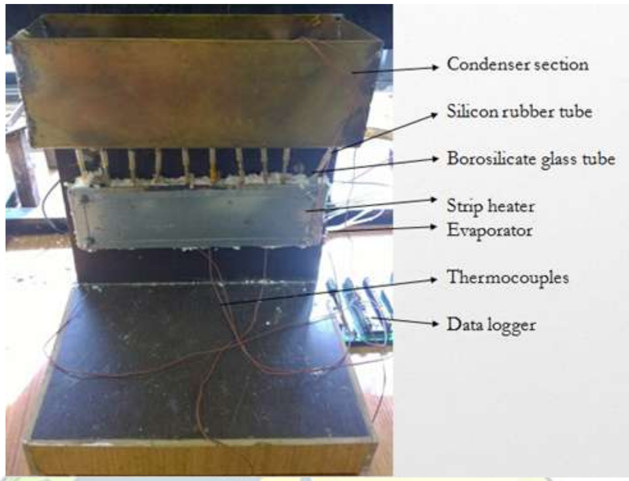

Fig 2 - Experimental setup of Multiloop pulsating heat pipe

In the present work, copper is used as the tube material which is an excellent conductor of heat. In order to study the fluid flow in the PHP, a glass tubes are connected to the copper tubes for a length of 65mm. The glass tube also acts as the adiabatic section as it is an insulator and also helps in flow visualization. In the present study, Borosilicate glass of inner diameter 2 mm and outer diameter 3mm is employed.

Silicon tubes are used as connectors between glass and copper tubes. They have high flexibility, elasticity, longer life and are resistant to chemical reactions.

Heater is an electrical appliance that converts electrical energy into heat. The heating element inside every electric heater is simply an electrical resistor, and works on the principle of Joule heating. In the present study a mica strip heater of heating capacity 0-200 W is used to heat the working fluid.

Thermocouples are used to measure the temperatures. In the present work T-type thermocouples are used. T-type thermocouples have a positive copper wire and a negative Constantan wire. In the present experimental setup totally six thermocouples are used, four in the evaporator section and two in the condenser section

A temperature data logger, also called temperature monitor, is a portable measuring instrument that is capable of autonomously recording temperature over a defined period of time. The digital data can be retrieved, viewed and evaluated after it has been recorded. The temperature values are recorded with a frequency of 1 Hz.

A water cooling arrangement is provided in the condenser to cool the working fluid of the PHP. The cold water enters the condenser from a constant head water container and the rise in the temperature of the cooling water is maintained around 1^0C to 2^0C by controlling the water flow rate.

The first consideration is the identification of a suitable working fluid and the operating temperature range.

Within the approximate temperature band, several possible working fluids may exist. A large number of characteristics must be examined in order to determine the most acceptable fluids for the application. In the present work based on the available literature, water and acetone are used as the working fluids. In the present work acetone, methanol ethanol and heptane are used as working fluid because it has some desirable properties to increase thermal performance.

Inner diameter of the php	2mm
Outer diameter of the php	3mm
Total length of the php	2.15 m
Total volume of the php	7 ml
Number of loops of php	10
Mass flow rate of water	7 g/s

ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
Available online at www.ijartet.com

International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 5, Special Issue 3, January 2018

Length of adiabatic section	900 mm
Length of condenser section	750 mm
Length of evaporator section	500 mm

Procedure of conducting experiments

a. Clean the PHP tubes using compressed air by means of Syringe.
b. Before filling the working fluid, make sure that there is no other fluid exists inside the tubes of PHP.
c. The required amount of working fluid is then filled by opening the valve by means of syringe.
d. The cooling water is allowed to the condenser section of PHP from the water source.
e. The required wattage is set using the power supply unit. In the present work, the experiments were conducted by varying the heat inputs from 80W to 140W respectively with increments of 20W.
f. The temperature Data logger is then switched on to record the temperature readings and the frequency of Data logging is adjusted to 1 Hz so that one temperature value recorded in one second.
g. Conduct the experiment for the required time without changing the heat input at atmospheric conditions.
h. After completion of experiment dry out the PHP tubes using compressed air.
i. Repeat the same for various other fluids and heat inputs and different fill ratios.

III. EXPERIMENTAL RESULTS

A. *Effect of fill ratio on performance of php*

In the PHP the heat transfer takes place in the form of latent heat from vapour plug and sensible heat from the liquid slug.

Fill ratio is defined as the ratio of amount of working fluid filled to the total volume of the CLPHP.

CLPHP has two extreme condition that can operate with respect to working fluid fill ratio is 0 % filled and 100 % filled.

If the filling ratio is 0 % then CLPHP structure has bare tubes having no working fluid inside and it is only a poor conduction mode heat transfer having very high thermal resistance.

If the filling ratio is 100 % then CLPHP acts as a single phase natural thermosyphon in this liquid starts circulating inside the device due to density difference associated with temperature difference

In this the buoyancy force should overcome the liquid viscous forces and wall shear stresses to set the fluid into circulation causing a sensible heat transfer from evaporator to Condenser. Since there is only liquid plugs and no vapour bubbles in the PHP there will be no pulsating effect

In order to increase the heat transfer a two phase flow is to be introduced rather than a single phase flow [2]

If the fill ratio is nearly 100% (i.e. > 90%) it leads to the formation of few vapour bubbles in the tubes. With the introduction of these first few bubbles there is a remarkable drop-in performance. In the single-phase mode (FR=100%), the liquid could freely circulate in the tube resulting in convective heat transfer. This naturally circulating flow is hindered due to the formation of few vapour bubbles. Under these working conditions, the driving force generated due to the density gradient has to overcome additional forces to induce a flow. These new retarding forces are due to:

I. The additional frictional resistance (or pressure drop) created due to the head and tail section of the bubble,
II. The buoyancy force which acts on the bubble due to which it is difficult to bring the bubble in the downward direction against the gravity.

Since nearly 95% of the CLPHP is filled with an incompressible working fluid, the overall required perturbations. The buoyancy induced liquid circulation, which was present in the100%filledCLPHP, is hindered due to additional flow resistance of the bubbles. Thus, the performance of the device is greatly decreased resulting in a thermal resistance that is much higher than forthe100%filledCLPHP.

If the fill ratio is near to 0% fill ratio (i.e. < 10%) there is very little liquid to form enough distinct plugs and there is a tendency towards a dry-out of the evaporator U-turns.

Between filling ratios of about 20% to 80%, the CLPHP operates as a true pulsating device. This working range will differ for different working fluids, operating parameters and construction. The more bubbles (lower filling ratios), the higher is the degree of freedom, but simultaneously there is less liquid mass for

ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
Available online at www.ijartet.com

International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 5, Special Issue 3, January 2018

sensible heat transfer. Less bubbles (higher filling ratios) cause less perturbations and the bubble pumping action is reduced there by lowering the performance. Thus, an optimum-filling ratio exists for a given thermal requirement.

In this the experiment is conducted for 1800 seconds with acetone as a working fluid at a constant heat supply of 80 W to the evaporator and at a constant mass (water) flow rate of 7 g/s in condenser

The evaporator temperature at 60% fill ratio is more stable than the other fill ratios because at 60% there is proper formation of vapour bubbles and liquid slugs combination

There will be a proper pulsating action due to the pressure differences in vapour plugs and liquid slugs which is the cause for pulsating action thus the evaporator temperature is less for 60% fill ratio as shown in fig.3

The condenser temperature is more for 60% fill ratio because the pulsating action is more and frequent in case of 60% because of that the large amount of heat is released at 60% fill ratio leading to increase in the condenser temperature as shown in fig.4

From the fig.5 it is clear that the temperature difference between the evaporator and condenser is lower at a lower fill ratio of 60%. At lower fill ratio, the saturation temperature is lower. The pressure difference between a liquid slug and a vapour bubble will decrease at lower fill ratio which will reduce the saturation temperature. As the pressure difference between a liquid slug and a vapour bubble decreases, the temperature difference also decreases. However, sufficient pumping action is created leading to more vapour phase in the tube with a consequent decrease in the heat transfer. Because of lower heat transfer from the wall to the fluid, the temperature difference between evaporator and condenser reduces.

From the fig.6 it is clear that the thermal resistance decreases with increase in fill ratios considered. The fill ratio of 60% exhibits the lower values of thermal resistance compared to higher fill ratio of 70% and 80%. As the temperature difference between evaporator and condenser is less at lower heat load of 60% .The magnitude of thermal resistance is also less. This shows that the heat transfer characteristics in a PHP are better at 60% fill ratios.

From the fig.7, it is seen that the heat transfer coefficient decreases with increase in fill ratios.

Higher values of heat transfer co-efficient can be seen at a lower fill ratio of 60% which indicates better performance of PHP.

B. *Effect of heat input on performance of php*

From the fig.8 it is clear that The Thermal resistance decreases with increase in heat input

From the fig.9 it shows Heat transfer coefficient increases with increase in heat input due to reduction in thermal resistance.At lower heat input the Energy given to system is less hence flow velocity is less and system take more time to reach steady state Te is more, Tc is less, (Te-Tc) is more.

At higher heat input the Energy given to system is more hence flow velocity is moreand system take less time to reach steady state flow hence Te is less and Tc is more, (Te-Tc) is less at higher heat input thus the thermal resistance decreases and heat transfer coefficient increases

C. *Effect of working fluid on performance of php*

Temperature difference between the evaporator and the condenser is less for acetone and more for heptane

For acetone saturation temperature is less thus forming more vapour creating the the diving force for pulsating action thus taking away the heat at evaporator. And the heat is rejected at the condenser making the raise in the temperature of condenser making the evaporator and condenser temperature difference is less

For heptane saturation temperature is more the given heat is not enough to create enough vapour bubbles causing more liquid to be in the PHP hence the evaporator temperature is more and it delivers less heat to condenser thus condenser temperature is lessand causing the temperature difference to be more that can be seen in fig.10

Acetone exhibits lower values of thermal resistance compared to other working fluids, due to lower value of temperature difference between evaporator and condenser in case of acetone can be seen from fig.11

From fig.12 Acetone shows higher heat transfer coefficient values compared to other fluids. This is due to the lower values of temperature difference between evaporator and condenser for acetone. And low thermal resistance. Acetone has better heat transport capability compared to other working fluids considered

ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
Available online at www.ijartet.com

International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 5, Special Issue 3, January 2018

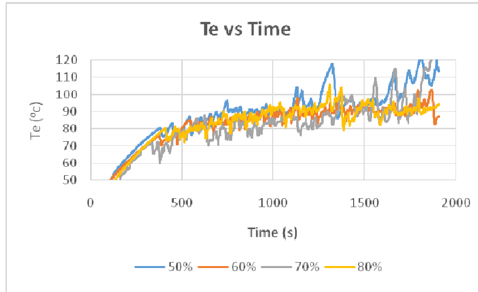

FIG.3.The variation of the evaporator temperature for different fill ratios is shown

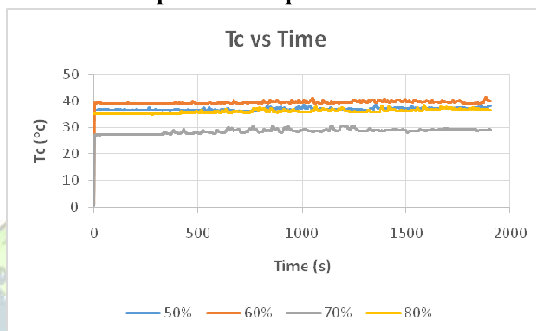

FIG.4.The variation of condenser temperature for different fill ratios with time are shown

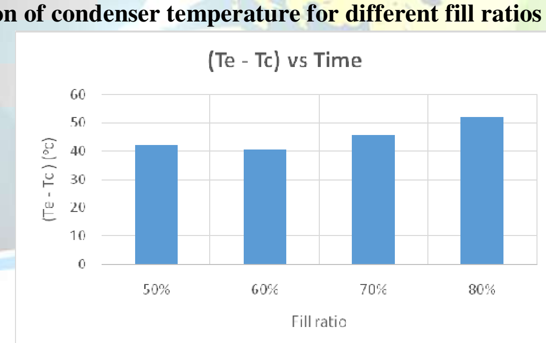

FIG.5.The variation of temperature difference between the evaporator and condenser for different fill ratios with time are shown.

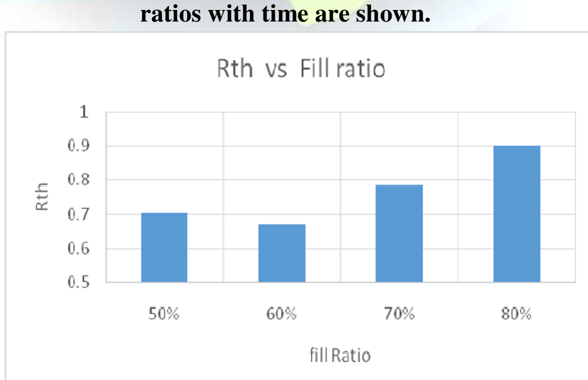

FIG.6.The variation of thermal resistance for different fill ratios with time are shown

ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
Available online at www.ijartet.com

International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 5, Special Issue 3, January 2018

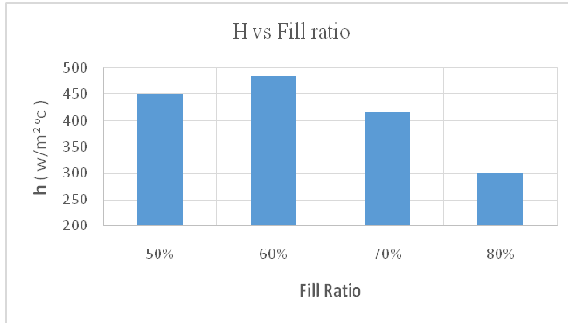

FIG.7.The variation of heat transfer coefficient for different fill ratios are shown

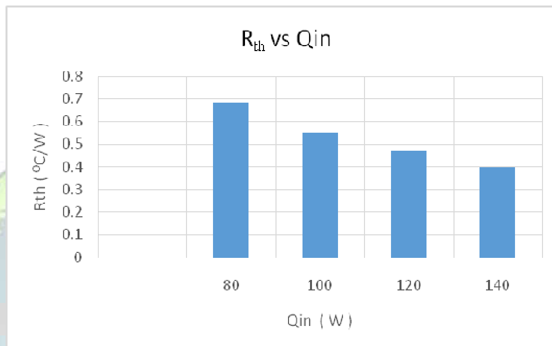

FIG.8. The variation of Thermal Resistance for different heat inputs are shown

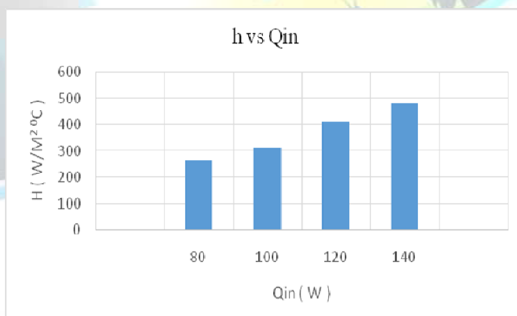

FIG.9. The variation of heat transfer coefficient for different heat inputs are shown

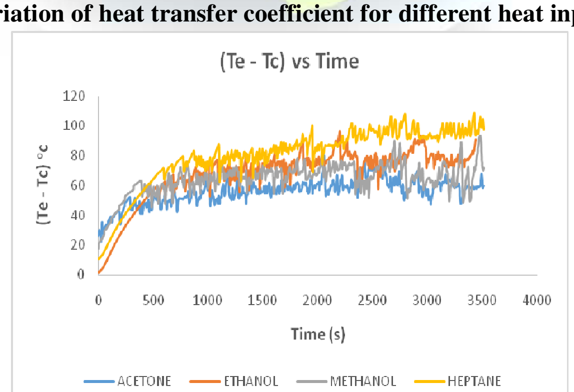

FIG.10.The variation of (Te – Tc) temperature for different fluids with time are shown

ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
Available online at www.ijartet.com

International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 5, Special Issue 3, January 2018

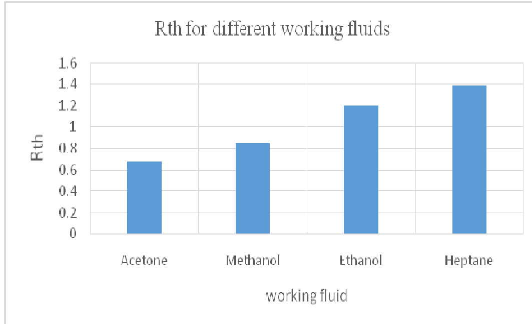

FIG.11. The variation of thermal resistance for different fluids are shown

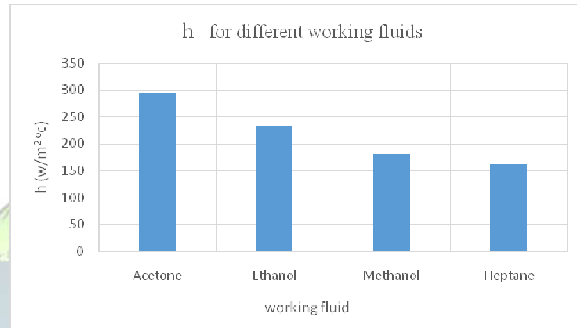

FIG.12. The variation of heat transfer coefficient for different fluids are shown

IV. NUMERICAL RESULTS

"Critical heat flux" – It is the maximum possible heat that can be transferred by fluid before the evaporator dries out. When compared with critical heat flux the thermal performance of the individual working fluid is not reasonable. The working fluid with low critical heat flux has lower heat transfer capability. In order to normalize the experimental data, thermal performance is represented by Kutateladze number (*Ku*)

Kutateladze number is a well-known dimensionless number in heat transfer involving in the heat pipe. It is a ratio of transferred heat flux to the critical heat flux. The higher Ku implies that the heat pipe has higher thermal performance.

$$\mathrm{Ku} = \frac{\dot{q}_c}{\rho_v h_{fg}\left[\sigma g\left(\frac{\rho_l - \rho_v}{\rho_v{}^2}\right)\right]^{1/4}}$$

$$\text{where}\dot{q}_c = \frac{\dot{m}_c c_{pc}(T_{out} - T_{in})}{A_c}$$

$(T_{out} - T_{in})$ Raise in the temperature of the cooling water

A. Effect of Prandtl number on thermal performance

Prandtl number (Pr) is a dimensionless number involved with working fluid properties. It is defined as the ratio between momentum diffusivity and thermal diffusion of working fluid.

$$Pr_l = \frac{c_{p,l}\mu_l}{k_l}$$

Pr can be in two phases, i.e. Prandtl number of the liquid working fluid and Prandtl number of the vapour working fluid. Since Pr_v rarely had an effect on the thermal performance Pr_v could be neglected from this analysis.

From fig.13 It was found from the experiment that when Pr_l increased or the working fluid changed from the Acetone to Methanol, Heptane and Ethanol – which has highest Pr_l the thermal performance is increased.

ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
Available online at www.ijartet.com

International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 5, Special Issue 3, January 2018

Ethanol can transfer higher heat from evaporator to condenser section due to its higher liquid specific heat capacity, comparing with the other working fluids of same mass. This causes the thermal performance to increase.

Moreover, increase in liquid viscosity leads to decrease flow velocity of the working fluid. Therefore time duration that the working fluid receives and releases the heat in the evaporator and condenser section is more

Methanol with higher liquid thermal conductivity is used, the maximum heat will freely diffuse in liquid slug. The remaining portion of the heat that causes evaporation, thun thermal performance decreases. These are the physical reasons to support that when Pr_l increases, Ku or thermal performance of VCLPHP increases.

B. *Effect of Bond number on thermal performance*

Bond number (Bo) is a dimensionless number involved with geometry of the heat pipe and working fluid properties. It is defined as ratio between buoyancy force and surface tension of the working fluid.

$$Bo = \frac{g\,(\rho_{l-}\rho_v)D_i^{\,2}}{\sigma}$$

From fig.14 When fluid changed from Acetone to Methanol Heptane and Ethanol -which has lowest bond number it is found that when Bo increases, Ku or thermal performance decreases. This is primarily due to decrease in surface tension appearing in a denominator of Bo. When surface tension decreases, the vapour tends to form into small bubbles instead of long vapour plugs. Since smaller bubbles have lower vapour's mass than longer bubbles. This causes the working fluid to transfer the less heat and the thermal performance is subsequently lower.

On the other hand, another tendency was found that when Bo increases, Ku or thermal performance increases. This is a major effect due to buoyancy force. When a difference between liquid and vapour densities increases, it can be seen that vapour plug is obviously lighter than liquid slug compared in the same volume. This causes the buoyancy force to be higher and vapour plugs can flow from evaporator to condenser section which stays at the top of the VCLPHP with shorter time duration. The working fluid transfers the heat at a faster rate and thermal performance consequently increases.

It could be seen from both experimental results and physical reasons as mentioned above that the effect of Bo on thermal performance is still not clear. Thus, one or more dimensionless number that has stronger effect on the thermal performance than that of Bo is possibly existed, and also both thermodynamics properties of the working fluid and geometry of the heat pipe must involve in this dimensionless number as same as a case of Bo.

C. *Effect of Karman Numbers on Thermal Performance*

Karman number (Ka) is a dimensionless number involved with geometry of the heat pipe and working fluid's properties, which is similar to Bo. It represents a ratio between driving force of the fluid and frictional force of the working fluid. When$(\Delta P)_{sat}^{e\text{-}c}$, P is saturated pressure difference between evaporator and condenser section (P_a), L_{eff} is effective length of the heat pipe (m), which is calculated from ($0.5L_e+L_a+0.5L_c$)

$$Ka = \frac{\rho_l(\Delta P)_{sat}^{e\text{-}c}D_i^{\,3}}{\mu_l^{\,2}L_{eff}}$$

From fig.15 When the fluid changed from Acetone to Methanol, Heptane, Ethanol –which is having highest Karman number, It was found from the experiment that when Ka increased, the thermal performance increased, since the thermal performance according to ethanol isolates from overall data. The driving force (saturated pressure difference of the working fluid between evaporator and condenser section) is the main mechanism of working fluid's circulation in the CLPHP, the working fluid flows forth and back between evaporator and condenser section due to this force. Therefore, when the pressure difference increases or Ka increases, the driving force increases. The flow velocity of working fluid and heat transferred quantity is increased. Also, when internal diameter increases, loss of pressure decreases along flow passage between evaporator and condenser section. Net pressure difference of CLPHP is higher with bigger internal diameter than that of the smaller one. Since an increase in internal diameter strongly reduces the effect of pressure difference, when diameter increases, Ka increases, and Ku or thermal performance increases.

D. *Effect of Jacob Numbers on Thermal Performance*

Jacob number (Ja) is a dimensionless number involved with working fluid's properties. It implies to be a ratio of heat quantity transferred by latent heat and heat quantity transferred by sensible heat of heat pipe. Where

ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
Available online at www.ijartet.com

International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 5, Special Issue 3, January 2018

$(\Delta T)_{sat}^{e\text{-}c}$ is saturated temperature difference between evaporator and condenser section. It can be seen that as the Ja increased, the thermal performance increased.

$$J_a = \frac{h_{fg}}{c_{p,l}(\Delta T)_{sat}^{e\text{-}c}}$$

From fig.16 Working fluid when changed from Heptane to Methanol - which has higher ratio between latent to sensible heat or higher Ja causes the CLPHP to have higher thermal performance, as the working fluid transfers high quantity of the heat by means of the phase change from liquid to vapour in evaporator section relatively to remaining heat quantity that is transferred by means of temperature change

On the recent day, actual portion of heat transferred in the CLPHP according to latent heat and sensible heat is still in a black box. Therefore, when Ja increases, the thermal performance can possibly change in either direction.

E. Correlation to calculate Thermal Performance

Correlation is obtained by mathematical combination of 5 dimensionless numbers that affect the performance of VCLPHP. More precise thermal performance according to certain operating condition of the VCLPHP can be predicted by this established correlation. The correlation was started from a function as of

$$Ku = f\ (Pr_l, Ja, L_e / D_i, Ka, Bo)$$

All dimensionless numbers were arranged into the correlation by means of the least-square curve fitting. Experimental data involving in the curve fitting consisted of the results obtained from this study and from the past studies on VCLPHPs in order to expand the correlation's available condition and to increase prediction's precision of the correlation. Availability of combining these results from other studies into the correlation's establishment was acceptable, since scopes of experiment in both studies were nearly the same. The correlation [4] to predict the thermal performance of the VCLPHP was finally established as expressed.

$$Ku_{model} = 5.27x10^{-2}\, Pr_l^{0.522} J_a^{-0.507}\, (L_e/D_i)^{-0.727} Ka^{0.057} Bo^{-0.164}$$

Thermal performances calculated from the correlation (Ku_{model}) and obtained from the experiment (Ku_{exp}) were plotted against each other to verify the precision of the correlation. Percentage of data deviation between Ku_{model} and Ku_{exp} was43% for heptane and 5% for ethanol from fig.17. Hence the heptane can't be used as a working fluid for the PHP.

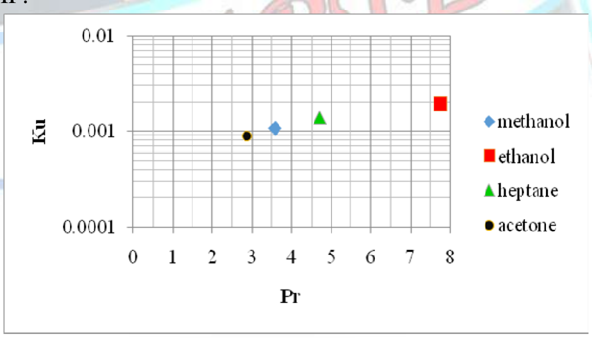

FIG.13.shows variation of Thermal Performance with Prandtl Number

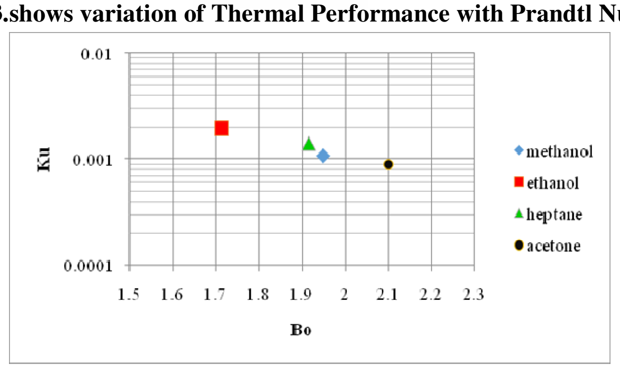

FIG.14. shows variation of Thermal Performance with Bond Number

ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
Available online at www.ijartet.com

International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 5, Special Issue 3, January 2018

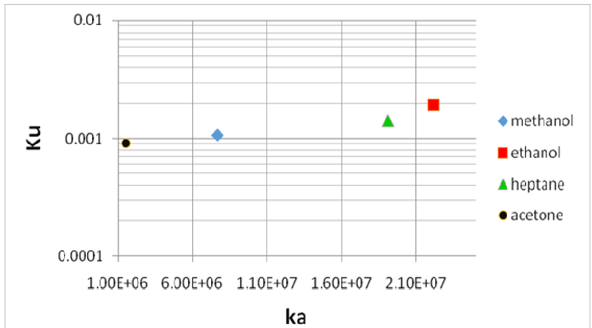

FIG.15. shows variation of Thermal Performance with Karman Number

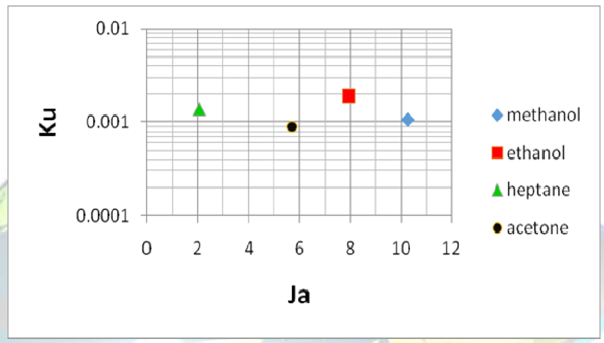

FIG.16 shows variation of Thermal Performance with Jacob Number

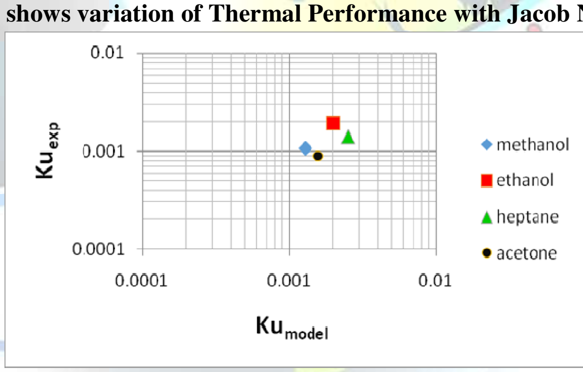

FIG.17 shows variation of Ku_{exp} with Ku_{model}

V. CONCLUSION

This work presents the experimental and numerical investigations on a Multiloop PHP.

The effect of heat input at 60% fill ratio and effect of fill ratio on the performance of PHP are studied for acetone through experimentation.

Numerical investigation of thermal performance of CLPHP using Dimensionless numbers.

The following are the conclusions drawn from the above.

- Thermal performance of CLPHP increases with increase in the heat input
- The thermal performance of CLPHP is better at 60% fill ratio than other fill ratios
- With the experiments conducted acetone exhibits better thermal characteristics than other working fluidsWith the numerical investigations
- Thermal performance increases with increase in Prandtl number
- Thermal performance decreases with increase in Bond number

ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
Available online at www.ijartet.com

International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 5, Special Issue 3, January 2018

- Thermal performance increases with increase in Karman number
- Heptane can't be suited as working fluid for operation of PHP

SCOPE FOR FUTURE WORK

There is lots of scope for future work for PHP as these are still in research Stage Following are the possibilities which can be undertaken.

1. Mathematical modeling to predict the behavior of fluid within PHP[5]
2. Simulation of PHP to show how the temperature is distributed and how the pulsation occurs.
3. Experimentations on PHP using Nano fluids to see how the thermal performance varies.

REFERENCES

[1] K. Rama Narasimha1†, S.N. Sridhara2, M.S. Rajagopal3 and K.N. Seetharamu "Influence of Heat Input, Working Fluid and Evacuation Level on the Performance of Pulsating Heat Pipe"

[2] Rahul S. Borkar , Pramod R. Pachghare"Effect Of Working Fluid, Filling Ratio And Number Of Turns On Pulsating Heat Pipe Thermal Performance"

[3] Christo Ananth, M.A.Fathima, M.Gnana Soundarya, M.L.Jothi Alphonsa Sundari, B.Gayathri, Praghash.K, "Fully Automatic Vehicle for Multipurpose Applications", International Journal Of Advanced Research in Biology, Engineering, Science and Technology (IJARBEST), Volume 1,Special Issue 2 - November 2015, pp.8-12.

[4] NitiKamuang-lue, kritsada On-ai, Phrut Saulchangsatjatai, Prandit Tedron "Correlation To Predict Thermal Performance According To Working Fluids Of Vertical Closed-loop Pulsating Heat Pipe"

[5] Takurou Daimaru, Shehei Yoshida and Hiroki Nagai "Mathematical Modeling and Experimental Validation Of Oscillating Heat pipes"