"Experimental Study of Close Loop Pulsating Heat Pipe Using Thermic Fluid(HP-Hytherm-500) "

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Abstract

The main purpose of this study is to investigate the influence of the use of thermicfluids on two-phase heat transfer, particularly on the thermal performance of the heat pipes. In the first stage, the properties of the thermicfluids were studied, then, these thermicfluids were used as the working fluids of the heat pipes. The thermal performance of the heat pipes when using different fluids was investigated under different operating conditions experimentally and analytically.

This research investigate the effect of pure water and thermicfluid on thermal resistance of closed Loop Pulsating Heat Pipe (CLPHP). CLPHP is made up of copper tubing with internal diameter of 3mm and outer diameter of 4mm. the tube had 2 meandering turns. The length of evaporator and condenser section was 380mm. Working fluids are selected as HP-Hytherm-500, water and different binary mixtures. The graphs are plotted, in order to study, characteristics of the thermal resistance and average evaporator temperatures at different heat input for different working fluids. Experimental study on PHP indicated that working fluid is an important factor for the performance of PHPs. The result shows that, the thermal resistance decreases more rapidly with the increase of the heating power , whereas slowly decreases at input power above . HP-Hytherm-500 gives best thermal performance in comparison with the other working fluids.

Keywords: *Pulsating heat pipe, Thermicfluid(HP-Hytherm-500)*

I. INTRODUCTION

Their operation is based on the principle of oscillation for the working fluid and a phase change phenomena in a capillary tube. The diameter of the tube must be small enough such that liquid and vapor plugs exist. Due to its excellent features, such as high thermal performance, rapid response to high heat load, simple design and low cost, PHP has been considered as one of the promising technologies for electronic cooling, heat exchanger, cell cryopreservation, the spacecraft thermal control system, etc. . Over the years, researchers have continuously search new methods of heat transfer augmentation. The results of employing different working fluid proved to be one effective way of improving the system's overall performance Phase changing phenomenon is used in heat pipe and the PHP to take away the heat. Because of the phase change, it will cause to absorb a large amount of latent heat. So the heat from the heat source can be rapidly extracted from the condenser. The principal of pulsating heat pipe proposed and presented by Akachi H. in 1990[1], due to its excellent features the device used in many electronic cooling application.

The pulsating heat pipe has two main region i.e. evaporator and condenser. The evaporator is the heating section and condenser is the cooling section, which is separated by adiabatic region. Adiabatic section is optional and its presence is depends on the location of evaporator and condenser.

Fig. 1: Schematic diagram of Pulsating Heat Pipe and its variations physical configuration from "An introduction to pulsating heat pipe", by Manfred Groll et.al. 2003 [13]

A. Tube Diameter: The internal tube diameter is very important parameters to define a PHP. Only a certain range of diameters can adheres physical behavior to the "pulsating" mode. The critical Bond number (or Eötvös) criterion gives the tentative design rule for the diameter [16]. Akachi H. in 1990 presented formula for theoretical maximum inner diameter of capillary tube, which is as follows- If $D < D_{cri}$, surface tension force dominate and stable liquid plugs and vapour slugs are formed. However, if $D > D_{cri}$, the surface tension is reduced and the working fluid will fall down by gravity and oscillations will not happen. The OHP may operate as an interconnected array of two-phase thermosyphons. Firstly, device is evacuated and then filled with the suitable working fluid. Due to capillary dimension of PHP and surface tension of fluid, fluid fills takes a shape of vapor plugs and liquid slugs. When heat is input to the evaporator section the thin film liquid layer near the vapor plug starts evaporate, this evaporation of causes the expansion of vapor The pulsating heat pipe has

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2009 investigated the effect of aspect ratios (evaporator length to inner diameter of capillary tube), inclination angles, and concentrations of silver nanofluid on the heat transfer rate of a closed-loop oscillating heat pipe with check valves (CLOHP/CV).and he found that, CLPHP using silver nanofluid gives better performance than CLPHP using pure water, because silver nanofluid increases the heat flux by more than 10%. N. Bhuwakietkumjohn*et al.* [4] in 2010 investigate the internal flow patterns and heat transfer characteristics of a closed-loop oscillating heat-pipe with check valves (CLOHP/CV).Ethanol and a silver nano-ethanol mixture were used as working fluids with a filling ratio of 50%. Result shows that, when the velocity of slug increases, the length of vapor slug rapidly decreases and the heat flux rapidly increases. In addition, the silver nano-ethanol mixture gave higher heat flux than the ordinary ethanol. Qu*et al.*[5] in 2010, performed an experiment using Al2O3nanofluid of 56 nm to investigate The effects of filling ratios, mass fractions of alumina particles, and power inputs on the total thermal resistance of the OHP. Result shows that, the maximal thermal resistance was decreased by 0.14 °C/W (or 32.5%) when the power input was 58.8Watt 70% filling ratio and 0.9% mass fraction. P.Gunnasegaran et al. [6] in 2104 work on impact of nanopartical concentration of Al2O3 on heat transfer characteristics of Loop heat pipe (LHP). 0% to 3% mass concentration is used. It is found that thermal resistance of LHP decreases when nanoparticles mass concentration of Al2O3-H2O nanofluid increases

Various nanofluids at different operating condition give different results. Until now, may nanofluids were used many researches having good thermal conductivity. But thermicfluid not used until now. No data is available related to thermicfluid(HP-hytherm-500) as working fluid in CLPHP. In addition double turn loop PHP also is not much used. Thus, in present work HP-Hytherm-500 fluid in double turn loop PHP is used to investigate the effect of thermicfluid on thermal resistance. Better heat transfer fluid as compared to any mineral oil based thermic fluid like Hytherm 500, Hytherm 600, Servotherm medium, Servotherm Special, Shell Thermia B etc. due to its special chemistry. 2 to 3 times higher thermal stability 2 to 3 times higher life Very very low (nil) carbonaceous depositions. It has lower viscosity and Lower power consumption of circulating pump High co efficient of heat transfer *means* Higher Thermal Efficiency *means* Lower Fuel Consumption. Generally it has been observed that industries are getting very high proportionate of fake lubricants at their end. In our case since we are directly supplying to industries there is no possibility of getting fake lubricantsIt can be also used for top up purpose in the system already containing any make of mineral based thermic fluid. It is better than any other synthetic thermic fluids. And can be used for top up purpose containing any similar synthetic thermic fluid. Indirect closed heat transfer systems up to 320°C. For best life it should be used at or below 300° C for continuous operation.

Benefits Of HP-Hytherm-500:

As compared to other mineral based thermic fluid,

- High thermal stability.
- High oxidation stability
- Very low carbon deposits.
- Long Life.
- It has lower Viscosity as

Properties of Thermic Fluid

Base Oil	**Hytherm-500**
Appearance	Bright Yellow liquid
Max. Temperature	320˚ C / 608˚ F
Kin. Vis. @40˚C	19 - 23 cSt
Specific Gravity@15˚C	0.86 ± 0.005
Flash Point (COC)	200 - 240˚ C
Pour point	(- 60) - (- 40) ˚C
Moisture content	50 - 100 ppm
Total Acid No.	0.005-0.01 mg KOH/g
Specific Heat @ 260 ^{O}C Kcal/Kg ^{O}C	0.731

2. Experimentation

II. CONSTRUCTION

The basic structure of typical pulsating heat pipe (PHP) is small, light in weight, simple in structure, high effective thermal conductivity and highly efficient. A PHP consists of capillary tubes with many U turns and they are categorized in following manner:-

- Open loop system
- Closed loop system and
- Closed loop pulsating heat pipe (CLPHP) with additional flow control check valves

The pulsating heat pipe has two main region i.e. evaporator and condenser. The evaporator is the heating section and condenser is the cooling section, which is separated by adiabatic region. Adiabatic section is optional and its presence is depends on the location of evaporator and condenser. All copper tubeshave 4.0 mm O.D. and 3.0 mm I.D. Two smaller copper tubes (4 mm O.D., 3 mm I.D.) has been brazed on the main tube of the condenser section in order to connect the vacuum/filling valve and pressure indicator

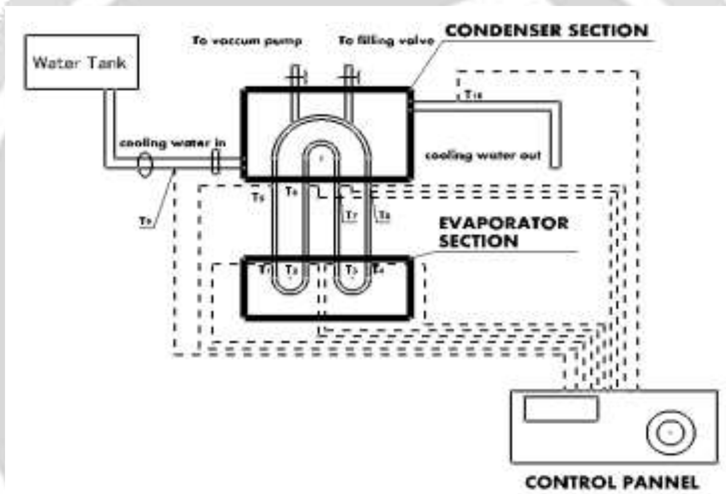

Fig1. Schematic of Experimental setup

Evaporator section

In the evaporator section oil bath is used. Oil bath is made of aluminum sheet having dimension 75 60_15 mm3. It is heated with press coil of 600 Watt. This whole assembly is insulated with glass wool .

Adiabatic section

The adiabatic zone is made of four straight copper tubes as shown in Figure The straight tubes in the adiabatic section are covered with insulated material so that there is no contact with the environment. All copper tubes have 4.0 mm O.D. and 3.0 mm I.D. Two copper tubes (4.0 mm O.D., 3.0 mm I.D.) has been brazed on the main tube of the condenser section in order to connect the vacuum/filling valve and pressure indicator.

Condenser section

The condenser section was cooled by (coolant) normal water with maintained flow 50ml/min and inlet and outlet temperature measured. The copper tubes in the condenser section are embedded into a shell made of transparent acrylic plates .Four holes allow the coppertube branches to come out the shell and connect with the adiabatic section The heat input is measured in terms of electrical power supply through Dimmerstat (2Amp). The voltmeter (0 – 250V) and Ammeter (0 – 2 A) was connected in line for the input power measurement. The output of the experimental setup is calculated in terms of thermal resistance, for that, the various temperatures were recorded at different location by means of thermocouple wires (Chromel-Alumel, K-type, accuracy ± 0.20C). The position of the thermocouple wires are shown in fig. With the help of knob ten different temperatures can be noted. Pure water and Thermicfluid are selected as working fluids for experimentation.

2.2 Experimental Procedure

1. The first step is to create a vacuum inside the tube. In order to create vacuum inside the PHP, a reciprocating vacuum pump is connected to the filling valve.
2. Thereafter the device is fill with the desired working fluids and closed the valve.
3. Water was supplied from storage tank to the condenser section. Wait till the condenser tank is completely filled. Then flow rate was measured with beaker and stop watch.
4. Switch on the control panel and set appropriate power supply for oil bath with the help of dimmerstat
5. Oil in oil bath starts heating. This in turn heats the evaporator section.
6. Provide a constant heat input to the oil bath up to steady state reached and temperature at different points of CLPHP note down between 10 minute intervals.
7. The heat input is increased with step of 10 W input powers after steady state reached. After a quasi-steady state was reached, note down the readings.
8. At steady state from the inlet - outlet temperature and mass flow rate of the coolant, the heat transfer could be calculated. Above procedure was repeated for the different working fluids.

3. Data Reduction

The heat output from condenser is calculated from the following equation:
$Qout=mCp\ (Tout-Tin)$
Where, m – mass flow rate
Cp - specific heat at constant pressure
Tout - outlet temperature of cooling water and
Tin - inlet temperature of cooling water
The total thermal resistance is obtained from the following equation:
$Rth = (Te - Tc)/\ Qin$
Where, Rth - Thermal resistance
Te - Average temperature of evaporator
Tc - Average temperature of condenser
Qin – Heat input (V×I)

4. Results and Discussion

From the experimental analysis, graphs are plotted showing effect of Thermicfluid and pure water on average evaporator temperature, average condenser temperature, evaporator-condenser temperature difference and thermal resistance with different heat inputs as shown in figure 2, 3,4 and 5 respectively.With increasing heat input to the device, the evaporator temperature rises resulting in a greater density gradient in the tubes. Simultaneously the liquid viscosity also drops diminishing the wall friction and it proportional to heat input therefore thermal resistance decrease with increase in heat input for all working fluids.
Figure 2 shows the change in average evaporator temperature of PHP for various heat inputs as well as Thermicfluids and pure water.. It is due to the higher saturation temperature and high specific heat of water. As concentration of Thermicfluid increases saturation temperature and specific heat of water decreases tends to decrease in evaporator temperature. Minimum evaporator temp is obtained for thermicfluid.

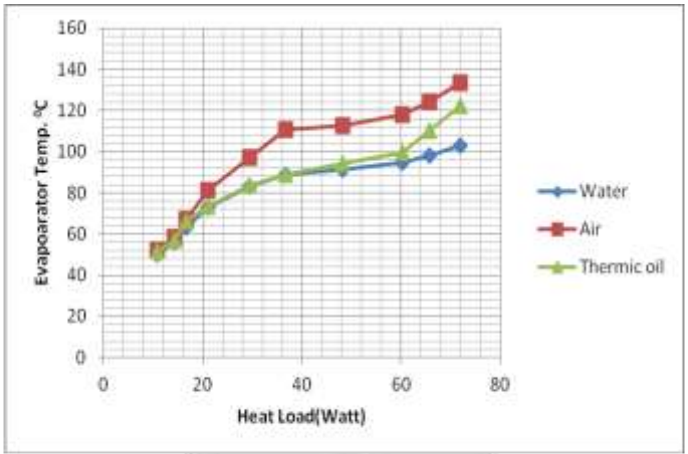

Figure 2: Average evaporator temperature of Water/air/ThermicFluid

Figure 3 shows the change in average condenser temperature of PHP for various heat inputs as well as Thermicfluids,Air, and pure water. Average condenser temperature increases with increasing heat load and increase as increase during Thermicfluid. Because thermal conductivity of fluid is increases due to addition of HP-Hytherm-500, hence more heat is transported towards condenser section.

Figure 4 shows the change in evaporator-condenser temperature difference for various heat inputs as well asThermicfluids and pure water and air. Evaporator-condenser temperature difference increases with increasing heat load and increases with Thermicfluid as compair to air and water. Minimum value is found for water and middlevalue is found for thermicfluid.

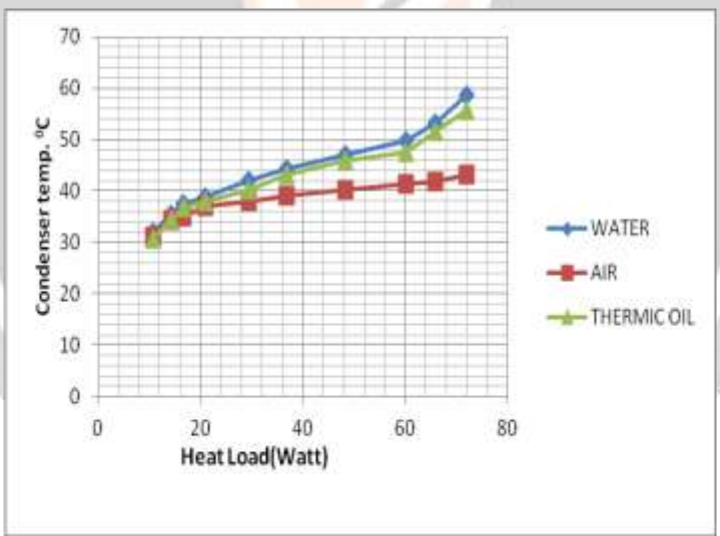

Figure 3: Average condenser temperature of Water/air/ThermicFluid

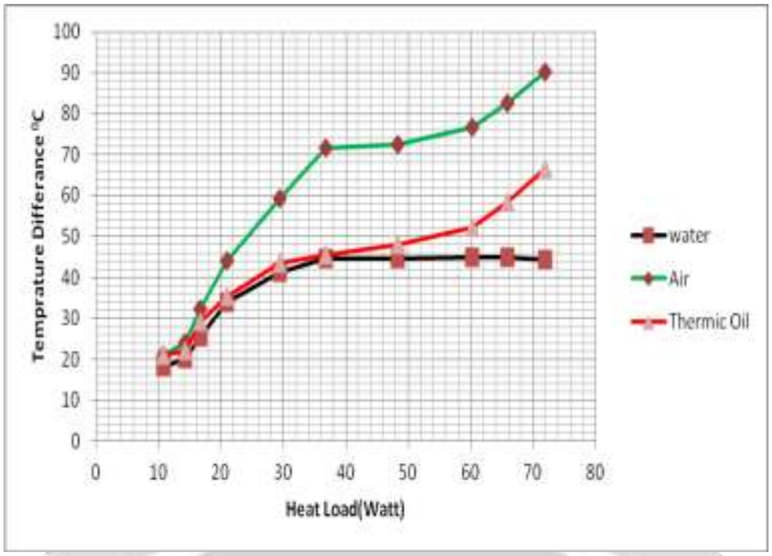

Figure 4: Average temperature differance of Water/air/ThermicFluid

Figure 5 shows the change in thermal resistance of PHP for various heat inputs as well as thermicfluids and pure water and air. Thermal resistance decreases with increasing heat load . This increases thermal conductivity of base fluid. Reason for enhancement of thermal conductivity is micro-convection between liquid molecules.

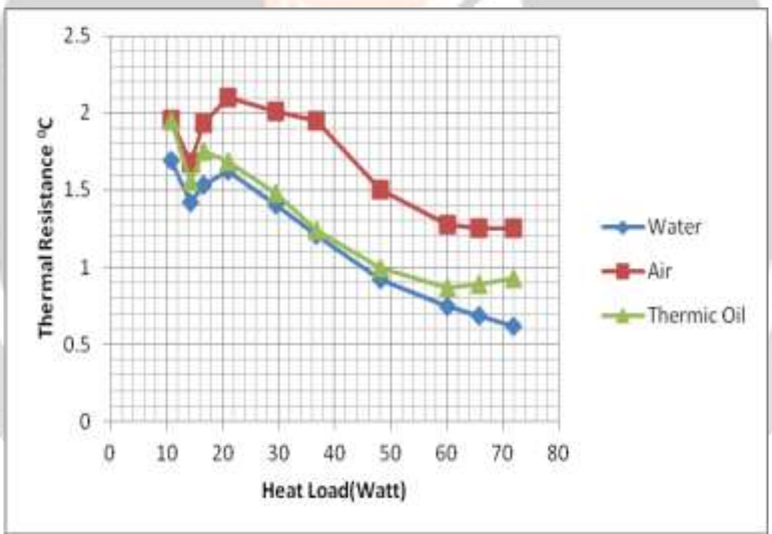

Figure 5: Average Thermal resistance of Water/air/ThermicFluid

5.Conclusion

From these experimental studies, following conclusions are drawn:

- Thermal resistance decreases with increase heat input of PHP for both pure water,air and thermicfluids. .
- Thermal performance of PHP strongly depends on thermo physical properties of working fluids.
- HP-Hytherm-500 fluid PHP gives the good thermal performance than air PHP.

Nomenclature

Q- Heating power input (W)
FR- filling ratio *R* thermal resistance (0C/W)
T- temperature (0C)
Te- temperature of evaporation section (0C)

Tc- temperature of evaporation section (0C)
Ts- temperature of boiling point (oC)
Tc- temperature of condenser section (0C)
C heat capacity (J/m3·K)
Cp- specific heat (KJ/kg·K)
Hfg- latent heat of evaporation (KJ/kg)
t- time (s)
Greek Symbol
ρ - density (kg/m3)
σ- surface tension(N/m)
υ- dynamic viscosity (Pa·s)
λ- thermal conductivity(W/m0C)
*Subscripts l*liquid *v*vapor *sat*saturation state *e*evaporation section c condensation section

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