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RESEARCH ARTICLE

EXPERIMENTAL STUDY OF TWO PHASE CLOSED THERMO SYPHON CHARGED WITH ETHANOL AND AL2O3 NANO FLUID

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ABSTRACT

This paper represents the experimental investigation of closed thermo-syphon for checking the thermal performance. The thermo-syphon selected for this application is 25.4 mm inner diameter, 1mm thick and 500 mm length designed to dissipate 20 to 60 watt. The working fluid used is ethanol and the second trial was done by addition of suspended particles of 10 nm aluminium powder in solution of ethanol 10 % by volume. The four factors were studied; the effect of heat load, the effect of working fluid types, the effects of flow rates of cooling water and the inclination with vertical. It is observed that heat transfer increases as heat load increases, heat transfer increases by using Al_2O_3 Nano fluid than ethanol. As flow rates of cooling water decreases the heat transfer increases. The maximum heat transfer takes place at vertical orientation (i.e.90^0) and also as the inclination decreases the heat transfer also decreases.

INTRODUCTION

Thermosyphons used in here are two phase heat transfer device. Heat transfer can be occurring by condensation and evaporation process. The heat transferred by this device is normally several orders of magnitude greater than pure conduction through solid metal. They are used in many applications including but not limited to passive road anti-freezing, ground temperature control, baking ovens, heat exchangers in waste heat recovery applications, water heaters and solar energy systems and are showing somepromise in high-performance electronics thermal management for situations which are orientation specific.

A cross section of a closed two-phase thermo syphon is illustrated in Fig.1 the thermo syphon consists of an evacuated sealed tube that contains a small amount of liquid. The heat applied at the evaporator section is conducted across the pipe wall causing the liquid in the thermo syphon to boil in the liquid pool region and evaporate in the liquid film region. In this way the working fluid absorbs the applied heat load converting it to latent heat. The vapours in the evaporator zone are at a higher pressure than in the condenser section causing the vapour to flow upward. In the cooler condenser region the vapours condenses thus releasing the latent heat that was absorbed in the evaporator section. The heat then conducts across the thin liquid film and exits the thermo syphon through the tube wall and into the external environment. Within the tube, the flow circuit is completed by the liquid being forced by gravity back to the evaporator section in the form of a thin liquid film. As the thermo syphon relies on gravity to pump the liquid back to the evaporator section, it cannot operate at inclinations close to the horizontal position.

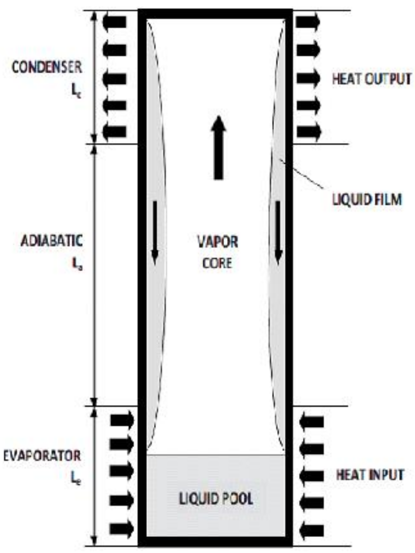

Fig.1 operating principle of two phase closed thermo syphon

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S.H. Noie, S. ZeinaliHeris, M. Kahani and S.M. Nowee [1]Presents Nano fluids of aqueous Al_2O_3 nanoparticles suspensions were prepared in various volume concentration of 1–3% and used in a TPCT as working media. Experimental results showed that for different input powers, the efficiency of the TPCT increases up to 14.7% when Al_2O_3/water Nano fluid was used instead of pure water. Fluids with nanoparticles (particles smaller than 100 nm) suspended in them are called Nano fluids that they have a great potential in heat transfer enhancement.

PreechaKhantikomoland WasanSrimuang [2] Presents an experimental investigation of the heat transfer characteristics of a CEOFHP. The effects of four factors were examined: types of working fluids, heat loads, and flow rates of cooling water and total lengths. R123, ethanol and water with filling ratio of 50% of the total internal volume were used for working fluids. Three total lengths of the CEOFHP: 150, 300 and 450 mm were performed in same evaporator length. The heat load was varies in the range of 5-15 kW/m^2. The results showed that the maximum heat flux of 14.5 kW/m^2 occurred at the following conditions: R123 as working fluid with the total length of 150 mm and heat load of 15 kW/m^2. The increasing levels of heat flux are water, ethanol and R123 respectively. The heat flux increases with heat loads. The flow rate of cooling water had a significant effect on heat flux. The heat flux decreases with the increasing in the total length.

Gabriela Huminic and Angel Huminic [3]investigated the heat transfer characteristics of two-phase closed thermosyphon (TPCT) with iron oxide-Nano fluids are presented. The TPCT is fabricated from the copper tube with the outer diameter and length of 15mm, 2000 mm, respectively. The TPCT with the de-ionic water and Nano fluids (water and nanoparticles) are tested. Effects of TPCT inclination angle, operating temperature and nanoparticles concentration levels on the heat transfer characteristics of TPCT are considered. The nanoparticles have a significant effect on the enhancement of heat transfer characteristics of TPCT.

W. Srimuang, S. Rittidechand and B. Bubphachot [4] investigated on the heat transfer characteristics of a vertical flat thermosyphon(VFT). Several tests were performed to assess the effects of filling ratios, hydraulic radius, working fluid, and aspectratio (Le/4HR) at a vertical orientation on the heat transfer characteristics of the VFT. It was found that the filling ratioand hydraulic radius affect heat flux, while the aspect ratios of VFT increased, the heat flux decreased. In addition, theworking fluid changed from water and ethanol to R123 as the heat flux increases.

Data reduction

In this study TPCT was insulated completely.The absence of any heat loss from evaporator, adiabatic and condenser sections of the TPCT to the surroundings. Therefore amount of heat input at the evaporator section is equal to the amount of heat rejected at the condenser section. The heat input that transferred to the evaporator section was calculated from the following relation

$$Q_{(in)} = \frac{V^2}{R} \quad (1)$$

The heat flux that transferred to the evaporator section was calculated from the following relation

$$q_{(In)} = \frac{V^2}{R \times A_{se}} \quad (2)$$

Where V is the voltage supplied to evaporator section, R is resistance of coil,A_{se} is the surface area of evaporator section.

The heat out removed from the condenser section was obtained by using the equation as follows

$$Q_{(out)} = \dot{m} \times C_p \times (T_{out} - T_{in}) \quad (3)$$

The heat flux removed from the condenser section was obtained by using the equation as follows

$$q_{(Out)} = \frac{\dot{m} \times C_p \times (T_{out} - T_{in})}{A_{sc}} \quad (4)$$

Where ṁ is the mass flow rate of cooling water,C_p is constant pressure specific heat of water, T_{in} is the water temperature of the inlet cooling jacket and T_{out} is the water temperature of the outlet cooling jacket,A_{sc} is the surface area of condenser section.

The efficiency of TPCT can be expressed as a ratio of the output heat by condensation to the inlet heat by evaporation

$$\eta = \frac{Q_{out}}{Q_{in}} \quad (5)$$

Experimental Set up

Aluminum oxide (Al_2O_3) nanoparticles with physical characteristic presented in Table 1 were used in this study.

Table 1 Physical Characteristic of Al_2O_3 nanoparticle used in this experiment

Particle	Average Diameter (nm)	Superficial Density (Kg/m^3)	Actual Density (Kg/m^3)	C_p (J/Kg K)	K (W/m K)
Al_2O_3	10	160-400	3700	880	46

The schematic diagram of experimental set up is illustrated in Fig. 2 The test rig consist of TPCT made of copper tube with internal diameter 25.4 mm, 1mm thickness and 500 mm in length. The evaporator, adiabatic and condenser sections had 125mm,125mm and 250 mm length respectively.Band heater used for heating the evaporator section, ammeter used to measure voltage and resistance. Digital temperature indicator was used to measure temperature along the thermo syphon tube; coolant tank was used to supply the cold water to evaporator section. Beaker was used to measure mass flow rate of outlet of coolant by using stop watch.

The power supplied to evaporator section can be varied by varying the voltage supplied to the electrical heating element and can be controlled by using ammeter. The evaporator, condenser and adiabatic sections were wrapped with insulation (Asbestos thread of 6 mm thick) to prevent heat loss from these sections. The coolant tank was used to pump the cooling water in to the condenser section. Inlet temperature of cooling water kept constant and outlet temperature was varied and these temperatures were measured by using thermocouples type K and recorded by digital temperature indicator. There were 10 thermocouples type K mounted on the surface of thermosyphon tube starting from evaporator section which can measure the surface temperature of tube.

Experimental procedures began after charging the working fluid in the TPCT and supplied the cooling water to the condenser section. The electrical heater was turned on and time was allowed for the operating temperature to reach a steady state. Then the Temperatures (T_1-T_{10} points) were recorded.

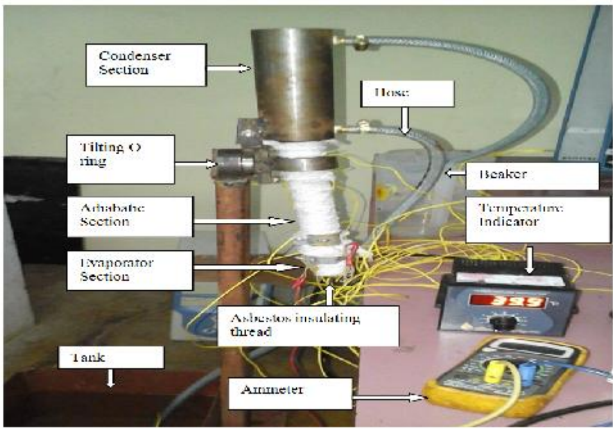

Figure 2 Experimental set up

RESULT AND DISCUSSION

The effect of heat loads

The TPCT with total length of 500 mm was used for determining the effect of heat loads on thermal performance. The tests were conducted at different heat loads and working fluids. Fig.3 shows the relationship between heat loads that was supplied to evaporator section and heat flux of TPCT.

The results shows that the heat loads have significant influence on the heat flux. As heat load increases the heat flux also increases, if the heat load changed from 2, 4 to 6 Kw/m^2, the heat flux increased from 0.75, 1.6 to 2.5 Kw/m^2 respectively in case of ethanol-Al_2O_3 Nano fluid. Thus it can be concluded that the heat flux increases linearly with the heat load.

Fig 4 shows the relationship between input power and efficiency for different working fluids. The result shows that as input power increases the efficiency also increases. The maximum efficiency was observed 86.44% at 60 w in case of ethanol-Al_2O_3 Nano fluid. It can be concluded that the efficiency increases linearly with the heat load.

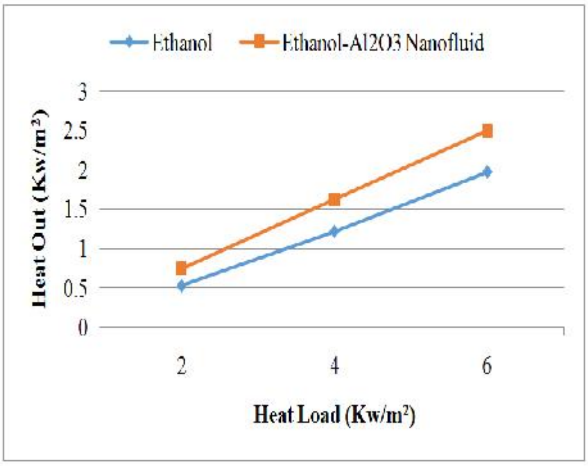

Fig.3 Relationship between heat loads and heat flux for different working fluids.

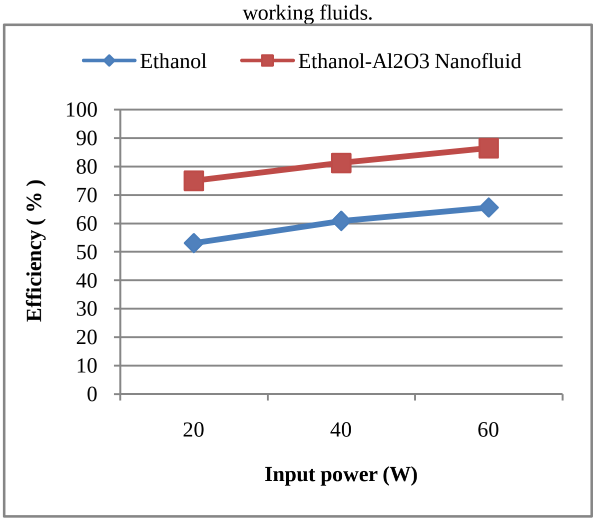

Fig.4 Relationship between input power and efficiency for different working fluids.

The effect of working fluids types

For checking the effect of working fluids types test was conducted at constant parameter: total length of 500 mm, heat load of 2Kw/m^2 and mass flow rate of 0.0014925 Kg/s. The temperature distribution along the surface of TPCT was used to explain the effect of working fluids on thermal performance. Fig 5 shows temperature distribution along the surface of the TPCT with different working fluids.

The experimental results shows that the temperature of each working fluid increases in evaporator section at one point it reaches maximum and after this point, the temperatures decreased toward the adiabatic section and reached its minimum value at the bottom part of condenser section. If the working fluid was changed from ethanol to ethanol-Al_2O_3 Nano fluid, it was found that the temperature at surface increased. The maximum temperatures obtained by ethanol and ethanol- Al2O3 Nano fluid were 42.8^{0}C and 46.6^{0}C respectively. From above it can be concluded that the heat transfer increases as working fluid changes from ethanol to ethanol- Al2O3 Nano fluid.

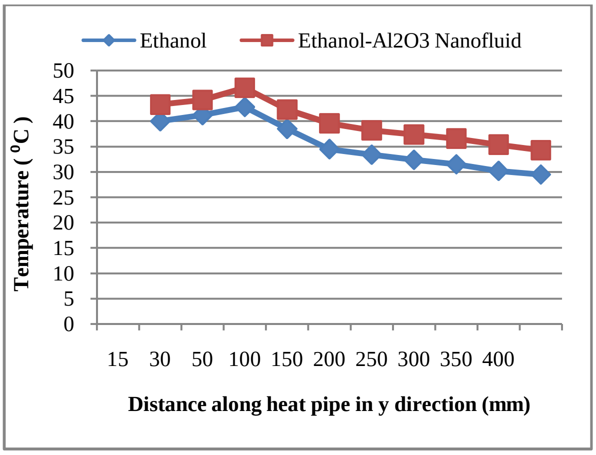

Fig.5 Temperature distribution along the surface of the TPCT with different working fluids for
Total length = 500 mm, heat load = 2 Kw/m^2 and mass flow rate = 0.0014925 Kg/s

The effect of flow rates of cooling water

For checking the effect of flow rates of cooling water test was conducted with constant parameter, total length of 500 mm, heat load of 2 Kw/m^2 and working fluid of ethanol. Temperature distribution along the surface of TPCT with different mass flow rate of cooling water were plotted in Fig.6 For instance, at the heat loads of 2kw/m^2, if the mass flow rate changes from 0.0014925 kg/s, 0.002439 kg/s to 0.005 kg/s, the maximum temperature decreases from 42.8 ^{0}C,38.1^{0}C to 34.2^{0}C respectively. Thus it can be concluded that as mass flow rate of cooling water decreases the heat transfer increases.

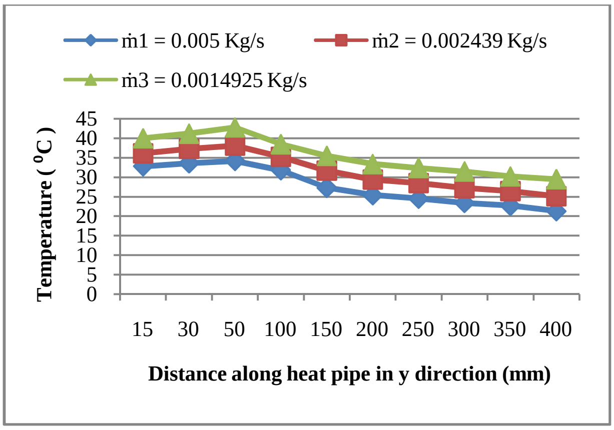

Fig.6 Temperature distribution along the surface of the TPCT with different working fluids for
Total length = 500 mm, heat load = 2 Kw/m^2.

The Effect of inclination with vertical

For checking the effect of inclination with vertical tests were conducted with constant parameter of total length of 500 mm, heat load of 2 Kw/m^2, mass flow rate of 0.0014925 Kg/s and working fluid of ethanol. The temperature distribution along the surface of TPCT with different angles were plotted in Fig.7 At instant of heat load of 2 Kw/m^2 if the angle changes from 90^0, 80^0, 70^0 and 60^0 to 50^0 the maximum temperatures decreases from 42.8, 41.3, 39.2 and 36.7 to 33.4. Thus it can be concluded that the maximum heat transfer occurred at vertical orientation and as angle decreases the heat transfer also decreases.

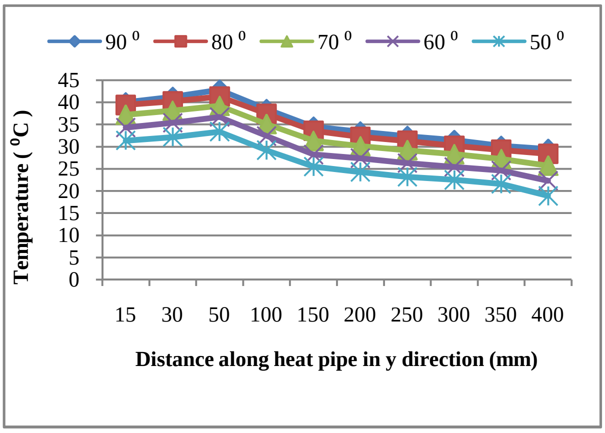

Fig.7 Temperature distribution along the surface of the TPCT with different working fluids for
Total length = 500 mm, heat load = 2 Kw/m^2 and mass flow rate = 0.0014925 Kg/s

CONCLUSIONS

1. The use of ethanol-Al_2O_3 Nano fluid as the working fluid gives better transfer of heat flux and efficiency as compare to ethanol.
2. The heat input had effect on the heat flux of the TPCT. The heat flux increased linearly with the heat load
3. The mass flow rate of cooling water also affect the thermal performance of the TPCT. The heat transfer increases as mass flow rate of cooling water decreases.
4. Inclination thermo syphon tube had significant effect on the thermal performance of the TPCT. The maximum heat transfer occurred at vertical orientation and as angle decreases the heat transfer also decreases.

Nomenclature

A	Total heat transfer area (m^2)
D	Diameter of thermo syphon tube (mm)
C	Specific heat (kJ/Kg ^{0}C)
L	Length of tube (mm)
ṁ	Mass flow rate (kg/s)
Q	Heat transfer rate (kW)
q	Heat flux (kW/m^2)
T	Temperature (^{0}C)
R	Resistance (ohm)
V	Voltage (V)

Subscripts

a	Adiabatic
e	Evaporator
c	Condenser
in	Input
out	Output
s	Surface area
p	Pressure constant

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