Thermal Performances Of Two Phase Closed Thermosyphon With Different Inclination Angles

Shrikant V. Pawar, Abhimanyu K. Chandgude,

Abstract: Thermal performance of a two phase closed thermosyphon (TPCT) is analyze for different inclination angles. TPCT is circular pipe and filled with acetone. A Simple circular pipe made up of aluminum and it tested for heat input of 50W to 300W at a different inclination angle 30, 40, 50, 60, 90. TPCT used with 30% filling ratio. Thermal efficiency of TPCT and the mean temperature difference between evaporator and condenser (Te-Tc) determined and plotted with 30% of filling ratio. Whole analysis shows that inclination has no significant effect thermal performance of TPCT.

Index Terms: Acetone, Aluminum, Angle, Condenser, Evaporator, Inclination, Thermocouple.

1 INTRODUCTION

Thermosyphon is a heat transfer device. The basic principle of heat transfer is phase change mechanism. It is two phase heat transfer device. It is a passive device. Heat is transfer by the process of evaporation and condensation. It is closed loop system. Heat is transfer by natural convection and buoyant forces. Technology is developing day by day. High performance devices with advance technology are more compact in structure and generate more heat. So for stability of a system, it is necessary to dissipate heat. Therefore, it is need to develop high performance TPCT. Construction of TPCT must be compact and light in weight and have a good thermal conductivity. All these requirements are fulfill by aluminum, so use of aluminum is intensively increase nowadays. Telecommunications, aerospace and electronic cooling are some application of TPCT.

Surface modification is an one way to enhance the nucleate boiling and heat transfer coefficient for an inner surface of TPCT. Some studies had been done in recent years. A. Brusly Solomon analyzes comparative performance of anodized and non-anodized TPCT. The anodized and non-anodized TPCT filled a blend of refrigerant R600a and R290a as working fluid [1]. K.s. Ong conducted experiment with water as working fluid. The thermal performance of TPCT was observed to be constant with respect to inclination and filling ratio [2]. H. Mirshahi analyze the results of filling ratio, heat flux, extra volume on TPCT. The whole analysis shows that trapped non condensable gases occupied a portion of a condenser and deactivate it [3]. B.jiao analyze the performance of vertical TPCT with different filling ratio. This model developed by considering of flow pattern and transition as per distribution of liquid film and liquid pool. TPCT is filled with nitrogen as working fluid [4]. Pure N_2 -Ar binary mixture used by Z.Q. long as working fluid in cryogenic thermosyphon. It observed that N_2 Ar mixture as working fluid can broaden the working temperature range of cryogenic thermosyphon. It can be performed in the temperature range of 64K-150K [5]. A. Ordar-Flores used methanol and acetone as working fluid in an indirect two phase water heating solar system. Methanol and acetone comparatively have more latent heat of vaporization than other refrigerant like R134a [6]. S.H. Noir investigated TPCT for input heat transfer rates, filling ratio (30%<filling ratio <90%) and evaporator height (aspect ratio) [7]. In past few years research had been made on Nano fluid as working fluid to enhance the thermal performance of TPCT. Different type of Nano fluids such as Al_2O_3/water, CuO/water are used in TPCT. S.H. Noir used Nano fluid of aqueous Al_2O_3 with different volume concentration of 1-3%. This analysis shows that for various heat input thermal efficiency of TPCT increase up to 14.7% compare with pure water as working fluid [7]. Hamidreza Shabgard analyze closed thermosyphon under various working fluid and filling ratio. Filling ratio can be defined as ratio of volume of working fluid in TPCT pipe to the volume of TPCT pipe. In this analysis finite volume model is develop and validate by using experimental data. The model is able to predict the optimum filling ratio [9]. Mehmet Esen analyzes the effect of different refrigerant on the performance of TPCT solar collector. R-134a, R407C and R410A refrigerant filled in TPCT and tested under various load condition [12]. [1, 8, 11] shows that thermal performance of TPCT is improve with surface modification when acetone and refrigerant as working fluid. From literature survey, it found that research work is focus on working fluid, surface modification and filling ratio. So it is clear that the effect of inclination on TPCT performance is one of the most ignore part. So, this paper has been focused on performance of TPCT with different inclination angle. The TPCT pipe has circular cross section. It filled with acetone. TPCT is analyze with six angular position with six different heat input. In whole experiment 30% filling ratio is used.

2 EXPERIMENTAL SETUP

TPCT is 350 mm long and inner diameter is 17.5mm and wall thickness is 1mm. TPCT is filled with acetone as working fluid. TPCT is made up of aluminum. TPCT pipe is divide in three section adiabatic, evaporator, and condenser having length of 100mm, 100mm, and 150mm respectively. Main components of testing unit are Pump, Control panel, Thermocouple, Rota meter, tilting bracket, heating coil. TPCT pipe placed in two aluminum block at two end called as evaporator block and condenser block. Middle section made up of glass wool is called as adiabatic section. Evaporator is 100 mm block with slot at center for TPCT. Four holes drilled for heating coils around TPCT slot. Three thermocouple place at equidistance to measure a surface temperature of TPCT. Similar block is use for condenser with two opening for water inlet and outlet. Water is use to carry the heat reject by TPCT pipe. Three thermocouple are place over condenser section. Adiabatic

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section made up of glass wool so that no heat transfer should take place. Three number of thermocouple are place over there. Two number of thermocouple are used for measuring the temperature of inlet (T11) and outlet temperature (T12). One thermocouple measure atmosphere temperature (T10). Rota meter is use to adjust flow of cooling water (LPH). Control unit is use for vary the heat input. Tilting bracket is used to vary the angle. It has nine division with step of 10^0 (0^0-90^0). Heating coil is insert in evaporator block. Power given heating coil in watt is called input heat. Acetone is use as working fluid [6]. Most of working fluid use has lower latent heat of vaporization and lower boiling point at atmospheric pressure. But in case of acetone latent heat of vaporization and boiling point both are high as compare to refrigerant like R134a. Also acetone shows good compatibility with aluminum metal [8]. Due to lower amount of working fluid in pipe dry out situation may be arise. So to deal with this phenomenon 30/% of filling ratio is use in TPCT. In this experiment, six angular position are analyze. For each angular position six different heat input are given.

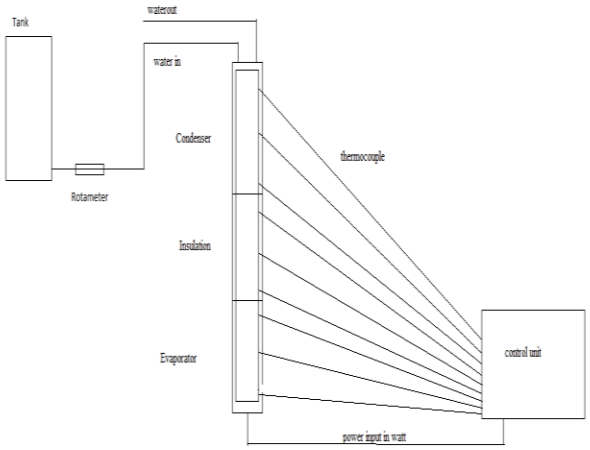

***Fig.** 1. Schematic view of Experimental Setup and position of thermocouple*

3. RESULT AND CALCULATION

Heat output can be calculated as,

$$Q_{out} = mc\ (T12-T11)$$

Efficiency of TPCT can be calculated as,

$$n = Q_{out}/Q_{in}$$

Heat input can be calculated as,

$$Q_{in} = VI$$

Overall thermal resistances is proportional to,

$$R_{overall}\ \alpha\ (Te-Tc)$$

Te: - Evaporator temperature
Tc: - Condenser temperature
W: - Watt
LPH: - Liter per hour
m :- mass flow rate of water, 0.007Kg/s
c :- specific heat of water, 4.187KJ/kgK
V. :- Voltage in volt
I. :-. Current in Ampere
T11:- Water inlet temperature
T12:- Water outlet temperature

Fig.2 (a,b,c,d,e) shows a plot of temperature at different heat input for different angular position. The continuous straight line in the evaporator section which mean that the temperature of evaporator (T1, T2, and T3) is nearly constant. Phase change process is take place at constant temperature (that is from liquid to vapour). Similar trend is observe in condenser section (T7, T8, and T9). For the adiabatic section continuous downward straight line is observe. It shows that temperature of adiabatic section (T4, T5, and T6) is continuously decrease. This because of vapour coming from evaporator and rejects some of heat to the liquid coming from condenser. While conducting experiment, initially (50W, 90^0) temperature is increases steadily to some degree Celsius, then it start decreasing slowly, and after some time it achieve steady state. Initially heat is absorb by working fluid slowly and liquid is start converting into vapour. During this period temperature is increases. Now vapour reaches to condenser where it convert into liquid by rejecting heat to water. This liquid come back to evaporator and loop is complete. This liquid decreases temperature of evaporator by few degree Celsius. This phenomenon is observe every time only at starting of TPCT. The maximum temperature achieve in this study at evaporator and condenser section is 90.5^0C and 42.6^0C (300W and 90^0). Fig.3 shows plot of (Te-Tc) vs power input at different angular inclination. The Maximum temperature difference achieve in this study is 45.4 degree Celsius. The percentage change in temperature difference from 30^0 to 90^0 is 6.8% at 300W. Performance of TPCT is nearly constant irrespective of its inclination. Fig. 4 shows that at higher heat input (200,250,300W) efficiency of TPCT is increases for all angular position. Graph of efficiency vs heat input for different angular position are overlaps expect at 30^0. At 30^0 angle for higher heat input there is 1-3% lower efficiency is observe.

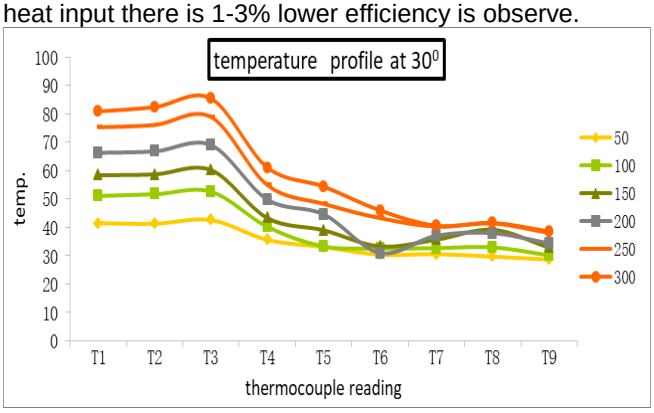

Fig.2 (a)

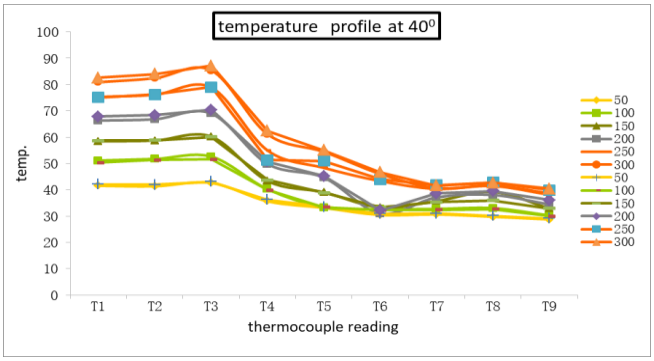

Fig.2 (b)

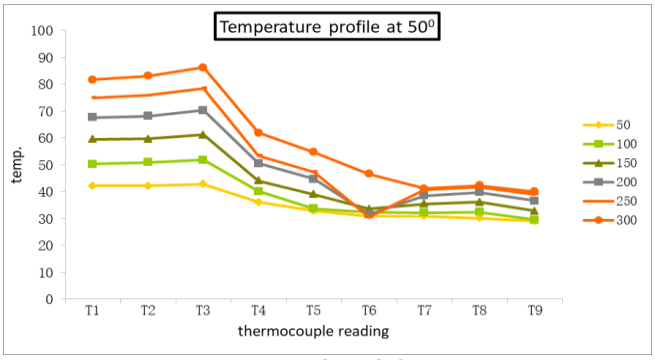

Fig.2 (C)

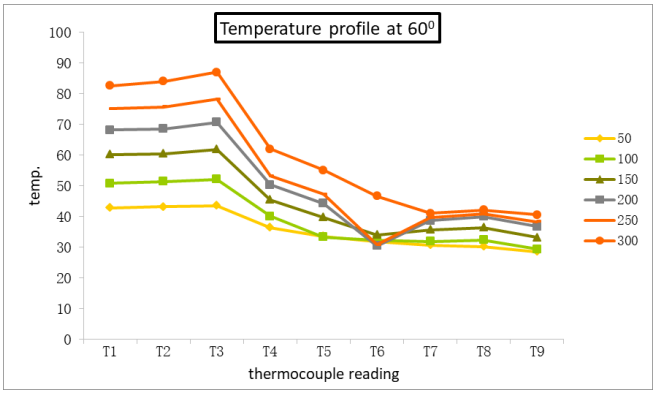

Fig. 2 (d)

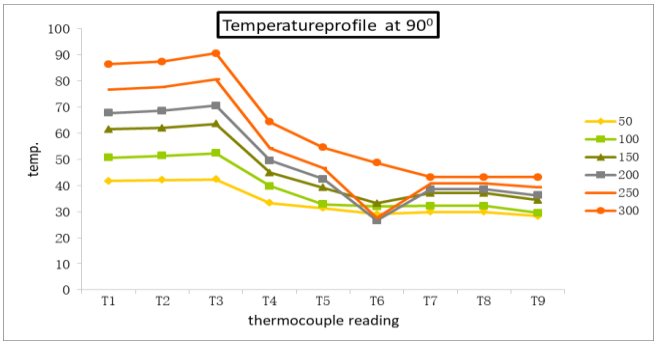

Fig.2 (e)

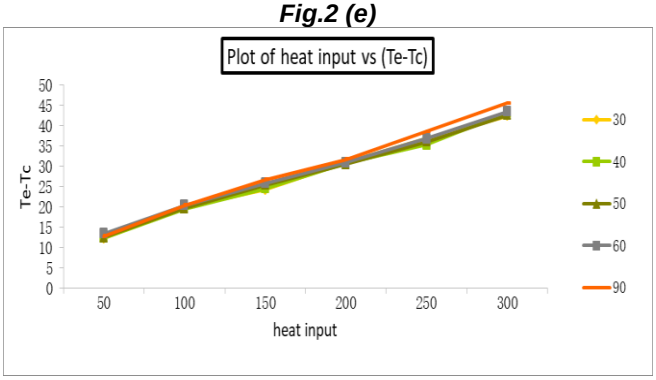

Fig.3

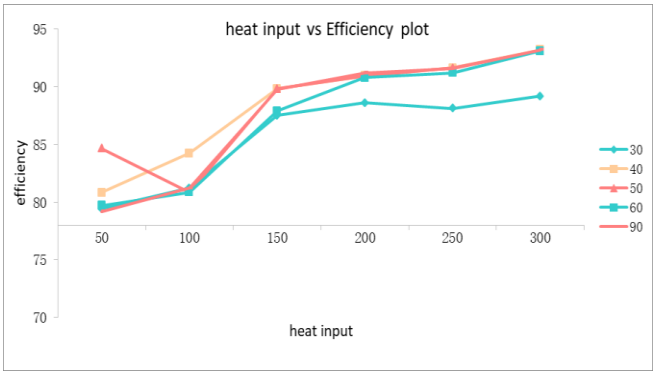

Fig.4

4 CONCLUSION

Thermal performances of TPCT is analyze in this paper. The Performance of TPCT is evaluate with different angular position at various heat input. TPCT is filled with acetone. Filling ratio is 30%. Temperature profile at different inclination is following same pattern. The maximum temperature achieve in whole study in evaporator and condenser section is 90.50C and 42.6^{0}C (300W and 90^0). Adiabatic section temperature is continuously decreases because vapours of acetone reject heat to liquid acetone coming from condenser section. (Te-Tc) is nearly constant for all angular position and increases with increase in heat input. The percentage deviation in temperature difference from 30^0 to 90^0 is 6.8% at 300W. The Maximum temperature difference achieve in this study is 45.4^{0}C. So inclination has no effect on (Te-Tc). Maximum Efficiency of TPCT is nearly 93% at 300W. Efficiency of TPCT is increase with increase in heat input. There is no significant variation in efficiency for all angular position. A thermal performance of TPCT is remains unchanged for different inclination angles with in the limit of experiment.

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