Performance analysis of aluminium Thermosyphon at Various Inclination

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Abstract- **Electronic Devices, Power plants, etc. have losses in form of heat and to increase their efficiency it is essential to liberate heat from them at high rates. A model is being developed to investigate the performance of two phase close thermosyphon. A aluminium thermosyphon of length 350 mm and internal and external diameters of 17.5 mm and 19.5 mm is used for experiment. The thermosyphon charged with acetone with filling ratio of 30% is investigated. The performance analysis was conducted at inclination angles of 30º, 50º, 70º and 90º. And heat input of 50 W to 250 W was given at evaporator section.**

I. INTRODUCTION

A Two-phase Closed Thermosyphon (TPCT) is a heat transfer device of very high thermal conductance in which fluid circulates. The heat transfer is considered to be affected by many factors, such as working fluid, quantity of the working fluid, inside pipe diameter, pipe length, ratio of cooled surface to heated surface, adiabatic length between heated and cooled sections, heat flux and operating temperature. TPCT are found in many applications: gas turbine-blade cooling, thermal stabilization, air-to-air or gas-to-gas heat exchangers, prevention of icing on a buoy, utilization of hot water and for recovering waste heat in industrial fields. Heat is transferred along the tube by a process of boiling, vapour flow, condensation and condensate return. The vapour travels at high speed to a condensation section, where the heat is rejected during condensation. The condensate is returned by Gravity so the evaporation section must be below the condensation section. No external driving force is required, other than a small temperature difference. Less experimental work is done on aluminium thermosyphon with acetone as a working fluid. In this experiment we have used TPCT made of aluminium and acetone as working fluid with filling ratio of 30%. The mass flow rate of water at condenser section was maintained constant. The performance was investigated at different inclination angles and various

heat input. And the results are plotted on the graph.

II. EXPERIMENT INTRODUCTION

2.1 Experimental Setup

A aluminium TPCT charged with acetone was manufactured for the experiment. Manufacturing of Thermosyphon included following steps :

    i) Material Selection
    ii) Pipe cutting
    iii) Inner surface grinding
    iv) Cleaning of pipe
    v) End cap preparation
    vi) Welding end cap of condenser side
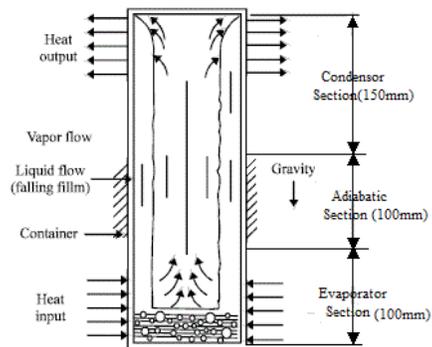   vii) Vacuum creation and charging the pipe.

Fig (a): Sections of TPCT.

The schematic of sections of TPCT is shown in fig (a). The length of TPCT is 350 mm and the internal and external diameters are 17.5 mm and 19.5 mm respectively. The schematic of experimental setup is shown in fig(b). The Evaporator Section consist of 4 cylindrical heater of power 100 W each. At condenser section the condenser block was used with internal water loop. The water pump is connected at inlet of condenser block. The pump takes water from inlet tank and water from outlet of condenser block is sent to outlet tank. To maintain constant mass flow rate a

bypass line is introduced at the outlet of pump. RTD thermocouples were used for measuring temperatures
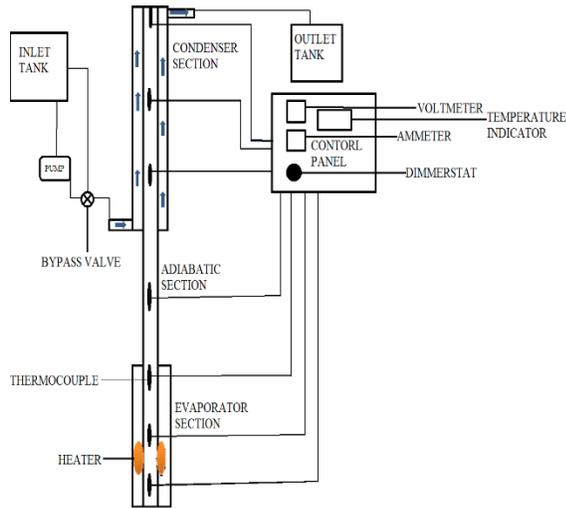
Fig(b): Schematic diagram of experimental setup

at different points on TPCT throughout its length of 350mm as shown in fig(c). Three thermocouples were placed on evaporator section at a distance of 20mm, 60mm and 100mm. Thermocouple at adiabatic section was placed at its midpoint i.e. at 150mm.
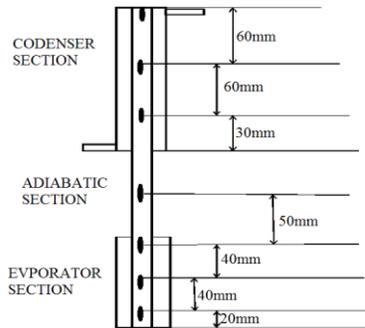
Fig(c): Location of Thermocouples

Three thermocouples were placed on condenser section, at distance of 230mm, 290mm and 350mm. Dimmerstat was used for controlling heat input at evaporator section.

2.2 Experiment Procedure

The experimental procedure is as follow:

Step 1- Start the pump and check for leakages. If found than seal the leakages. And make sure that head is maintained in between inlet and outlet water tank.

Step 2- Set the inclination angle of heat pipe according to the requirement for analysis (30º, 50º, 70º and 90º).

Step 3- Check mass flow rate of cooling water. It can be controlled with the help of bypass valve. (NOTE-maintained constant mass flow rate of water).

Step 4- Give heat input at evaporator section using dimmerstat. And wait till steady state is achieved at evaporator section i.e. constant temp reading at evaporator section. Heat input of 50 W, 100 W, 150 W, 200 W and 250W are given for every angle.

Step 5- Note down the temperature readings.

Step 6- Repeat the above steps for different inclination angles and heat input.

III. RESULTS AND DISCUSSIONS.

The mean evaporator temperature was calculated using reading of 3 thermocouple placed on condenser section.

$$T_{e\text{-}mean} = \frac{T1 + T2 + T3}{3}$$

The mean condenser temperature was calculated using reading of 3 thermocouple placed on condenser section.

$$T_{c\text{-}mean} = \frac{T5 + T6 + T7}{3}$$

The thermal resistance of the OHP is a measure of thermal

performance, which is shown as:

$$R = \frac{Te - Tc}{Qin}$$

where, Te is the wall temperature of the evaporator and Tc is the wall temperature of the condenser. Q_{in} is the input heat load and is calculated by,

$$Q_{in} = VI \, ,$$

where V is the input voltage that enter the cylindrical electrical heater and I is the current measured by the digital ammeter. The current is controlled by dimmerstat.

The energy removes the condenser section can be calculated by performing energy balance across condenser section,

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

The thermosyphon efficiency can be calculated from the ratio of cooling capacity rate of coolant and electric supplied power,

$$E = \frac{Q_{out}}{Q_{in}}.$$

In our experimentation we investigated effect of heat input and inclination angle on performance of thermosyphon
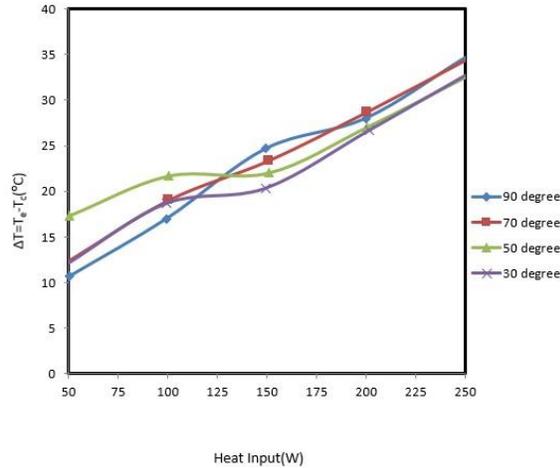
Fig(d): Temperature difference (T_e-T_c) vs heat input.

It can be seen from graph 1 that as the heat input increases the temperature difference (T_e-T_c) increases since heat input is directly proportional to ΔT. We have investigated effect of different inclination angle on temperature distribution we found that the maximum temperature difference was shown when heat input of 250W was given to thermosyphon was inclined at 90º, which was 34.6667 ºC. We also found that increase in temperature difference causes decrease in efficiency since efficiency is inversely proportional to ΔT (i.e. T_e-T_c).

It can be seen in fig(e) that for higher inclinations of 90º the thermal resistance increases till 150W and then decreases and then again increases from 200W similar phenomenon is seen for 30º inclination at 100W and 150 W.
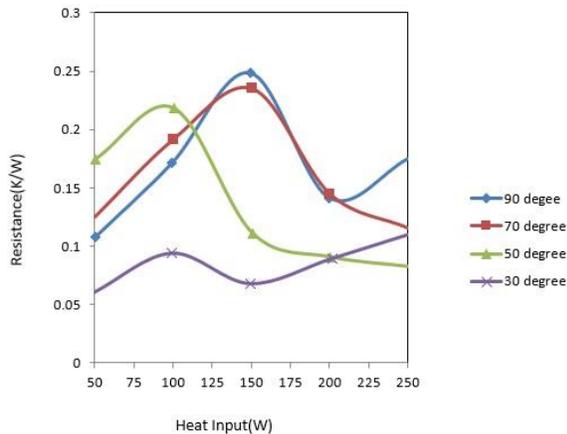

Fig(e): Variation of thermal resistance vs heat input.
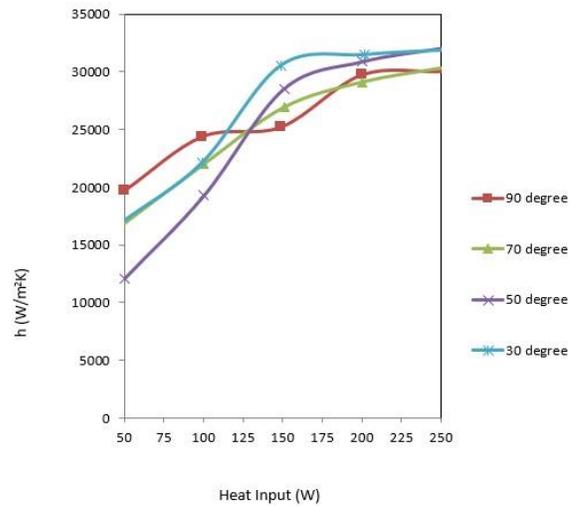
Fig(f): Coefficient of heat transfer vs heat input.

We investigated the effect of heat input on coefficient of convective heat transfer at different inclination angles it was found that as input is increase the heat transfer also increases as shown in fig(f).

The efficiency of thermosyphon goes on decreasing and then goes on increasing for different inclinations. The heat input from which the thermal efficiency being 115W for 30º inclination, 100W for 50º, 150W for 90º and 70º.The variation is shown in fig(g).
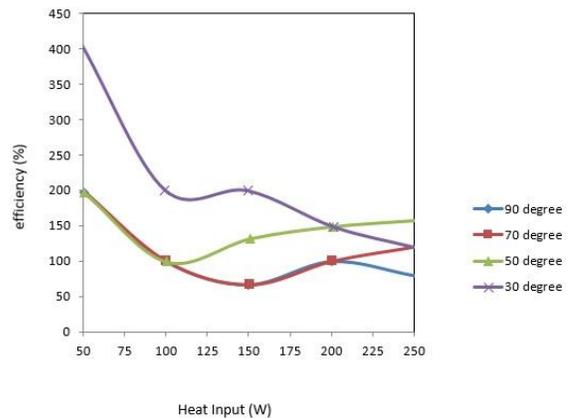

Fig(g): Thermal efficiency vs heat input.
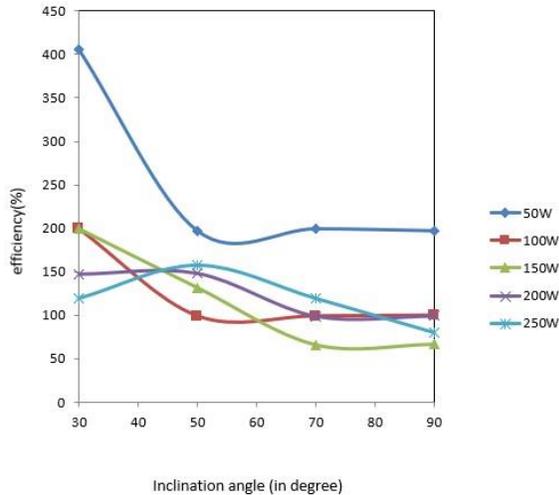
Fig(h): Heat pipe efficiency vs inclination angle.

The fig(h) shows variation of heat pipe efficiency with tilt angle at 30% filling ratio it can be seen that for heat input of 200 W and 250 W the efficiency increases first and then goes on decreasing after 50º inclination angle, while for 150W it decreases till 70º tilt angle then slightly increases till 90º similar phenomenon is observed for 100W and 50W input at 50º tilt angle. It is observed that maximum efficiency is given at 30º tilt angle at 50W input.

It is seen in fig(i) that for heat input of 50W and 100W the thermal resistance goes on increasing with increase in tilt angle till 50º inclination and again decreases there upon. In case of heat inputs 150W and 200W the thermal resistance goes on increasing with increase in inclination till 70º and remains constant there upon. For heat input of 250W thermal resistance goes on
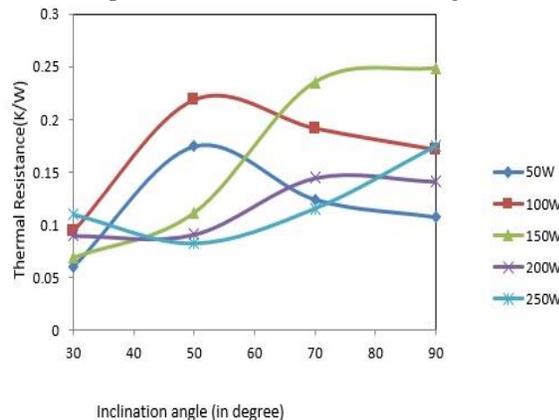
Fig(i): Thermal resistance vs inclination angle.
decreasing with increase in inclination till 50º and again increases.

IV. CONCLUSION

The experiment was conducted for investigating the effect of heat input and inclination angle on performance of TPCT thermosyphon with 30% filling ratio. The working fluid used was acetone. The optimum thermal efficiency was obtained at 70º at 50 W heat input for aluminum TPCT.

The inclination operating angle changes the internal flow pattern thereby resulting in different performance levels. There is possibility of delay star when the inclination angle is low (i.e. in between 30º to 50º). At a certain inclination angle, the mean heat transfer coefficient of the thermosyphon reached a maximum value. From the experimental results and discussion on the performance characteristic of aluminum TPCT, the following conclusions may be drawn:

1.The heat transfer performance of TPCT was improves with decrease in inclination angle. The effect of heat input and inclination angle on thermal efficiency is shown in fig.   and fig.   respectively.

2.The It is seen that for heat input of 50W and 100W the thermal resistance goes on increasing with increase in tilt angle till 50º inclination and again decreases there upon. In case of heat inputs 150W and 200W the thermal resistance goes on increasing with increase in inclination till 70º and remains constant there upon. For heat input of 250W thermal resistance goes on decreasing with increase in inclination till 50º and again increases. The optimum performance was found at 70º inclination.

3. Angle of inclination of heat pipe also has an impact on the heat pipe performance. It encourages the condensation of liquid in the condenser section and can take more liquid flow to the evaporation. However, larger tilt angles i.e., closer to vertical position results in deterioration of performance. It is due to faster condensate returns which affect the function of evaporation section.

ACKNOWLEDGEMENT

REFERENCES

[1] Kanji Negishi and Teruo Sawada (1982) Heat Transfer Performance of An Inclined Two-Phase Closed Thermosyphon.

[2] T. Payakaruk et al. (1999) Correlations to predict heat transfer characteristics of an inclined closed two-phase thermosyphon at normal operating conditions.

[3] S.W. Chang and C.Y.Lin (2013)Thermal Performance of of rotating two-phase thermosyphon disc.

[4] Xue Zhihu and Qu Wei (2014) Experimental study of effect of inclination angles to ammonia pulsating heat pipe.

[5] B. Jiao et al. (2007) Investigation on effect of filling ratio on the steady-state heat transfer performance of a vertical two phase closed thermosyphon.

[6] Z.Q. Long and P. Zhang (2011) Impact of cooling condition and filling ratio on transfer limit of cryogenic thermosyphon.

[7] Hamidreza Shabgard et al. (2013) Thermal characteristics of closed thermosyphon under various filling condition.

[8] Zhen Tong et al. (2011) Experimental study on effect of filling ratio on an R744 two phase thermosyphon loop.

[9] H. Mirshahi and M. Rahimi (2009) Experimental study on the effect of heat load, Fill ratio and extra volume on performance of partial-vacuumed thermosyphon.

[10] Te-En Tsai et al. (2010) Two phase closed thermosyphon vapor-chamber system for electronic cooling.

[11] Alessandro Franco and Sauro Filippeschi (2013) Experimental analysis of closed loop two phase thermosyphon.

[12] Khurram Kafeel and Ali Turan (2014) Simulation of the response of thermosyphon under pulse heat input condition.