Thermal Performance of a Two Phase Closed Thermosyphon Using Nanofluid

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Abstract--- A two-phase closed thermosyphon (TPCT) is an enclosed, passive device for heat transmission. It consists of an evacuated close tube filled with a certain amount of working fluid. Fluids with suspended nanoparticles (particles smaller than 100 nm) are called nanofluids that they have a great potential in heat transfer enhancement. In this paper, the thermal performance of a two-phase closed thermosyphon filled with Al_2O_3nanoparticlesusing water as the base fluid. The experiment was performed in order to measure the temperature distribution and compare the heat transfer rate of the thermosyphon heat pipe with nanofluid and with distilledwater. Nanofluids were prepared in 1% volumetric concentrations. Different filling ratios and heat loads (100 W, 200 W, 300 W, 400 W, 500 W and 600 W) were applied to the evaporator section. Results show that the addition of 1% (by volume) $Al_2O_3$of nanoparticles in water presented improved thermal performance compared with the operation with distilled water.

Keywords: - Al_2O_3nanoparticles, Nanofluid, Two-phase closed thermosyphon, Heat transfer enhancement

I. INTRODUCTION

Grover (Los Alamos Laboratory, USA) introduced the term heat pipe in 1964. The two-phase closed thermosyphon used in this study is essentially a gravity-assisted wickless heat pipe, which is very efficient for the transport of heat with a small temperature difference via the phase change of the working fluid. It consists of an evacuated-closed tube filled with a certain amount of a suitable pure working fluid. The simple design, operation principle, and the high heat transport capabilities of two-phase closed thermosyphons are the primary reasons for their wide use in many industrial and energy applications. The two-phase closed thermosyphon (TPCT), which is essentiallya gravity-assisted wickless heat pipe, utilizes the evaporationand condensation of the working fluid inside the heat pipes totransport heat. In contrast to the conventional heat pipe using capillaryforce to return the liquid to evaporator, a TPCT uses gravity toreturn the condensate. Its position is not restricted and it may beused in any orientation. The TPCT has a simple structure, smallerthermal resistance, higher efficiency and lower fabrication costs.Given these advantages, the TPCT has been widelyused in manyfields, such as industrial heat recovery, electronic component andturbine blade cooling, solar heating systems and so on.

A cross section of a closed two-phase thermosyphon is illustrated in Fig. 1. The thermosyphon 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 thermosyphon to boil in the liquid pool region and evaporate and/or boil in the film region. In this way the working fluid absorbs the applied heat load converting it to latent heat. The vapour in the evaporator zone is at a higher pressure than in the condenser section causing the vapour to flow upward. In the cooler condenser region the vapour condenses thus releasing the latent heat that was absorbed in the evaporator section. The heat then conducts across the

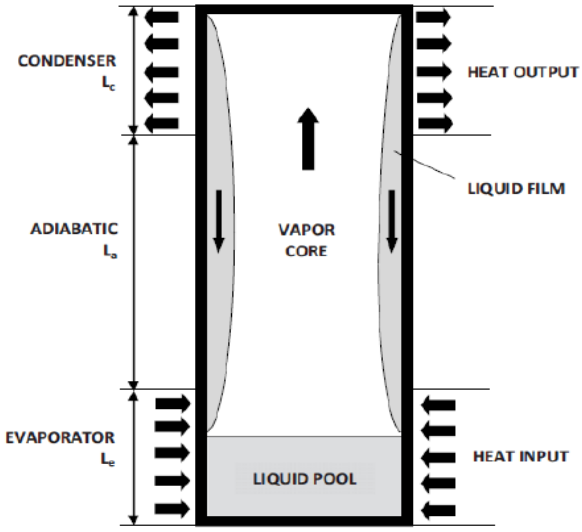

Fig. 1: A typical two-phase closed thermosyphon.

thin liquid film and exits the thermosyphon 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 thermosyphon relies on gravity to pump the liquid back to the evaporator section, it cannot operate at inclinations close to the horizontal position.

II. LITRATURE SURVEY

Gabriela Huminic and Angel Huminic.[1] per formed the experimentsof two-phase closed thermosyphon (TPCT) with iron oxide-nanofluids.The TPCT is fabricated from the copper tube with the outer diameter and length of 15, 2000 mm, respectivelyEffects 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. S.H. Noieet al. [2] performed the experimentation in various volume concentrations of 1–3% using nanofluids of aqueous Al_2O_3 nanoparticles in a TPCT. Experimental results showed that for different input powers, the efficiency of the TPCT increases up to 14.7% when Al_2O_3/water nanofluid was used instead of pure water.Gabriela Huminicet al. [3] performed an experiment with diluted nanofluid (with 0%, 2% and 5.3% concentration) in DI-water and DI-water. The thermosyphon was a copper tube with internal and external diameter of 13.6mm and 15 respectively. The overall of length of thermosyphon was 2000mm, They obtained the results that the addition of 5.3% (by volume) of iron oxide nanoparticles in water improved thermal performance of thermosyphon.Various water based nanofluids (of Al_2O_3, CuO and laponite clay)nanofluids shows inferior performance than pure water[4].A. Kamyar et al.[5] performed experimental investigation filled with two nanofluids using water as the base fluid mixed with Al_2O_3 and $TiSiO_4$ nanoparticles. Results demonstrate that both nanofluids improve the performance through reduction in thermal resistance by 65% (at 0.05 vol. % for Al_2O_3) and 57% (at 0.075 vol. % for $TiSiO_4$). Other improvements were also found in forms of increase in heat transfer coefficient and decrease in evaporator wall temperature. Although heat transfer coefficient improved by increasing particle concentration for $TiSiO_4$/water, it had the highest value at 0.05 vol. % for Al_2O_3/water showing a limit for increments in particle concentration.

In 2010,Karthikeyan et al.[6] carried out the experiments with distilled water and aqueous solution of n-Butanol for filling ratio of 60%,inclinations of 45^0, 60^0 and 90^0. Flow rate of 0.08Kg/min, 0.1 Kg/min and 0.12 Kg/min and heat input of 40 W, 60 W and 80 W. The thermosyphon was of a copper material with inside and outside diameter of 17mm and 19mm respectively. The overall length of thermosyphon was 1000mm.The result conclude that the thermosyphon charged with aqueous solution has the maximum thermal performance than compared to thermosyphon charged with distilled water.Minor or no effect is experienced with R134a below the boiling limit and enhancement up to 250% existed above the boiling limit[7].The change in heat flux, fill ratio and employing different extra volumes has a significant effect on the performance of thermosyphon[8].K.S. Ong et al.[9] investigated performance of a R134a,they obtained the results that the heat flux transferred increased with increasing coolant mass flow rate, fill ratio and temperature difference between bath and condenser section.T. Parametthanuwat et al. [10] investigated the effect of using silver nanofluid on the thermal characteristics of TPCT. The thermosyphon was made with copper tubes with 7.5, 11.1 and 25.4 mm ID. The filling ratios of 30%, 50% and 80% by evaporator length and aspect ratios of 5, 10, and 20 with an inclination angle 90^o.They found that the filling ratio has no effect on the ratio of heat-transfer characteristics in the vertical position, but the properties of the working fluid affected the heat-transfer rate.

A. *Objective of work*

This study therefore aimed to investigate the effects of inclination angle, heat load, filling ratio on the thermal performance of thermosyphon charged with distilled Water and Al_2O_3 nanofluid and to investigate the best configuration of factors affecting the performance of thermosyphon for maximum heat transfer and effectiveness of nanofluid over distilled Water.

III. EXPERIMENTATION

Figure 2 illustrate that, the experimental setup. The setup comprises the thermosyphon tube, cooling water unit, heater and a control panel.

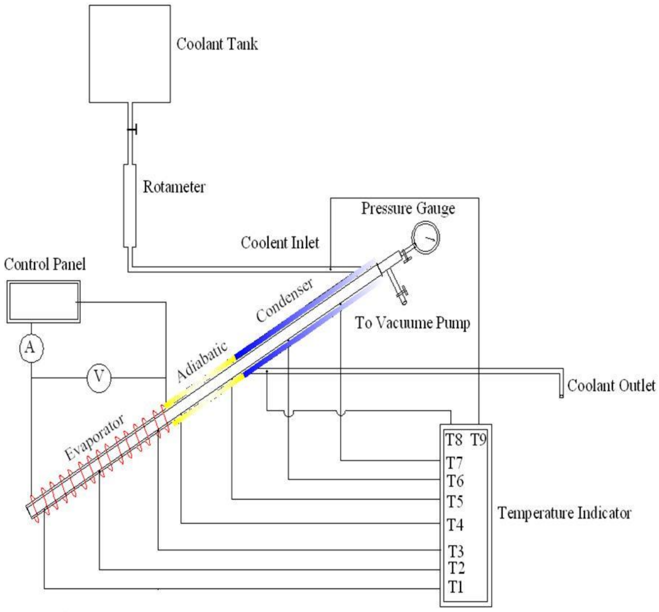

Fig. 2: Schematic view of thermosyphon experimental model

Table 1: Experimental Model Description

Tube Material		Copper
Diameter (mm)	Internal	26
	External	32
Dimensions (mm)	Total	1000
	Evaporator	300
	Condenser	450
	Adiabatic	250
Aspect ratio		11.53
Filling Fluid		Distilled Water, Al_2O_3 nanofluid
Filling ratio (%)		30%,40%.60%,80%,100%
Inclination Angle		90 (With Horizontal)
Heat Input (W)		100 to 600
Condenser Fluid flow rate (kg/s)		10 LPH
Thermocouple		K Type

The efficiency of thermosyphon has been defined as the ratio of heat absorbed by the condenser section to the energy introduced to the evaporation section as follow:

$$\eta = \frac{Q_{out}}{Q_{in}} \times 100$$

Where, Q_{out}, the amount of heat absorbed by the cooling water in the condenser section can be calculated using the following relation:

$$Qout = mc_p\,(T_h - T_c)$$

In which ρ is the density, m is the volumetric flow rate and C_P is the heat capacity of cooling water. In addition, T_c and T_h are the inlet and outlet temperatures of cooling water, respectively. The performance of thermosyphon at different heat inputs and filling ratios is calculated and plotted.

IV. EXPERIMENTAL RESULTS AND DISCUSSION

Fig. 3 and Fig.4 shows the performance curves of thermosyphons heat pipes with water and Al_2O_3 nanofluid as a working fluids and an inclination angle of $90^o$for different heat input. Heat transfer efficiency increases up to 500 W and it decreases slightly at 600W for both working fluids. Comparing with the water thermosyphon heat pipe, remarkable increases of the heat transfer rate were observed in the case of the thermosyphon heat pipe charged with Al_2O_3nanofluid.This may be due to the increase in the critical heat flux. During nucleate boiling some nanoparticles deposits on the heater surface and form porous layer, this improves wettability of surface. The suspended nanoparticles tends to bombard the vapour bubbles during bubble formation. Hence nucleation size of vapour bubbles is much smaller, hence it creates lower thermal resistance which increases heat transfer from solid surface to liquid. Alsonanofluidleads to improves thermal conductivity, liquid density and viscosity.

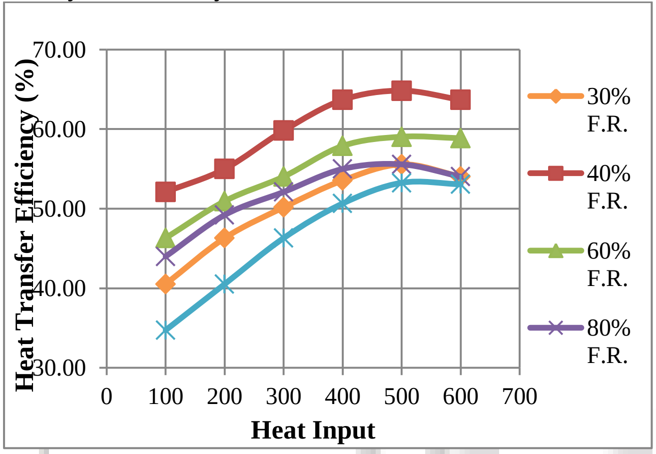

Fig. 3: Heat Transfer Efficiency at Various Filling Rations and 90^0InclinationAngle for Distilled Water

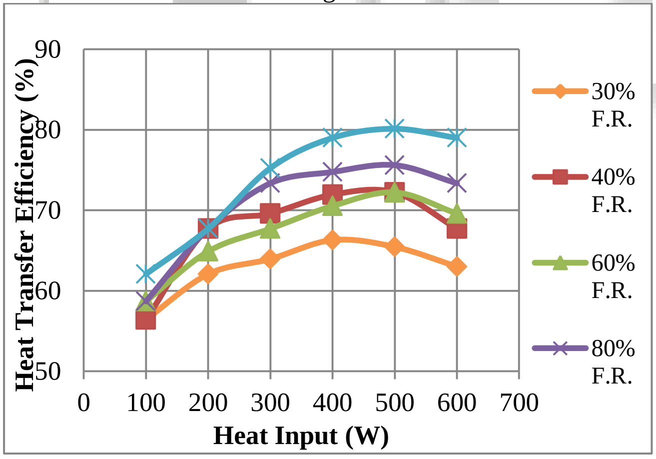

Fig. 4: Heat Transfer Efficiency at Various Filling Rations and 90^0 Inclination angle for Al_2O_3nanofluid.

V. CONCLUSION

Filling ratio and heat load have significant effect on the thermal performance of thermosyphon.

– Thermosyphon shows maximum heat transfer efficiency for filling ratio of 40% and inclination angle of 90^o using distilled water.
– Distilled water as a working fluid shows better performance at high heat load but inferior performance at low evaporator section temperature.
– For distilled water, heat transfer efficiency increases from heat load 100W to 500W and then slightly decreases at 600W.
– Thermal performance of thermosyphon improved when charged with Al_2O_3/water nanofluid.
– Increasing the percentage of nanofluid decreases the thermal resistance of pipe and hence thermal performance increases.
– For nanofluid, Heat transfer efficiency increases from 100W to 200W and then decreases up to 600W for filling ratio of 30%, 40%, 60%.
– Heat transfer efficiency increases from 100W to 500W for F.R. of 80% and 100%, fornanofluid. Maximum heat transfer efficiency was observed for filling ratio of 100% and at 500W.

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