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A REVIEW ON EFFECT OF WORKING FLUID WITH NANO PARTICLE ON THE THERMAL PERFORMANCE OF TPCT

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Abstract— The demand for energy is severally increased as the world's population increases. Now a days use of nanofluids in heat recovery system for heat transfer enhancement is topic of interest. In this work two phase closed thermosyphon is used. The thermosyphon has main three components, an evaporator with a boiling enhancement structure, adiabatic section at the center and condenser. In this Experiment the effects of working fluid on the performance of the thermosyphon at different inclination will be consider with different types of nanofluids could be used as working fluids in two phase closed thermosyphon for different fill volume, inclination angle, and heat inputs by designing a suitable experimental set up. Some of the key features of nanaofluids revealed from the recent research work are better thermal conductivities as compared to the conventional solid–liquid suspensions, strongly non-linear temperature dependent effective thermal conductivity. An increase in critical heat flux under pool boiling conditions. The method tested by applying heat load to the thermosyphon as per application and also the condenser section is cooled by vessel with fluid pump and flow control arrangement. The testing of the thermosyphon will at inclination of 90°, 75°, 60°, 45°, 30° and 15° with respective horizontal axis to study the effect on heat transfer ability of the system.

Keywords— Thermosyphon, Nanofluid, Working fluid, Angle Inclination

I. INTRODUCTION

Two-phase passive heat transfer devices like heat pipes and thermosyphons have played an important role in a variety of engineering heat Transfer systems, ranging from electronics thermal management to heat exchangers and reboilers for many years. The two-phase closed thermosyphon is the high performance heat transfer device with features such as simple structure, special flexibility, high efficiency, good compactness and excellent reversibility [4]. It is used to transfer a large amount of heat at a high rate with a small temperature difference. It can transfer heat through small cross section area over relatively large distances without any moving parts such as pumps and active controls [1]. In this context, the present scenario of high thermal loading coupled with high flux levels demands exploration of new heat transfer augmentation mechanisms besides the conventional techniques so that more efficient and reliable systems are developed [14].

Nanofluids are fast emerging as alternatives to conventional heat transfer fluids, due to their better thermophycal properties. The term 'Nanofluids' is used to indicate a newly introduced special class of heat transfer fluids that contain nanoparticles (<∼100 nm) of metallic or non-metallic substances uniformly and stably suspended in a conventional heat transfer liquid. Recent studies have indicated that by adding nanoparticles to conventional heat transfer fluids can alter the thermophysical and transport properties of the base fluid. Thus, the introduction of nanofluids has given an impetus to the idea of developing and using nanofluids in principle, as working fluids to enhance the thermal performance of closed two phase thermosyphon [10-13].

An advanced electronic devices employing high speed and high level of heat generation have to be small in size, light-weight. However, the level and reliability of heat rejection efficiency largely require for these devices. Thermosyphon / Heat Pipe technology has been used in a wide variety of applications in the heat transfer devices. The most frequently used coolants in the heat transfer devices study are air, water, and fluoro-chemicals. However, the heat transfer capability is limited by the working fluid transport properties [4].

Effective thermal management has become one of the most vital challenges in many technologies because of constant demands for faster speeds and continuous reduction of device dimensions. Recent technological advances in manufacturing have led to the miniaturization of many devices with various applications. So from small size component for effective heat transfer thermosyphon plays an important role [5].

The thermal–hydraulic behavior of thermosyphons involves the use of rather large diameter units. This is likely because the target technologies, such as heat recovery systems, were large in scale demanding large heat exchangers. However, applications, where there may be severe size and weight constraints (e.g. automotive heat recovery) demand much more compact heat exchangers requiring the deployment of smaller diameter and shorter thermosyphons. Further to this, some sensitive applications may require the use of working fluids other than water. In some instances, in particular low operating temperatures, it has even been shown that water gives less satisfactory heat transfer performance compared with low saturation temperature fluids [6].

In many investigation of thermosyphon it is observed that water gives better performance as a working fluid than other solutions. Due to its high boiling point it generally not used for cold temperature regions. By using other solutions as a working fluid does not get better thermal performance than water. So it time comes to use binary mixture of various mixtures to get better thermodynamic property for using working fluid in two phase closed thermosyphon [2]. In this

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project, ethanol-methanol of different mixture proportions of fluid with 60% FR is used. Its performance can be assessing with its different proportions at various angle inclinations of pipe and mass flow rate of water at condenser side.

A. *Working Principle*

Following figure shows the working principal of two phase closed thermosyphon. It is oriented in the vertical position to understand its working principle. It can be divided into three sections:

- Evaporator which is located near the heat source;
- Condenser which is located near the heat sink;
- Adiabatic section in the middle of the thermosyphon .

It is empty sealed thermal pipe which contains a small amount of working fluid (Phase Change Material). The evaporator section is exposing to band hater and heat conducted across the pipe wall so the liquid in the thermosyphon absorbs the applied heat and it converting to latent heat of vapour. So its pressure increases and high pressure vapour flow to upward direction. At the middle, insulation is fitted at adiabatic region so no heat transfers to surrounding. In the condenser region, the water or air is circulated around it as shown in the Figure 1.1. The vapour condenses thus releasing the latent heat that was absorbed in the evaporator section. Then heat exits through the tube wall and into water jacket. Then the liquid is flow due to gravity back to the evaporator section in the form of a thin liquid film.

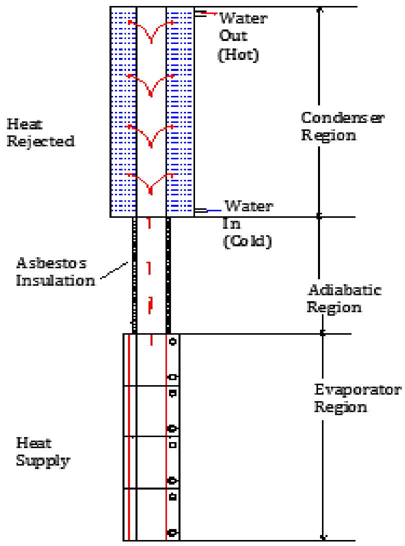

Fig.1 Thermosyphon Working Principle

As it works on gravity to back liquid to the evaporator section, thermosyphon not be operating at inclinations close to the horizontal position. The working fluid, fill ratio, heat input is main parameters of the performance of thermosyphon and it can be assessed with dimensional less numbers.

II. LITERATURE REVIEW

In this project, the study of various categories research papers on the thermosyphon are studied. After going through these research papers, it seems that a lot of work has been done on the heat transfer performance of the thermosyphon system. Research work includes different input conditions of thermosyphon system i.e. filling ratio, aspect ratio and combination of various working fluids and angle inclination. The proposed work has been done mainly for effect of binary mixture proportions, angle inclination and cooling water flow rates. The purpose of this literature review is to go through the main topics of interest i.e. effect of angle of inclination and mass flow rate of water for cooling process of condenser and binary mixture proportions on thermosyphon performance.

a. *Effect of Working Fluid on Thermosyphon*

Gadge A.B. et al [1] an experimentally investigated the performance of thermosyphon charged with ethanol and methanol along with Al2O3. The Al2O3 nanoparticles are spherical in shape with 10% concentration by volume in working fluid. The copper thermosyphon was 1000 mm long with an inner diameter of 26 mm. The evaporator length was 300 mm and the condenser length was 450 mm. With ethanol methanol as the working fluid corresponding to approximately 60% filled and overfilled evaporator section in order to ensure combined pool boiling and thin film evaporation/boiling conditions. From this review summarize that it can be the use ethanol and methanol as working fluid with 60% FR.

N. A. Faddas et al [2] an experimentally analyzed thermosyphon heat pipe with the ethanol-methanol (60-40) mixture by volume. Selected thermosyphon was copper tube of 1000 mm length with ID and OD of 24 mm and 26 mm respectively. Experiments were carried out on the inclination angle 40o to 90o, coolant flow rate 3.6 kg/h to 21.6 kg/h, heat load 25 W to 200 W. From result, maximum heat transfer efficiency is 86.39% which is higher at 3.6 kg/h coolant flow rate with

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80o inclination angle and 190 W heat loads. Binary mixture shows better thermal performance of thermosyphon.
T. Parametthanuwat et al [3] an investigated silver nanofluid in two-phase closed thermosyphon. The thermosyphon was made with copper material 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°. The operating temperatures were 40°C, 50°C and 60°C. This paper gives information about the effect of dimensionless parameters on heat- transfer characteristics. It seen that FR has no effect on the ratio of heat-transfer characteristics in the vertical position, but working fluid properties affected the heat-transfer rate.

TABLE I. EFFECT OF BINARY WORKING FLUID ON THERMOSYPHON

Investors	**Description**	**Major Findings**
Gadge A.B. et al [1]	Experimental investigation of the performance of thermosyphons with ethanol and methanol along with Al2O3	Ethanol- methanol as the working fluid corresponding to approximately 60% filled and overfilled evaporator section in order to ensure combined pool boiling and thin film boiling conditions can be used.
N. A. Faddas et al [2]	The effect of binary mixture and heat input and angle inclination on heat transfer characteristics of thermosyphon.	From this it can be fined for binary mixture gives maximum heat transfer efficiency 86.39% which is higher at 3.6 kg/h coolant flow rate with 80o inclination angle and 190 W heat loads.
T.Parametthan uwat et al [3]	Study correlation to predict heat-transfer rates of a two-phase closed thermosyphon (TPCT) using silver nanofluid at normal conditions.	Heat transfer rate of thermosyphon is characterized by dimensional less numbers. They depend upon various operating parameters of fluid and pipe.

Paisarn Naphon et al [4] analyzed refrigerant–nanoparticles mixtures for heat pipe efficiency enhancement. The heat pipe is fabricated from the straight copper tube with the outer diameter and length of 15 mm, 600 mm, respectively. In this pure refrigerant (R11) is used as a base working fluid with titanium nanoparticles of diameter 21 nm. Effects of the charge amount of working fluid, heat pipe tilt angle on the efficiency of heat pipe are considered. From this paper it come to know that with pure refrigerant as working fluid, heat pipe at 60° angle inclination & 50% FR gives the highest efficiency. At the optimum condition for the pure refrigerant, the heat pipe with 0.1% nanoparticles concentration gives efficiency 1.40 times higher than that with pure refrigerant.

S.H. Noie et al [5] an experimentally investigated the Al2O3 nanoparticles (smaller than 100 nm) with pure water. Nanofluids of aqueous Al2O3 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 Al2O3/water nanofluid was used instead of pure water.

Hussam Jouhara et al [6] an experimentally assessed the performance of thermosyphons charged with water and the dielectric heat transfer liquids FC-84, FC-77 and FC-3283. The copper thermosyphon of 200 mm length, 6 mm ID, 40 mm evaporator length and 60 mm the condenser length was selected. With water as the working fluid 0.6 ml and 1.8 ml load of fluid consider, corresponding to approximate half-filled and overfilled evaporator. Liquid gives thermal performance up to 30–50 W after which liquid entrainment compromised their performance.

Robert W. Mac Gregor et al [7] studied on alternative working fluid for refrigerants to reduce high Global Warming Potential. A shortlist of potential replacement fluids was drawn up, and considering the environmental, operating and storage conditions, and cost, five were selected for tests in representative thermosyphon. The results of the experimental work showed a water-5% ethylene glycol mixture was a suitable replacement fluid, although under certain conditions its performance was less than that of R134a. The tests also showed water alone can give the highest heat transfer, although it is not suited to the target temperature range, and methanol did not perform as well as R134a for most of the experimental range.

TABLE II. EFFECT OF REFRIGERANTS/WATER MIXTURES ON THERMOSYPHON

Investors	Description	Major Findings
Paisarn Naphon et al [4]	Find out the performance of the thermosyphon using Refrigerant and Nanofluid mixture at operating parameters.	From this paper it come to know that with pure refrigerant as working fluid, heat pipe at 60° angle inclination & 50% FR gives the highest efficiency. At the optimum condition for the pure refrigerant, the heat pipe with 0.1% nanoparticles concentration gives efficiency 1.40 times higher than that with pure refrigerant.
S.H. Noie et al [5]	Use Al2O3 nanoparticles (smaller than 100 nm) with pure water.	For different input powers, the efficiency of the TPCT increases up to 14.7% when Al2O3/water nanofluid was used instead of pure water
Hussam Jouhara, et al [6]	Experimentally investigated performance of thermosyphons charged with water and the dielectric heat transfer liquids FC-84, FC-77 and FC-3283	With water as the working fluid 0.6 ml and 1.8 ml load of fluid consider, corresponding to approximate half filled and overfilled evaporator. Liquid gives thermal performance up to 30–50 W after which liquid entrainment compromised their performance.
Robert W. MacGregor et al [7]	They have worked on alternative working fluid for refrigerants to reduce high Global Warming Potential	The results of the experimental work showed a water-5% ethylene glycol mixture was a suitable replacement fluid, although under certain conditions its performance was less than that of R134a.

Matthias H. Buschmann et al [8] studied overview to compile results of the application of nanofluids in thermosyphons, heat pipes, and oscillating heat pipes. All together 38 experimental studies and 4 modeling approaches are analyzed in his literature. In most cases recognize nanofluids as an advantageous working fluid, some others report negative effects. Performance effects which are related to filling ratio, inclination angle, and operation temperature seem to be similar to those for classical working fluids. Several authors report a decrease of the thermal resistance or an increase of the efficiency with increasing concentration, but also a reversing of this trend if a certain optimal concentration is exceeded.
Dadong Wang et al [9] an experimentally researched on a vertical looped pulsating heat pipe (PHP) have been done at 60% filling ratio (FR) and power inputs (Q) of 20 W, 40 W, 60 W, 80 W and 100 W. The PHP is made of copper tubes with internal diameters 2 mm and wall thickness 1 mm. Experimental investigations on PHPs indicated working fluid is an important factor for the performance of PHPs. Methanol, ethanol, acetone; water and different binary mixtures are selected as working fluids. According to the experimental results, the thermal resistance decreases with the increase of the heating power at the same filling ratio. Methanol/water PHP has better heat transfer performance than pure working fluids PHP, acetone/water PHP and acetone/water PHP.
Pramod R. Pachghare et al [10] an experimentally investigated the thermal performance of closed loop pulsating heat pipe (CLPHP). The copper capillary tube was used having internal and external diameter 2.0 mm and 3.6 mm respectively. For all experimentation, filling ratio (FR) was 50 %, number of turns was 10 and different heat inputs of 10 to 100 W were supplied to PHP. For all PHPs, Vertical bottom "heat mode" (90°) position is maintained. The equal lengths of evaporator, adiabatic and condenser sections were 50 mm each. Working fluids are selected as Methanol, ethanol, acetone, 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 various 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 from 20 to 60 W, whereas slowly decreases at input power above 60 W. Pure acetone gives best thermal performance in comparison with the other working fluids. No measurable difference has been recorded between the PHPs running with pure and binary mixture working fluids.

b. Effect of Angle Inclination on Thermosyphon

Kanji Negislii and Teruo Sawada [13] an experimental studied on the heat transfer performance of an inclined two-phase closed thermosyphon are described. Water and ethanol have been used as the working fluids. It is necessary to fill between 25 and 60% of the evaporator inner volume with water as the working fluid or between 40 and 75% for ethanol. Also the inclination must be between 20 and 40° for water, and more than 5° for ethanol.
T. Payakaruk et al [14] an experimentally studied the effect of dimensionless parameters on heat transfer characteristics

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of an inclined thermosyphon. The parameters studied in this paper are: Bond numbers, Froude numbers, Weber numbers and Kutateladze numbers, and experiments are conducted to find out their effect on the heat transfer rate and on the total thermal resistance. Copper thermosyphons with an ID of 7.5, 11.1 and
25.4 mm are employed with R22, R123, R134a, ethanol, and water as the working fluids. The selected filling ratios are 50, 80, and 100% and the selected aspect ratios are 5, 10, 20, 30 and 40 respectively. Experiments are conducted by varying the inclination angle from the horizontal axis by 5, 10, 20, 30, 40, 50,
60, 70, 80 and 90, and the controlled vapor temperature ranged from 0 to 30°C. It is found from the experiments that, the filling ratio has no effect on the ratio of heat transfer characteristics at any angle to that of the vertical position (Q = Q90), but the properties of the working fluid affected Q=Q90. Results show that the lower the latent heat of vaporization, the higher the Q=Q90. It is also shown that the modified Kutateladze number can be employed to predict the maximum Q = Q90, or QM = Q90. Another modified Kutateladze number can also be used to predict the ratio of minimum total thermal resistance to that at vertical position, or Rm=R90.

Nay Zar Aung et al [15] an investigated the effect of riser diameter and its inclination angle on system parameters in a two- phase closed loop thermosyphon solar water heater has been numerically investigated. Here, receivable heat flux by the collector, circulating mass flow rate, driving pressure, total pressure drop, heat transfer coefficient in risers and collector efficiency are defined as system parameters. For this aim, a model of two-phase thermosyphon solar water heater that is acceptable for various inclinations is presented and variations of riser diameter and inclination are considered. The riser tube size is varied from1.25 cm to 2.5 cm with inclination range 2–75°. The system absolute pressure is set as 3567 Pa and water is chosen as working fluid. The results show that higher inclination angle is required for higher latitude location to obtain maximum solar heat flux. At local solar noon of 21.996 north latitude, the optimum inclination angle increases in the range of 24–44° with increasing of riser diameter giving maximum circulating mass flow rate from 0.02288 kg/s to 0.03876 kg/s. The longer two-phase heat transfer characteristics can be obtained at smaller inclination angles and mass flow rate for all riser tube sizes. Therefore, it is observed that

the optimum inclination angles and diameters for solar heat flux, circulating mass flow rate and heat transfer coefficient in two- phase thermosyphon system do not coincide.

c. Summary of Literature Survey

From the above literature review it is seen that a lot of research work has been done in the field of thermosyphons by different researchers. From the above information, it observed that many researches is done on different kinds of working fluid solutions, Binary mixtures like N2-Ar, ethanol-methanol, water-5% ethylene glycol etc. and working fluids like methanol, petroleum ether and distilled water. These working fluids and their combinations are used to improve the performance of thermosyphon in different applications. Access this performance for change angle inclinations and mass flow rate of coolant.

In many investigation of thermosyphon it is observed that water gives better performance as a working fluid than other solutions. Due to its high boiling point it generally not used for cold temperature regions. By using other solutions as a working fluid does not get better thermal performance than water. So it time comes to use binary mixture of various mixtures to get better thermodynamic property for using working fluid in two phase closed thermosyphon. In this project, ethanol-methanol with 60% FR used and its performance can be assess with its different proportions at various angle inclinations and mass flow rate of water.The performance analysis of two phase closed thermosyphon, also known as wickless heat pipes have been analyzed different parameters like inclination angle, liquid charge ratio and choosing different liquids as working fluids by various researchers in recent times.

As the research work carried in the recent years shows different trends regarding thermal conductivity, heat transfer coefficient, critical heat flux, concentration and size of nanoparticles for closed two phase thermosyphon using nanofluids, therefore for benchmarking the results more research is needed in this field.

III.EXPECTED OUTCOME

- The aim of proposed work is focused on performance analysis of thermosyphon system by adopting the pure fluid and Nanofluid with them. For this purpose the performance analysis of the TPCT by considering the angle inclinations of pipe and mass flow rate of water, and their effects on it.
- Expected result from this proposed work is thermosyphon will give better thermal performance when it works by using working fluid as nanofluids.
- Expected Angle inclination of thermosyphon is in the range of 450 to 600 ,So that the such type of thermosyphon can be used for solar system.
- This type of thermosyphon experimental setup will run efficiently with 60 to 70 Percent filling ratio.
- Overall thermal performance of two phase closed thermosyphon will be improve after use of nanofluid in the working fluid.

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