Thermal performance of wickless heat pipe solar collector with surfactant added nanofluid and solar tracking- A Review

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Abstract— *These Several techniques for heat transfer enhancement have been introduced to improve the overall thermal performance of heat exchangers resulting in the reduction of the heat exchanger size and the cost of operation. In general, the heat transfer enhancement techniques can be classified into two methods including active method (requires external power source) and passive method (not requires external power source). The mechanism for improvement of heat transfer performance in the passive method is promoting the turbulence near the tube wall surface to reduce the thermal boundary layer thickness. This turbulence introduces a chaotic fluid mixing which acted by several enhancing modified tubes such as a finned tube, tube with rib, tube with spirally roughened wall, corrugated tube, fluted tube, helical tube, elliptical axis tube and micro-fin tube, etc.*

Active techniques, which require an extra external power source, include mechanical aids, surface vibration, fluid vibration, fluid pulsation, electrostatic fields, injection or suction of fluid and jet impingement. Consideration about tube heat transformation in the inner gradient of temperature was mainly concentrated on the boundary layer, if boundary layer could be broken effectively and the thermo-resistance which lay in laminar boundary layer or turbulence sub layer could be diminished, we could enhance local heat exchange coefficient and intensify heat exchange process by convection.

***Index Terms*—Wickless heat Pipe, Solar flat plate collector, Nano fluid, Surfactant.**

I. Introduction

The solar energy is the most capable of the alternative energy sources. Due to increasing demand for energy and rising cost of fossil type fuels (i.e., gas or oil) solar energy is considered an attractive source of renewable energy that can be used for water hearing in both homes and industry. Heating water consumes nearly 20% of total energy consumption for an average family. Solar water heating systems are the cheapest and most easily affordable clean energy available to homeowners that may provide most of hot water required by a family.

Solar heater is a device which is used for heating the water, for producing the steam for domestic and industrial purposes by utilizing the solar energy. Solar energy is the energy which is coming from sun in the form of solar radiations in infinite amount, when these solar radiations falls on absorbing surface, then they gets converted into the heat, this heat is used for heating the water. This type of thermal collector suffers from heat losses due to radiation and convection. Such losses increase rapidly as the temperature of the working fluid increases.

II Literature Review

The developments are being carried out continuously in the field of cover materials, absorber plate materials, absorber and glazing coating etc. along with the changes in the design, fluid used for heat transfer. Numbers of studies have been carried out on thermal performance of solar water heater and found more increase in the thermal efficiency in comparison to conventional solar water heater. These studies include use of double side absorber plate, honeycomb material, nanomaterial and more efficient coatings.

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Lee et al. [1] performed research specifically on nanofluids with oxide particles at Argonne National Laboratory. This experiment examined Al2O3 and CuO nanoparticles dispersed in both de-ionized water and ethylene glycol and their related thermal conductivities as measured by the transient hot-wire method. A strong dependence on particle size and an almost linear increase of conductivity with volume fraction of the particles were found. CuO nanoparticles were found to have a greater heat transfer effect than Al2O3 particles, which was suggested to be due to the CuO particles being smaller.

Hamilton and Crosser [2] performed research on the thermal conductivity of two-component systems in order to develop an understanding of the basis of many current modeling equations for nanofluid thermal conductivity. This research dealt specifically with identifying how the shape of the components of a system affected the thermal properties of that system. In this experiment various shaped aluminium particles and balsa wood particles were mixed into a rubber composite, which was then tested in a conductivity cell to measure the different conductivities attainable. This experiment provided data supporting the shape effect of metal particles on conductivity.

Wang et al. [3] examined the thermal conductivity of Al2O3 and CuO nanoparticles dispersed in various base fluids, including water, ethylene glycol, engine oil and vacuum pump fluid. Thermal conductivity was measured by the use of the one-dimensional, steady-state parallel plate method. This experiment resulted in data that suggests a possible relation between thermal conductivity and the size of the nanoparticles, as well as the method of dispersion used.

Abreu and Colle [4] focused on the experimental analysis of the thermal behaviour of two-phase closed thermosyphon with an unusual geometry characterized by a semi-circular condenser and a straight evaporator.

Noie[5] presented in his work an experimental study of a thermosyphons of (980 mm length and 25 mm internal diameter) made of smooth copper tube, with distilled water as a working fluid. The goal of the study was to obtain the thermal characteristics of the thermosyphon (temperature distribution in the outer wall along the tube, boiling heat coefficient and the maximum heat transfer rate), at: heat supply ($100 < Q < 900W$), filling ratios ($30\% \leq FR \leq 90\%$) and length of the evaporator (varying the length of electrical resistance).

Negishi and Sawada [6] made an experimental study on the heat transfer performance of an inclined two-phase closed thermosyphon. They used water and ethanol as working fluids. The highest heat transfer rate was obtained when the filling ratio (ratio of volume of working fluid to volume of evaporator section) was between 25% and 60% for water and between 40% and 75% for ethanol. The inclination angle was between 20° and 40° for water, and more than 5° for ethanol.

Zuo and Gunnerson [7] studied the heat transfer of an inclined two-phase closed thermosyphon. They showed that the minimum amount of working fluid remains almost constant from 20º to 90º, with respect to the horizontal axis, and then significantly increase by decreasing the inclination angle. They also found that the highest flooding limit is at an inclination angle ranging from 45º to 60º.

P.G. Anjankar, Dr.R.B.Yarasu [8] In this paper the thermal performance of a vertical two phase closed thermosyphon with different flow rate to condenser and different inputted heat to evaporator with different condenser lengths has been investigated experimentally. There are three lengths of condenser 450mm, 400mm; 350mm has been tried out. It is found that the thermal performance of thermosyphon at flow rate 0.0027 Kg/s and heat input 500 W with condenser length of 450 mm is higher. The paper also reviewed the thermal performance of two phase closed thermosyphon. The objectives of the present work are to study the new design and thermal performance of thermosyphon

Balkrishna Mehta and Sameer Khandekar[9] investigated the overall thermal resistance of a closed two-phase thermosyphon using pure water and various water based nanofluids (of Al2O3, CuO and Laponite clay) as working fluids. It was observed that all these nanofluids show inferior thermal performance than pure water. Furthermore, it is observed that the wettability of all nanofluids on copper substrate, having the same average roughness as that of the thermosyphon container pipe, is better than that of pure water.

Gabriela Humnic, Angel Huminic, Ion Morjan and Florian Dumitrache [10] performed an experiment to measure the temperature distribution and compare the heat transfer rate of

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thermosyphon 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 (evaporator length-850mm, condenser length-850mm, adiabatic section-300). They obtained the results that the addition of 5.3% (by volume) of iron oxide nanoparticles in water improved thermal performance of thermosyphon.

M. A. El-Nasr, S. M. El-Haggar:[11] The purpose of the study was to obtain a comprehensive understanding of the thermal performance of a wickless heat pipe solar collector on the basis of heat-transfer analysis using R-11, acetone, or water as a working fluid at different charging pressures. Also the effect of angle of inclination and the effect of liquid fill on the performance of the wickless heat pipe solar collector were studied. The experimental results show that the maximum efficiency occurs at 45° tilt angle. The optimum liquid fill in the wickless heat pipe with solar applications is 0.7, where the temperature flattening phenomenon occurred in the collector. The most suitable working fluid for wider temperature flattening is R-11 compared with acetone or water. The predicted theoretical results, using R-11, were compared with the experimental data and proved the validity of the theoretical analysis.

Hussein [12] studied the performance of wickless heat pipe flat plate solar collector having different cross section geometries and filling ratios. They investigated the water filling ratio to the flooding limit of the elliptical cross section and referred that it is very close to 35% for circular section so that an elliptical cross section significantly improves the performance of wickless heat pipe flat plate solar collectors at low water filling ratios. Theoretical and experimental studies on wickless heat pipe solar collectors for water heating have been reported Hussein. These studies use cross flow condenser heat exchanger. Distilled water was used as working fluid in heat pipes. The performance of wickless heat pipe solar collector was found to be sensitive to cooling water inlet temperature, absorber plate material and thickness and condenser length. It was also possible to know the optimum cooling water mass flow rate for best efficiency of the system.

Sandesh.S.Chougule, S.K.Sahu and Ashok T. Pise[13] A solar heat pipe collector was designed and fabricated to study its performance of the outdoor test condition. The thermal performance of the wickless heat pipe solar collector was investigated for pure water and nanofluid with varied range of CNT nanofluid concentration (0.15%, 0.45%, 0.60%, and 1% by volume) and various tilt angles (200, 320, 400, 500, and 600). CNT nanoparticles with diameter 10–12nm and 0.1–10μm length are used in the present experimental investigation. The optimal value of CNT nanofluid concentration for better performance is obtained from the investigation. The thermal performance of the heat pipe solar collector with CNT nanofluid is compared to that of pure water.

III OVERVIEW

To study the thermal enhancement of wickless heat pipe flat plate solar collector using surfactant added nanofluid with solar tracking mechanism, it is necessary to develop the system containing two heat pipe flat plate solar collector , one containing conventional fluid water and the other containing surfactant added nanofluid with solar tracking mechanism for both collector and other accessories and measuring instruments required for measuring required parameters to determine performance characteristics of both these collectors.

Planned objectives for this project are

(a) To study the effect on instantaneous collector efficiency of flat plate collector using nanofluid added surfactant and solar tracking mechanism. The effects are to be compared with wickless heat pipe containing conventional working fluid water with solar tracking mechanism.

(b) To study the effect of mass flow rate on the performance of wickless heat pipe flat plate solar collector with heat pipe working medium as nanofluid added surfactant and solar tracking. The performance of same is to be compared with conventional heat pipe solar collector with solar tracking mechanism.

3.1: Flat Plate Heat Pipe Solar Collector:

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Heat pipes are devices of high thermal conductance, which transfer thermal energy by two phase circulation of fluid, and can easily be integrated in to most types of solar collector. The basic difference in thermal performance between a heat-pipe solar collector and a conventional one lies in the heat-transfer processes from the absorber tube wall to the energy-transporting fluid. In the case with a heat pipe, the process is evaporation–condensation–convection, while for conventional solar collectors, heat transfer occurs only in the absorber plate. Thus, solar collectors with heat pipes have a lower thermal mass, resulting in a reduction of start-up time.

A feature that makes heat pipes an attractive for use in solar collectors is their ability to operate like a thermal-diode, i.e., the flow of the heat is in one direction only. This minimizes heat loss from the transporting fluid, e.g., water, when incident radiation is low. Furthermore, when the maximum design temperature of the collector is reached, additional heat transfer can be prevented.

This would prevent over-heating of the circulating fluid, a common problem in many applications of solar collectors. One of the first studies of heat pipes in solar applications was carried out by Bienert and Wol. In this case, the evaporator end of a heat pipe was inserted in a flat-plate collector, and the condenser protruded into a water manifold attached to the upper end of the collector. The results of this investigation were neither conclusive nor optimistic. Since then, numerous studies have been carried out, including theoretical analysis and calculation, experimental testing, combined investigation involving theoretical analysis and experimental trials, as well as applications in practice. Most of these studies involved the investigation of the thermal performance of various types of heat-pipe solar collectors by analytical, numerical or experimental methods with the aim of establishing suitable structures or system layouts, as well as optimum operating conditions for high efficiency.

Flat-plate heat-pipe solar collectors, have their own set of advantages, including simpler structure, lower cost, easier manufacture and simple operation. The lower efficiency of flat-plate collectors is mainly due to the heat loss via the cover surface due to conduction and convection. Standard flat-plate collectors have typical efficiencies of 50% or less, while evacuated devices have efficiencies of about 50–80%. It would be desirable to develop a new structure for flat plate collectors that would overcome heat loss problems and allow a high efficiency to be achieved, while its capital cost still remains low.

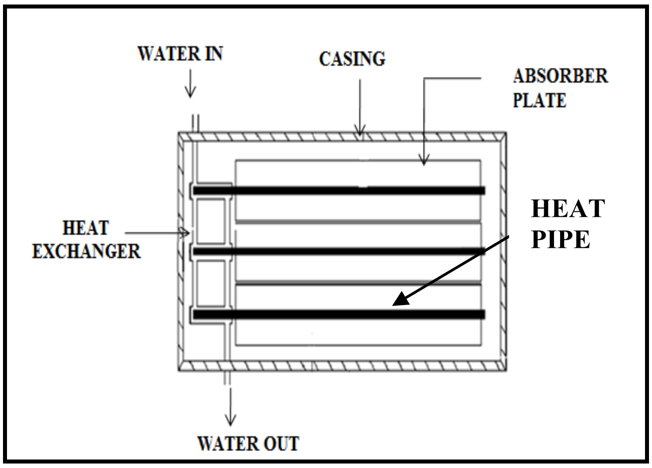

Fig. 1*:* Flat Plate Heat Pipe Solar Collector with three heat pipe

3.2: Solar tracking mechanism:

Solar tracker model can be fabricated. This model is based upon use of hydraulic mechanism in a cyclic manner in a closed loop. The solar collector can be mounted on panel seat driven by gravitational energy with an added advantage of dual axis mechanism tends to track sun effectively throughout the year. It suits the rural scenario with promising future to deliver better service.

IV Layout

In order to achieve the above stated objective the proposed layout of the experimental system is as follows

A schematic diagram of the experimental setup is as shown in Fig. 1. The solar collector performance could be experimentally investigated in Pune. The working fluid is to be circulated through the collector with gravity assistance. A heat exchanger can be placed to transfer heat load from the solar collector to the cooling water. A simple valve was also installed after the electric pump to control the working fluid mass flow rate. Two temperature sensors are to be used to measure the fluid temperature at the inlet and outlet of the solar collector. The ambient temperature is to be measured by

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a thermometer. The total radiations are to be measured with the help of radiation Pyranometer.

IV Conclusion

An experimental study has been carried out to investigate the thermal performance of heat pipe solar collector by using different working fluids for heat pipes such as: pure water, CuO-BN/water Nanofluid. Following conclusions are made from the experimental study and is detailed below:

The thermal performance of solar heat pipe collector is higher by using hybrid Nanofluid then by pure water as a working fluid for the wickless heat pipe flat plate solar collector.

The heat transfer rate is found to increase by increasing the tilt angle from 20° to 31.5° and decreases from 31.5° to 50° for both cases, namely, pure water and CuO-BN/water Nanofluid.

The temperature at the outlet of collector is more in case of wickless heat pipe containing Nanofluid as the working fluid than that obtained in case of wickless heat pipe containing pure water as the working fluid.

The maximum instantaneous collector efficiency for both the collectors (using heat pipe working fluid as water and hybrid Nanofluid) obtained at tilt angle 31.5 0.

The collector will provide improvement in the thermal performance by locating solar heat pipe collector at the place where the angle of getting maximum total solar radiation matches with higher performance tilt angle of solar heat pipe collector.

Solar heat pipe collector that uses hybrid Nanofluid as working fluid provides better performance at tilt angle (at 31.50).

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