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Nanofluid-Based Experimentation of a Flat Plate Elliptical Closed Thermosyphon Solar Water Heater

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Abstract: Due to its economic appeal and feasibility when compared to alternative forms of energy utilization, solar water heating systems are the most often used kind of solar energy use. Hot water that is necessary for both home and commercial uses can be supplied by the solar water heating system. One of the main concerns of energy-saving and compact designs is improving heat transmission in solar equipment. The new class of heat transfer fluids known as nanofluids are made up of minuscule amounts of evenly and steadily dispersed nanoparticles in fluids. More heat conductivity is exhibited by nanofluids than by any other type of conventional fluid. Nanofluids have been used in several investigations on circular heat pipe flat plate solar collectors. This investigation examined the wickless elliptical heat

Keywords: Two phased closed thermosyphon; solar water heater

1. Introduction

Solar energy is the best alternative energy source when compared to other energy sources. Solar energy is thought to be the most affordable and environmentally friendly energy source that can be utilized for water heating in both households and businesses, as the need for energy grows and the cost of fossil fuels rises. Approximately twenty percent of a family's energy consumption goes toward heating water. For the majority of a homeowner's hot water needs, solar water heating systems are the most accessible and reasonably priced sustainable energy source (Hussein HMS 2002). A lot of research has been done to increase the efficiency of the solar collector. A flat plate elliptical heat pipe with a base fluid of water and a copper is used in this investigation.

Elliptical heat pipes have a larger surface area for heat transfer than circular heat pipes. According to Abhijeet A. Pawar (2011), the heat transfer rate rises when the sun collector's tilt angle is progressively increased from 20° to 31.5° and falls from 31.5° to 50° in the two scenarios involving pure water and copper oxide-based water-based nanofluid.

The absorber plate of a traditional solar collector is connected to water tubes. Through forced or natural circulation, the solar energy is collected by the working fluid (water) and transmitted to the storage tank (Zuo Z. J. & Gunnerson F. S. 1995). Conventional solar collectors have a number of limitations, such as the pump and its power needs, the necessity for additional room for fluid circulation naturally, and night cooling. The aim of this study was to examine the impact of a copper oxide-water nanofluid on the efficiency and heat transfer rate of an elliptical-shaped wickless heat pipe flat plate collector. Additionally, the performance of the collector was examined in relation to varying mass flow rates and inclination angles. The outcomes of Circular heat pipe collectors and flat plate elliptical heat pipe solar collectors are contrasted

2. Theory and Design

2.1 Heat Pipe Section

The heat collected at the evaporator section of heat pipe (solar absorber) has to be dissipated in the condenser section of heat pipe. The condenser length depends on the amount of heat collected from sun and the mechanism of condensation. High heat transfer coefficient in condenser heat exchanger results in small condenser length. This can be done by increasing the condensing fluid velocity. Condenser length is also determined from the size of the evaporator and the cooling fluid temperature. During sizing the heat pipe sections, critical design values have to be considered. Adiabatic section length depends on at what distance heat is transferred from the evaporator. In solar water heaters, mostly adiabatic section length doesn't have a positive merit. Therefore, the length of adiabatic section must be keep as small as possible to reduce the heat loss. The condenser length can be optimized for the heat received from the solar absorber.

Fig. 1 Wickless Heat Pipes structured solar water heater

2.2 Connecting Pipe

Circular piping is needed in between water tank to inlet of condenser section and also at the outlet of condenser section. Material used for connecting pipe is mild steel.

2.3 Tank

A Tank having total capacity of 200 liters was selected to fulfill the purpose.

2.4 RTD/PT-100 Sensor and Temperature indicator

The temperature sensors are used to measure the temperature of heat absorbing fluid at inlet and outlet of the collector. The four RTD's and corresponding temperature indicator will be selected to measure the temperature up to 100^0C with indicator three and half digit for both collectors.

2.5 Solar meter/Pyranometer

Pyranometer is a device which is used to measure the solar radiations incident on solar collector. This meter directly gives the solar intensity values in W/m^2.

2.6 Angle finder

Commercially available angle finder is used to measure the tilt angle of collector.

2.7 Flow rate measurement

For measuring the flow rate of the water through collector flow control valve is used along with measuring cylinder and timer. At the beginning flow control valve is closed till collector section is completely filled. Then the flow control valve is adjusted to get required discharge by allowing water to fill measuring cylinder in fixed time set by the timer. From mass flow rate required per unit time the required discharge was calculated.

3. Preparation of nanofluid

In this study, the Nanofluid is prepared by two step method. The copper oxide nanoparticles having average size 50 nm are directly purchased from USA based company Nanoshell. In this study water is used as a base fluid for copper oxide. Volume of Nanofluid used is 50% of total volume all heat pipes. Calculated mass of nanoparticles is inserted in distilled water which is followed by stirring. After the stirring, sonication process is performed for

1 hour. By additionof surfactants or acids in nanofluids the thermo physical properties of nanofluids are affected hence they were not added in this study. Copper oxide nanofluid of 1% volumetric concentration is prepared in the laboratory.

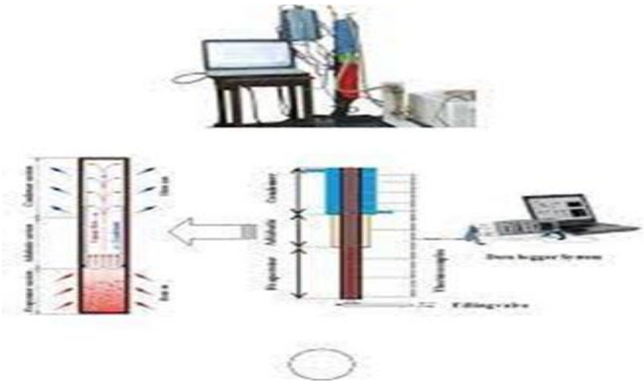

Fig. 2 Nanofluid preparation apparatus

4. xperimental Setup

A neat schematic diagram of the setup is as shown in Fig. 3. The solar collector performance could be experimentally investigated in Pune. A heat exchanger was placed inside the tank for transferring heat from the solar collector to the cooling outlet water. A flow meter is installed on the pipe before the cooling water inlet to measure the input mass flow rate and also at the outlet of hot water flow line. To measure the fluid temperature at the inlet and outlet of the two solarcollectors, four temperature sensors (PT-100) are to beused. The ambient temperature is to be measured by a thermometer. Pyranometer is used to measure the total solar radiations incident.

Fig. 3 Schematic of Experimental Setup

5. Test Procedure

The designed system assists in analyzing the thermal performance of circular and elliptical shape wickless heat pipe solar collector with nanofluid. Hence the major component of the system is heat pipe solar collector with wickless heat pipe. The cold water to be heated was stored in the tank. The water was passed tothe inlet of the header of the evacuated tube solar collector. The guide allowed filling completely byclosing the flow control valve. This valve is connected after the outlet of the condenser section. Once the collector condenser section is filled completely, flow control valve will open to adjust the mass flow rate of the water by noting the time required to fill measuring cylinder for volume calculation. Thus the mass flowrate of input cold water is set.

Set up have mechanism to vary the tilt angle of the collectors. The testing was carried out throughout the day from 10 A.M to 4 P.M. in Pune. Readings were taken at 30 minutes' interval. During the experimentation intensity at different times was recorded and also inlet water temperature, elliptical collector outlet water temperature and circular collector outlet water temperature was recorded. The intensity of solar radiation was measured by using Pyranometer. The temperature of inlet and outlet water from both the collectors along with ambient air temperature was measured using RTD's (PT-100 sensors). Readings were taken at different mass flow rates (2.5 LPH, 5 LPH, 7.5 LPH & 10 LPH) and also at

different tilt angles (20^0, 31.5^0, 50^0). Then the observations are tabulated for further analysis.

The rate of thermal energy input to system is given by, $Q_{in} = I_s \times A_c$ (1)

Where,

I_s= Intensity of solar radiation in W/m^2 A_c= Area of collector, m^2.

The rate of thermal energy gain by water is given by, $Q_g = m_w \times C_w \times (T_{out} - T_{in})$ (2)

Where,

m_w= Mass flow rate of water in Kg/s. C_w = Specific heat of water, J/KgK. T_{out}= Outlet temperature of water, ^{0} C. T_{in}= Inlet temperature of water, ^{0} C.

Efficiency of solar collector is given by,

$\eta_c = Q_g / Q_{in}$ (3)

6. Results and Discussion

The experiment was performed to know the thermal performance of flat plate elliptical TPCT solar water heater with copper oxide nanofluid and compared the results with circular heat pipe solar water heater with copper oxide nanofluid. Efficiency of solar collector is calculated with respect to time for different tilt angles and different mass flow rates. The efficiency of elliptical heat pipe collector is compared with the circular heat pipe collector for various parameters. Theresults are plotted as shown in following figures.

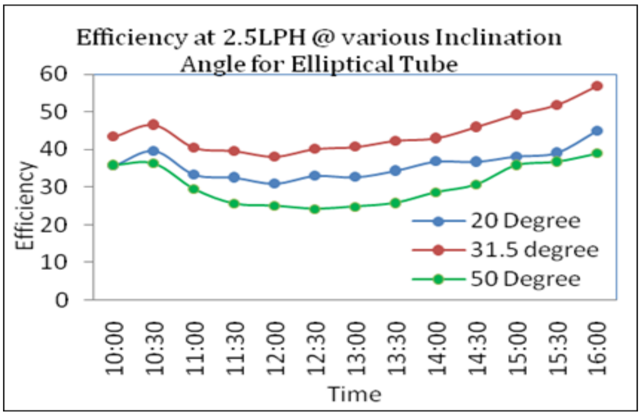

Fig.4 Variation of Efficiencies at 2.5 LPH mass flow rate

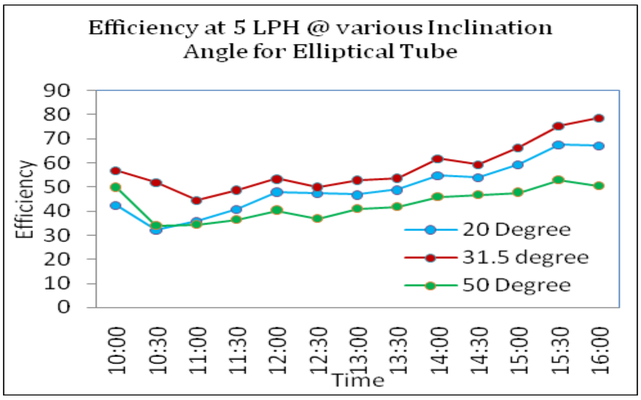

Fig.5 Variation of Efficiencies at 5 LPH mass flow rate

Above graphs shows that efficiency of elliptical solar water heater at different times is greater for 31.5^0 collector tilt angle followed by 20^0 and 50^0 tilt angle. The collector efficiency is maximum at 31.5^0 tilt angle because solar intensity is maximum at this angle. The value of solar intensity increases from 20^0 to 31.5^0 and again decreases from 31.5^0 to 50^0. The readings were taken at Pune, India having latitude 18.52^0 N & longitude 73.85^0 E. For circular flat plate solar collector also maximum collector efficiency is obtained at 31.5^0 collector tilt angle. By comparing readings for both the collectors it was found that maximum collector efficiency is obtained at 31.5^0 tilt angle.

Conclusion

After performing experimental study on flat plate elliptical TPCT solar water heater following conclusions can be made,

1. The maximum intensity of solar radiation is obtained at 31.5^0 collector tilt angle with respective to all time intervals in Pune region
2. As inlet cold water mass flow rate increases efficiency of the collector increases for both Circular and Elliptical solar collectors. Because, by increasing mass flow rate, thermal heat gain also increases which results in increase in efficiency.
3. As compared to flat plate circular solar collector, elliptical solar collector has more efficiency. The reason behind higher efficiency is, in case of circular pipe there is a point contact and in elliptical pipe there is line contact. Due to line contact the area available for heat transfer increases which results in higher efficiency.
4. Flat plate Elliptical solar water heater is having much higher efficiency than conventional solar water heater with water as working fluid, due to superior properties of nanofluid and heat pipe.

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