

Research Article

Experimental analysis of flat plate Elliptical TPCT solar water heater with CuO-H₂O Nanofluid

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Abstract

The most popular means of solar energy utilization is Solar water heating system because of its feasibility and economic attraction compared with other kinds of energy utilization. The solar water heating system can supply essential hot water which can be used for both domestic and industrial purposes. Enhancement in heat transfer in solar devices is one of the major issues of energy saving and compact designs. Nanofluids are the new kind of heat transfer fluid containing a very small amount of nanoparticles which are uniformly and stably suspended in fluids. Nanofluids are having high thermal conductivity than any other conventional fluids. Several studies have performed on circular heat pipe flat plate solar collector using nanofluids. In this study the thermal performance of wickless elliptical heat pipe (TPCT) solar collectors is to be investigated by using CuO-H₂O nanofluid. The effect of mass flow rate of water and tilt angle on collector efficiency can be investigated. The results are compared with wickless circular heat pipe solar collectors.

Keywords: TPCT, Nanofluids, Thermosyphon, Elliptical heat pipe

1. Introduction

Amongst all the energy sources solar energy is the best energy source in alternative energy sources. As demand for energy increases and cost of fossil type fuels rises solar energy is considered as most economical and environment friendly source of energy that can be used for water heating in both homes and industry. Out of total energy consumption by a family, approximately 20 % is utilized for heating the water. Solar water heating systems are less expensive and most easily affordable clean source of energy available to homeowners that may provide most of hot water required by a family (Hussein HMS 2002).

Solar energy is the energy which is coming from sun in the form of solar radiations in huge amount. After falling these solar radiations on absorbing surface, they get converted into the heat which is used to heat the water. Due to convection and radiation such type of solar collector suffers from heat losses. These losses increase as the temperature of the working fluid increases (Gabriela, H. Angel 2011). Hence the conventional solar water heating system is replaced by elliptical TPCT solar water heater.

Number of experiments has been performed to enhance the efficiency of solar collector. In this study the efficiency is improved by using flat plate elliptical heat pipe with copper oxide nanofluid with water as a base fluid.

As compare to circular heat pipe, elliptical heat pipes are having more area for heat transfer. The heat transfer rate increases by gradually increasing the tilt angle of solar collector from 20° to 31.5° and decreases from 31.5° to 50° for both cases, namely, pure water and Copper oxide-water based Nanofluid (Abhijeet A. Pawar, 2011).

In a conventional solar collector, tubes of water are attached to the absorber plate. The solar energy is absorbed by the working fluid (water) and transferred to the storage tank either by natural or forced circulation (Zuo Z. J. & Gunnerson F. S. 1995). The drawbacks associated with conventional solar collectors include the pump and its power requirement; they need more space for natural circulation of fluid, night cooling due to reverse flow of cooled water, pipe corrosion and more space requirement due to natural circulation, heavy total system weight and limited heat carrying capacity of fluid. The alternative solution to the above problems is heat pipe solar collector. The heat transfer performance is improved by recent advancement in nanofluids in the two phase gravity assisted Thermosyphon (TPGAT).

The purpose of this work was to investigate the effect of heat transfer rate and efficiency of elliptical shape wickless heat pipe flat plate collector using Copper oxide-water nanofluid and to investigate the performance of collector with respect to different inclination angle and mass flow rates. The results of

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flat plate elliptical heat pipe solar collector are compared with circular heat pipe collector.

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 kept as small as possible to reduce the heat loss. The condenser length can be optimized for the heat received from the solar absorber.

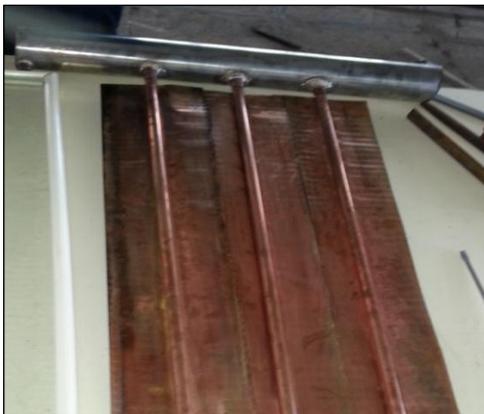


Fig. 1 Wickless Heat Pipes

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°C 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/m².

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 addition of 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. Experimental 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 solar collectors, four temperature sensors (PT-100) are to be used. The ambient temperature is to be measured by a thermometer. Pyranometer is used to measure the total solar radiations incident.

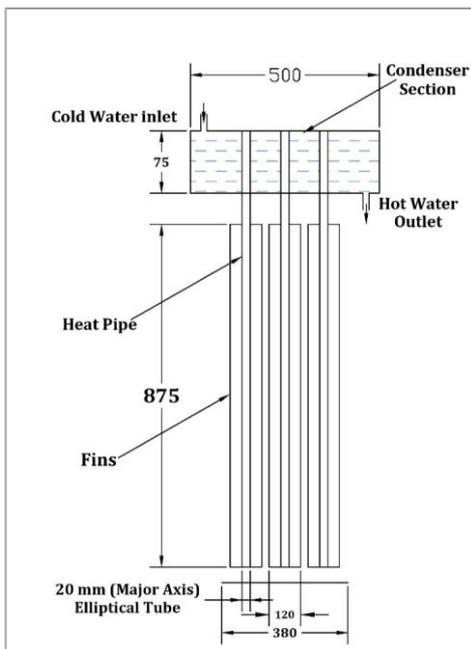


Fig. 3 Schematic of Experimental Setup

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 to the inlet of the header of the evacuated tube solar collector. The guide allowed filling completely by closing 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 flow rate 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 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°, 31.5°, 50°). Then the observations are tabulated for further analysis.

The rate of thermal energy input to system is given by,

$$Q_{in} = I_s \times A_c \tag{1}$$

Where,

- I_s = Intensity of solar radiation in W/m²
- A_c = Area of collector, m².

The rate of thermal energy gain by water is given by,

$$Q_g = m_w \times C_w \times (T_{out} - T_{in}) \tag{2}$$

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, °C.
- T_{in} = Inlet temperature of water, °C.

Efficiency of solar collector is given by,

$$\eta_c = Q_g / Q_{in} \tag{3}$$

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. The results are plotted as shown in following figures.

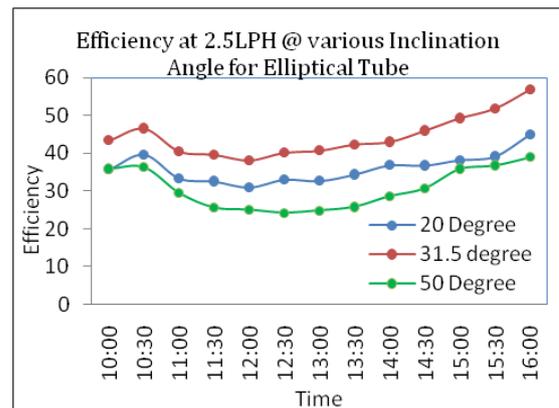


Fig.4 Variation of Efficiencies at 2.5 LPH mass flow rate

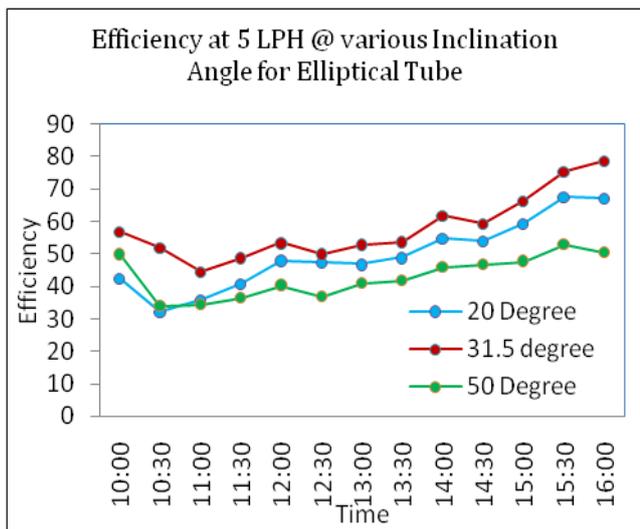


Fig.5 Variation of Efficiencies at 5 LPH mass flow rate

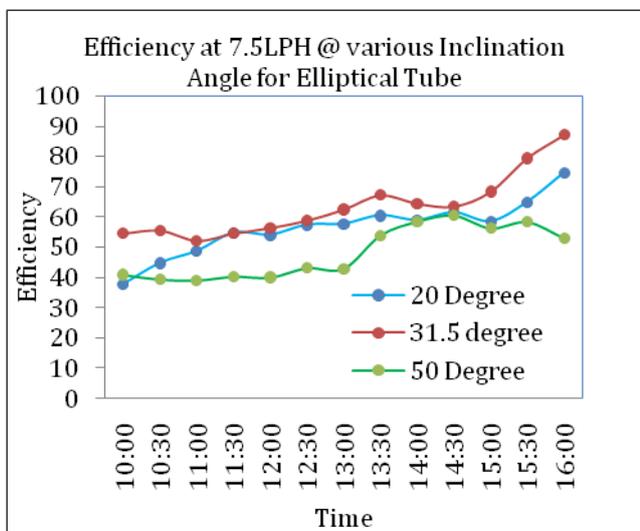


Fig.6 Variation of Efficiencies at 7.5 LPH mass flow rate

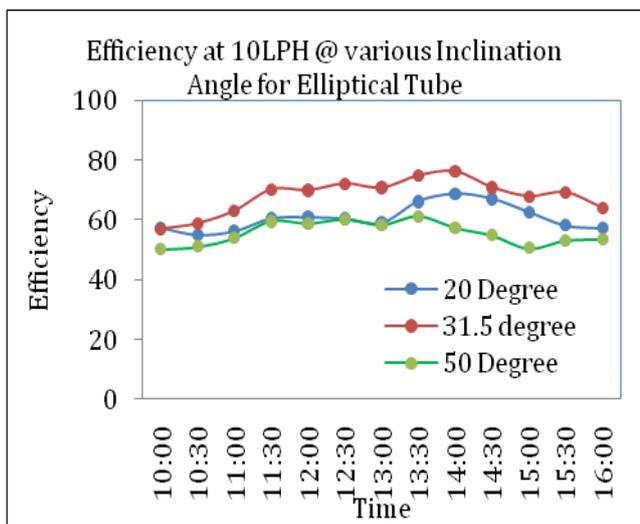


Fig.7 Variation of Efficiencies at 10 LPH mass flow rate

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

Hence for 31.5° tilt angle the efficiency of circular and elliptical heat pipe solar collector are compared as below,

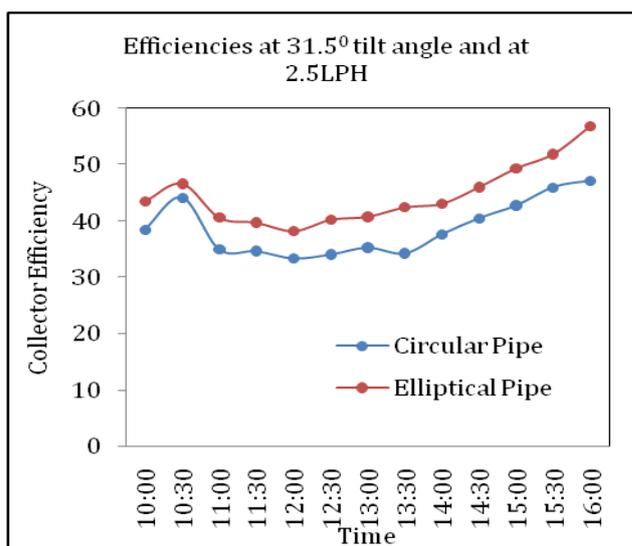


Fig.8 Variation of Efficiencies at 31.5° tilt angle and 2.5 LPH mass flow rate

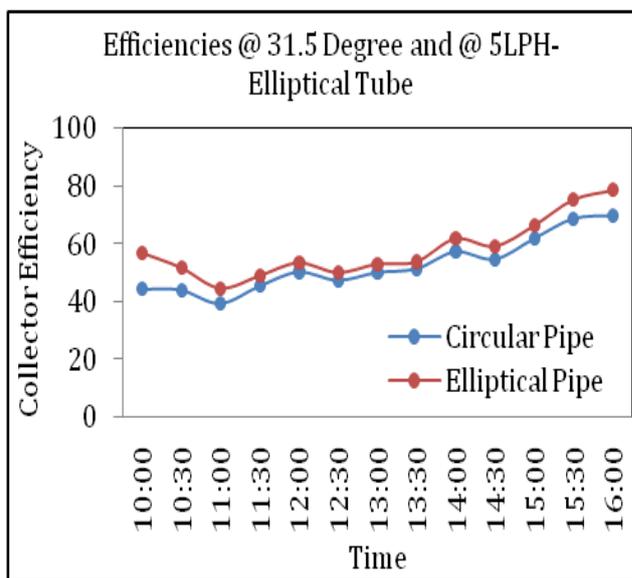


Fig.9 Variation of Efficiencies at 31.5° tilt angle and 5 LPH mass flow rate

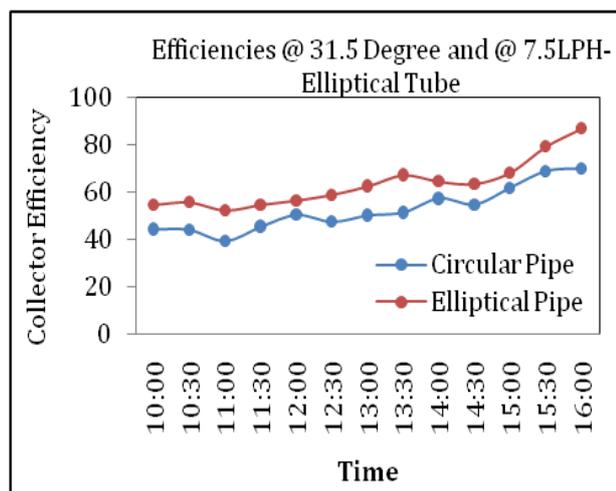


Fig.10 Variation of Efficiencies at 31.5° tilt angle and 7.5 LPH mass flow rate

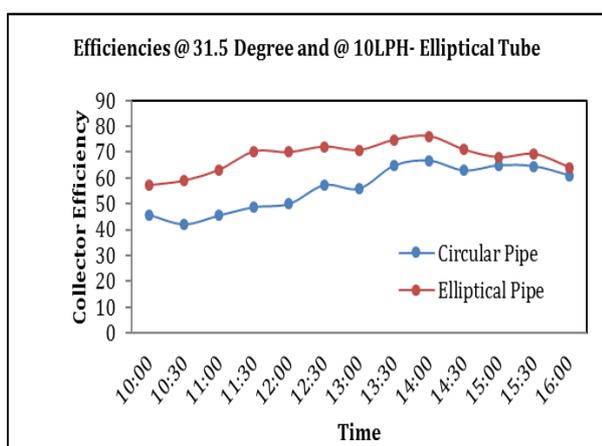


Fig.11 Variation of Efficiencies at 31.5° tilt angle and 10 LPH mass flow rate

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° 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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