PERFORMANCE ANALYSIS OF EVACUATED TUBE HEAT PIPE SOLAR WATER HEATING SYSTEM USING COPPER OXIDE NANOFLUIDS

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Abstract

Solar energy is one of the non-pollutant forms of renewable energy resource which is abundantly available with free of cost, which can be utilized for domestic and commercial purpose to archive the need of people in field of thermal energy. The study shows utilization of solar energy to heat the water with the help of experimental setup involves evacuated tube heat pipe containing nano-fluid and parabolic trough collector. Evacuated tube heat pipe absorbs heat and transfer to the water. Parabolic trough collector is used to concentrate solar irradiation on heat pipe to increase the efficiency of the system. The heat, absorbed by nano-fluid in evaporating section is transfer to condensation section, where heat is transfer to the water. Experimental setup consist four evacuated tube heat pipe, out of which two evacuated tubes as single unit having CuO Nano-fluid as working fluid and another two evacuated tubes as a single unit having distilled water as working fluid .Heat absorption and transfer capacity of CuO Nano-fluid is 15%-20% more than distilled water, use of parabolic trough collector and at same time effect of inclination of setup also increase the efficiency of water heating system.

Keywords: Evacuated tube heat pipe, Nano-fluid (CuO), parabolic trough collector.

Introduction

Solar energy has the greatest potential of all the source of renewable energy. It will be the most important supply of energy specially when the while condensation the application in commercial and domestic purpose. Utilization of solar energy is great important to it lies in a climatic temperatures of region of the world where sun light is abundant for a major part of year. Solar energy has a low density per unit area (1 kw/sq./m to 0.1 kw/sq./m) therefore it is collected by solar thermal collector. A solar thermal collector essentially forms the 1st unit in solar water heating system. A compound parabolic concentrator consists of two parabolic mirror segment which is connected to evacuated tube collector. The parabolic trough collector is situated in such a way that light rays reflected towards the evacuated tube. There are various type of material used for making parabolic trough collector using aluminum sheet. By the use of aluminum sheet get more reflection from the parabolic trough collector. The project is based on themosyohon principle. The results also showed that the addition of copper nanoparticles into the base fluid (water) significantly improves its absorption characteristics. With the help of copper oxide as a nanofluid it can increase efficiency by 10% other than distil water. By using CuO (copper oxide) is a nanofluid efficiency is increase than other conventional fluid liked distil water. In day to day life use of flat plate collector to absent all radiation but due to use of flat plate collector 50% radiation are absent so radiation are reflected back so to absorb maximum radiation parabolic trough collector is used. With parabolic trough collector all radiation incident on its surface then it comes back to one point to give a maximum radiation at one point. The parabolic trough collector give the maximum efficiency of 62.5% the outlet temperature of nanofluid is 65°C at 0.3% concentration of nanoparticle in volume.

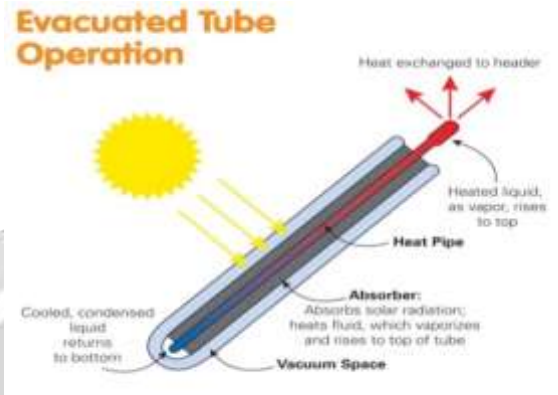

Fig. 1 Evacuated Tube Heat Pipe

Fig. 2 Actual Evacuated Tube Heat Pipe

Test Methodology:

Parabolic trough collector is used for concentrating solar radiation on evacuated glass tube. It's facing towards south-east direction and tracking is done through a day. The experiment conducted in the dated March21st 2017 at latitude 20.8049° N and longitude 78.5661° E. In experimental setup, 4 evacuated glass tube heat pipe, 2 storage tank and nano-fluid are used. In which two heat pipe contain nano-fluid and another two heat pipe contain distil water. The condensation section of heat pipe is inserted into the tank, having water. Tank has a capacity of 8 lit. This setup is arranged in such a way that, performance of solar collector at different tilt angle at 30°. During the analysis, solar collector were arranged at tilted position facing South-East direction and tested outdoor condition of Wardha, Maharashtra, India at latitude 20.8049° N and longitude 78.5661° E. Analysis were carried out thought at time from 11 AM to 3 PM and numerical data of solar intensity(Is) with different temperature observed such as ambient air temperature.

Fig.3 Actual Experimental set-up Photograph

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Nanofluid

The concept of nanofluids is developed at Argonne National laboratory (Choi, 1995) is directly related to trends in miniaturization and nanotechnology. Recent reviews of research programs on nanotechnology in the U. S., China, Europe, and Japan show that nanotechnology will be an emerging and exciting technology of the 21st century and that universities, national laboratories, small businesses, and large multinational companies have already established nano-technology research groups or inter-disciplinary centers that focus on nano-technology.

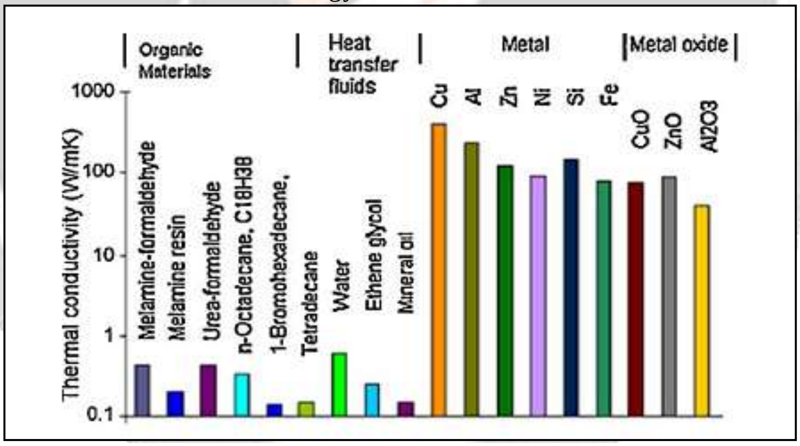

Fig 4: Thermal conductivity of typical materials

Thermo physical properties of Nanofluid

Cooling System Liquid Resistively Heated Crucible The thermal conductivity measurement of nanofluids was the main focus in the early stages of nanofluid research. Considering the application of heat transfer fluids, heat transfer coefficients of nanofluids in flow condition is also very important. The important properties other than thermal conductivity that affect the heat transfer coefficients are density, heat capacity and viscosity of dispersions. Since the nanoparticle concentration in nanofluids usually are very low (<1 vol. %), the particle effect on the density and heat capacity of the dispersions is not significant. However, due to the small particle size, the nanoparticle effect on the viscosity of the dispersions might be remarkable, especially for nanotube or other high or low aspect ratio nanoparticle dispersions. Some of the properties of nanoparticles & base fluids are listed in Table 3.1 useful for assessing the nanofluid properties.

Property	Water	Ethylene Glycol	Cu	Al_2O_3	CuO	TiO_2
C(J/kg K)	4179	2415	385	765	535.6	686.2
ρ(kg/m^3)	997.1	1111	8933	3970	6500	4250
k(W/m K)	0.605	0.252	400	40	20	8.95338

α (m^2/s)	1.47	93	1163	1317	57.45	30.7

Table 1 Thermo physical Properties of Nanoparticles and Base fluid

Experimental system develop

The concentrator usually used for concentrating solar radiation from large area on to the small area. Concentrating system concentrates large amount of solar radiation from large surface area to evacuated tubes to increase the performance of system. Concentrated solar systems use mirrors or lenses to concentrate a large area of sunlight, or solar thermal energy, onto a small area. Parabolic trough collector used for concentrating solar irradiation.

1. Gross Dimensions

- Length:1.8m
- Width:0.8m
- Depth:0.12m

2. Evacuated Glass Tube Dimensions

- Tube Length: 1.75m
- Outside Diameter of Outer Tube: 0.058m
- Inside Diameter of Outer Tube: 0.049m
- Outside Diameter of Inner Tube: 0.049m
- Inside Diameter of Inner Tube: 0.045m
- Total no. Of Tubes: 4 for each collector

3. Wickless Heat Pipes

- Material: Copper
- Outer Diameter of Condenser Section: 0.014m
- Outer Diameter of Evaporator Section: 0.008 m
- Length of Condenser Section:0.057m
- Length of Evaporator Section: 1.62m
- Total Length of Heat Pipe: 1.677m
- Heat Pipe Thickness:0.001m
- Volume of one Heat Pipe: 5.225×10^{-5} m^3
- Collector Effective Area: 0.31 m^2
- Working Fluid: Collector No.1: Distilled Water
  Collector No.2: CuO-BN/water Nanofluid

4. Insulation

- Material: Glass wool
- Thickness: 0.025m
- Position: Around the Condenser section casing inside the manifold.

1. Concentrating ratio =Input/Output

   Where,
   Input= parabolic trough collector area =7700cm
   Output= Evacuated tube area= 2100cm
2. Volume of tank= Area*Length

   Where,
   d= diameter of tank= 16 cm
   l= length of tank = 42 cm

3. Concentrating ratio =Input/Output

   Where,
   Input= parabolic trough collector area =7700cm
   Output= Evacuated tube area= 2100cm
4. Volume of tank= Area*Length

   Where,
   d= diameter of tank= 16 cm

l= length of tank = 42 cm

5. Area of collector
   A=b*d
6. Efficiency

$\eta_{inst} = Q_g / Q_{in}$ ………………… (1)

Where,

$Q_{in} = I_t.A_{coll}$, ………………….(2)

A_{coll} is the area of collector

Measuring the collector area on which solar radiations fall we get, A_{coll}=0.31m^2

$Q_g = m\ C_w(T_o\text{-}T_i)$ …………………...(3)

Where m is mass flow rate and Cw is specific heat of water

$\eta_{inst} = Q_g / Q_{in}$

Result and Discussion

Table 4.2 Comparison of Efficiency at Water and nanofluid at 30°

Inclination angle 30°		
Time	Instantaneous collector Efficiency (%)	
	Evacuated Tube Heat Pipe with Water	Evacuated Tube Heat Pipe with Nanofluid
11.00	51.49	62.37
11.30	53.69	63.77
12.00	55.35	64.89
12.30	56.10	65.78
1.00	55.05	65.72
1.30	54.88	64.38
2.00	54.67	63.79
2.30	53.92	63.32
3.00	53.10	62.89
3.30	52.16	62.17
4.00	51.37	61.67
4.30	50.05	61.37
5.00	49.77	61.15

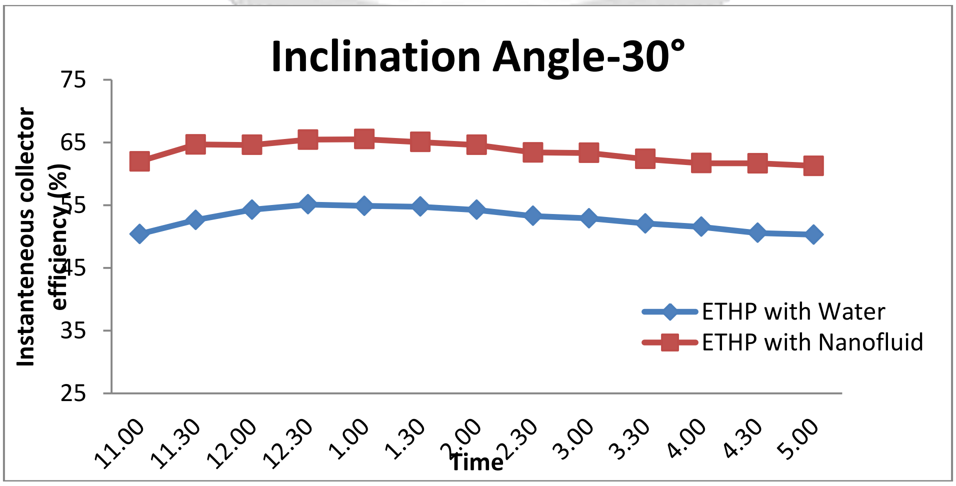

Fig 4.2 Comparison of Efficiency at Water and nanofluid at 30°

Above graph shows that efficiency of Evacuated tube heat pipe with nanofluid at 30° inclination angle , Graph shows that efficiency nanofluid is more than efficiency of water, and it shows maximum value of efficiency achieved by water and nanofluid are 56.10% and 65.78% respectively.

Conclusions

An experimental study has been carried out to investigate the effect of inclination angle and mass flow rate on thermal performance of two phase closed thermosyphon evacuated tube solar collector with working fluid in heat pipe as conventional fluid water and CuO-H_2O nanofluidcoupled with parabolic trough concentrator.Following conclusions are made from experimental study and are detailed as below:

1. The energy efficiencies for different inclination angle of the ETHPSC for 1% volume concentration of CuO nanofluids are 65.78%, at 30° tilt angle respectively.The average efficiencies of the collector that uses water as working fluid are: 56.10% at 30°.
2. The efficiency of the collector is higher for CuO nanofluid compared to water due to the improved thermal properties of nanofluids. Thus, we get optimum instantaneous efficiency at tilt angle 30° in both the solar collectors.

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