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Research Article

Experimental Investigation on Cylindrical Parabolic trough Collector with Water-Ethylene Glycol at Various Proportions

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Abstract

Energy resources which are available today are depleting day by day. Since the world requires continuous supply of energy. Non-Conventional and renewable energy sources have to be developed. Solar energy is a renewable form of energy and it is abundant in nature. There are many mechanisms to utilize solar energy. Parabolic trough collector is device to absorb energy from solar radiation. The present study deals with improving parabolic trough concentrating solar collector performance with water and ethylene glycol at various proportions as working fluids are carried out experimentally. Heat transfer fluids like water and ethylene glycol have been used in varying proportions of 70-30, 60-40, 50-50, 60-40, 70-30 to identify the composition which gives maximum Energy absorbing capacity.

Keywords: *Solar parabolic trough collector, performance, water and ethylene glycol heat transfer fluids.*

1. Introduction

At present, the world energy consumption is based on fossil fuels, which release a huge amount of gases that provoke the well-known greenhouse effect. This is the main reason for the significant climate change and natural disasters (e.g. hurricanes, flooding, etc.) taking place more often nowadays. Most of scientific studies performed in recent years have come to this conclusion. Together with this negative impact of fossil fuels consumption on the environment, there is another important reason that must be taken into consideration when evaluating the medium and long-term perspectives of current energy market scheme: the limited fossil fuel resources. Though the size and capacity of fossil fuel resources currently available can be discussed, there is no doubt about the impossibility to meet the energy demand with fossil fuels forever. It is therefore clear that alternative and renewable energy sources are needed to make compatible the future energy demand and a sustainable growth of the mankind. To this extent, wind and solar energies are the best candidates for massive energy production.

Solar radiation can be directly converted into electricity (by means of photovoltaic cells) or thermal energy (by means of solar thermal collector). Temperature level achieved when converting solar radiation into thermal energy depends on the type of system used for the conversion. While flat plate solar collector are suitable to produce hot water or air up to 80°C (approximately),higher temperature can be achieved when using evacuated tube collectors (125°C),parabolic-trough collectors(400°C),central receiver systems(1000°C) or dish concentrators (>2000°C).Though these temperature number are approximate, they give a good idea about the typical temperature range for the system mentioned.

Market studies performed in USA and Europe have shown that energy consumption at temperature below 400°C represent between 15% and 20% of the total energy consumption in those places. Though this energy demand is mainly supplied with fossil fuels at present it could be met with solar concentrating system suitable to work within this temperature range.(i.e. flat plate and parabolic-trough solar collector. while the typical temperature range of flat plate collectors is more suitable to produce hot water for domestic application, parabolic-trough collector are the best option nowadays for industrial application in the range 150°C-400°C.The commercial maturity of parabolic-trough collector is clearly stated by the more than $2*10^6m^2$ of this type of collector installed in California(USA) and in operation since the 1980s.

Various researchers tried to improve efficiency of the solary energy collections are described below Abdul jabber *et al* worked on a effecting of two axis sun tracking on the performance of compound cpc. P.Rushi prasad conducted an experiment on cylindrical parabolic collector with and without tracking system in winter and partly cloudy days. Sagade conducted on

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parabolic trough made of fiber glass- reinforcement plastic with its aperture area coated by alumunium foil with a reflectivity of 0.86[3].Several developments have been carried out to improve the performance of the PTC.The design and performance characteristics of a parabolic trough solar collector system were thoroughly studied by kalogairou *et al* (1994a).The optimization of the collector aperture and the rim angle as well as the selection of a receiver diamerter was addressed in this study.In a later study, the authors kalogirou *et al* (199b) described a low cost method[5].Almanza *et al* (1997) investigated the receiver behavior of PTCs in direct steam generation under different experimental conditions, and they concluded that by replacing the steel absorber tube with copper, it is almost possible to eliminate the thermal stress in the wall of the pipe, due to the smaller circumferential temperature differences. Lokurlu *et al* (2005) developed a new kind of solar air-conditioning unit through parabolic trough collectors,combined with a double effect absorption chiller for the air-conditioning of buildings.The performance and detection of the optical losses of the PTC are very important issues, in order to improve the optical efficiency to ensure the desired output energy quality. Brooks *et al* (2006) conducted the baseline performance study of a parabolic trough solar collector, using the ASHRAE 93-1986 standard. Luupfert *et al* (2007) summarized the various techniques available for analyzing the optical performance of the PTC .The use of the PTC on a small scale model for hot water generation was performed by Valan Arasu and Sornakumar (2006).

Apart from other studies present work deals with finding efficiency of solar concentrated parabolic trough collector with various mixutre combinations of ethylene glycol and water

2. Experimental set up

2.1. Components of experimental setup of parabolic trough collector

- Parabolic trough collector
- Digital thermometer with thermocouples
- Rota meter
- Water pump
- Pyrano meter
- Pyrheliometer
- Heat exchanger
- Energy meter

2.1.1. Cylindrical parabolic trough collector

- It is a Non-tracking type of solar collector
- Cylindrical parabolic trough collector consist of a parabolic reflector of about 1-5m^2 aperture area
- An absorber tube made of steel or copper with diameter 2.5-5cm and coated with selective coating and
- A concentric tubular glass cover surrounding absorber with a gap of about 1-2cm when is evacuated

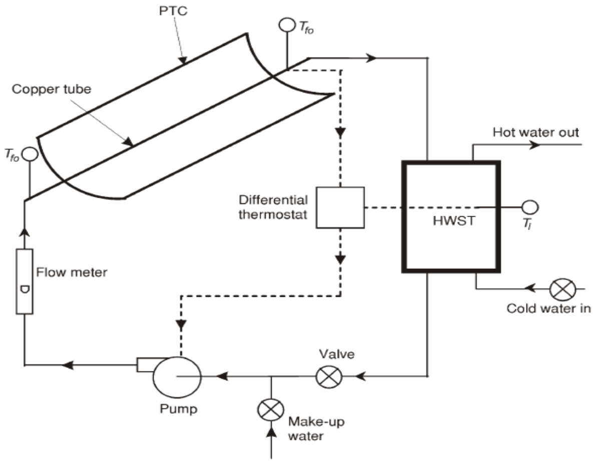

Fig.1 Parabolic Trough collector with storage tanks

2.2 Specification of the Cylindrical Parabolic Collector

1) Length of the receiver of the collector = 2m
2) Width of the receiver of the collector = 0.5m
3) Length of absorber pipe = 2m
4) Diameter of the absorber pipe = 25mm
5) Material of the collector = galvanised iron
6) Thermal conductivity of material= 204.2w/mk
7) Density of the material = 2707kg/m3
8) Material of the absorber pipe - copper
9) Thermal conductivity of the pipe= 386 w/mk
10) Density of the material pipe = 8954kg/m3
11) Thickness of the collector = 10 mm
12) Focal length of the collector = 300 mm
13) Location of the collector = Chickaballapur
14) Latitude and longitude of place = 130249”, 7704349

Fig.2. Cylindrical Parabolic Trough Collector

3. Methodology

It is a cylindrical parabolic collector on non-tracking Arrangements

- Tank and parabolic collector are to be filled with water completely.
- The inlet water temperature of the collector is to be noted by using calibrated digital indicator.
- The outlet water temperature of the parabolic collector to be by using calibrated digital indicator at an interval of every one hour between 9.30am to 4.30pm.
- Efficiency of the parabolic collector is to be calculated.
- Same procedure is repeated for different days.

4. Devices used to measure solar irradiation

(a) Pyranometer: It is a type of of actionometer used For measuring solar irradiance on a planar surface and it is designed to measure the solar radiation flux Density(W/m^2) from hemisphere above within a wave Length range 0.3µm-3µm

Fig.3 Pyranometer

(b)Pyrheliometer

Pyrheliometer is an instrument for measurement of direct beam solar irradiance. Sun light enters the instrument through window and it is directed into thermopile which converts heat to an electric signal that can be recorded. The signal voltage is converted via a formula to measure watts per square meter. A pyrheliometer is often used in same setup with a pyranometer.

Fig.4 Pyrheliometer

5. Performance analysis of parabolic trough collector

To find out efficiency of the system it is essential to know energy absorbed by aperture. Efficiency and energy absorbed by aperture can be calculated as below

1. To find the concentration ratio
C=Efficiency aperture area/Absorber tube area

=(W-D)L/πDL=W-D/πD

2. To find the useful heat gain of the fluid

Useful heat gain of the fluid (qu)

=Mw*Cpw*(Two-Twi)

Where
Mw=Mass flow rate of water (kg/sec)
Cpw=Specific heat of water (kj/kgk)
Two=Water outlet temperature (°C)
Twi=Water inlet temperature (°C)

3. To find the heat supplied to the collector

(a) Heat supplied to the collector (Hs)=Ib*Ac

(b)Solar flux (Ib) = Pyr heliometer reading (mV)*3.1552*221.4/4.95 W/m^2

(c)Effective aperture area (Ac)=Wc*Lc (m^2)

4. To find the thermal efficiency of parabolic trough collector

Thermal efficiency of the collector (η) =
Useful heat gain of the fluid (qu)/Heat supplied to the collector

Table 1 Efficiency of parabolic trough collector and parameters obtained from experimentation with 50% ethylene glycol concentration

S.No	T_{in} ℃	T_{out} ℃	T_{am} ℃	$\dot{m}$ kg/sec	I_b µV	H_s	η
1	31.5	38.8	30	0.005	651.3	338	47.2
2	35.3	40.7	30	0.005	691.3	381	31.2
3	33.3	40.7	30	0.011	701.4	409	48.2
4	34.5	41.2	29	0.011	751.5	423	54.5
5	30.9	39	30	0.016	801.6	451	59.7
6	33.3	40.6	31	0.022	791.5	367	63
7	32.1	40.2	31	0.022	801.6	423	65.8
8	34	40.1	31	0.022	751.5	409	67

6. Results and Discussion

To improve efficiency of the parabolic trough collector various compositions of ethylene glycol and water are used as working fluids. At 50% concentration of ethylene glycol the efficiency of the parabolic trough collector observed to be maximum. Since during experiment many graphs like time Vs solar flux, time Vs mass flow rate. But ultimately any change in above parameters should be reflected in the efficiency of the system.

At 50% concentration there may be increase in thermal conductivity of working fluid and density can be decreased (since ethylene glycol has lower density than water). So, thermal diffusivity may be lower for this composition from the experimental study.

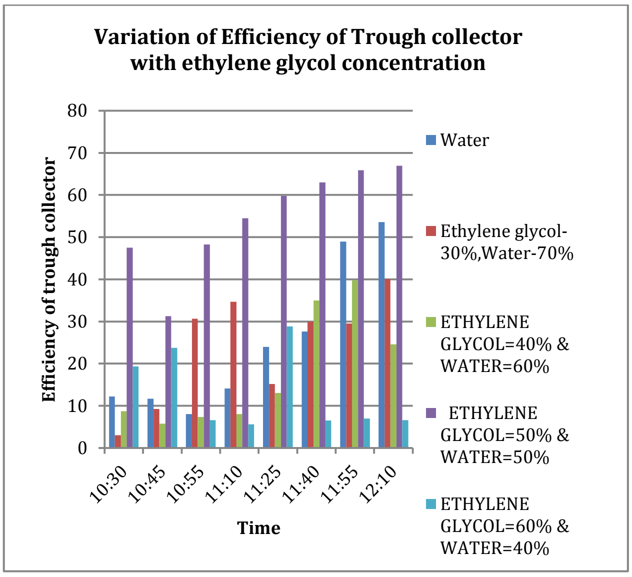

Fig.5. Variation of Efficiency of Trough collector with ethylene glycol concentration at same instants of time in consecutive days

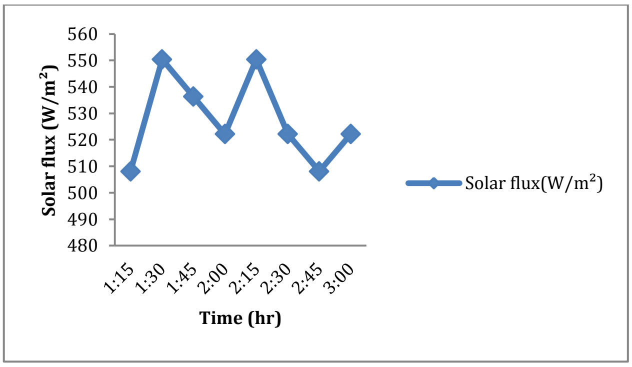

Fig.6. Variation of solar flux with time in day

Conclusion

From the above experimental investigation it can be concluded that solar parabolic concentrated trough collector with 50% concentration ethylene glycol as heat transfer fluid gives maximum efficiency compared to other compositions and water itself. It has following advantages.

1. Ethylene glycol is cheap in cost. Its installation cost can be easily recoverable
2. Mixture has lower C_p Values so that higher temperatures are produced.it is an added advantage because heat at higher temperature is very useful.
3. Thermal conductivity of fluid is enhanced.
4. Viscosity of resultant mixture is low which decreases pumping work.
5. Mixture is non-toxic and can have low freezing point since ethylene glycol is anti freezent.

These are the main advantages which shows impact on the efficiency of the system

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