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RESEARCH ARTICLE

DESIGN, FABRICATION AND PERFORMANCE EVALUATION OF SOLAR PARABOLIC TROUGH COLLECTOR

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ABSTRACT

In this paper an attempt has been made to design and fabricateand evaluate the performance of parabolic trough collector to produce hot water. In the design of PTC it was considered the parabolic aperture of 2.007m x1.0622m made up of acrylic mirror sheet as a reflector material and Galvanised iron pipe was used for receiver material. The results of the evaluation to determine the thermal performance of the parabolic trough collector have a maximum outlet temperature of 55oC and the corresponding maximum thermal efficiency calculated was 10.67%.

INTRODUCTION

Due to the energy crisis and scarcity in conventional energy resources and the subsequent increase in oil prices, the awareness to use alternate energy sources, including solar energy, has gained momentum both in industrialized and developing countries. Intensified research and development on renewable energy sources, which followed the energy crisis, resulted in demonstration of the technical feasibility of many alternate energy options which shows solar energy is the most promising unconventional energy sources. Solar collectors are special kind of heat exchangers that transforms solar energy to internal energy of the transport medium in the tubes to be carried out as usable energy. The most common applications of solar collectors are mostly found in solar water heating and space heating, industrial processes, vapour absorption and air conditioning system, desalination of seawater or generation of solar electricity. Therefore, due to their wide range of applications it is necessary for the engineers or designers to determine or optimise the thermal performance of solar collectors. One of the most important element of PTC system is the optically selective coating of solar absorber, which should ideally behave as a black body, absorbing a maximum of the incoming solar radiation, while minimizing energy losses by infrared radiation. There are so many absorbing surfaces exist, commercially available selective coatings for glazed solar collectors should typically absorb at least 95% of the incoming solar radiation and have a thermal emittance lower than 0.05. Another important element of PTC system isthe reflector, reflectors may be of anodized, aluminium Mylar or curved silvered glass. The polar configuration intercepts more solar radiation per unit area as compared to east-west, north-south orientation and thus gives the best performance.

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Experimental

PTC Design

The design parameter of a PTC can be classified as geometric and functional. The geometric parameters of a PTC are its aperture width and length, rim angle, focal length, diameter of the receiver and the concentration ratio. The functional parameters of a PTC are optical efficiency, instantaneous and all day thermal efficiency and receiver thermal losses. These parameters are largely influenced by the properties of the materials used and the optical errors associated with the system. The material properties are reflectivity of the mirror, transmissivity of the glass envelope and absorptivity of the absorber. The errors are due to the defects in the reflector material, support structure, location of the receiver with respect to the focal plane of PTC and misalignment of PTC with respect to the sun caused by tracking errors. In the design of the PTC system three acrylic mirror sheet of 2.007 m long and 1.062 m wide were placed longitudinally as a reflector unit and GI pipe was used as a receiver. The input parameters in collector design were aperture width of PTC (W_a)= 1.062 m and rim angle (Ψ)= 90^0.

Construction of PTC

PTC system basically consists of following three main components i.e., receiver, reflector, collector support structure. Cylindrical GI pipe was used for receiver of 2.12 m in length. For reflector three acrylic mirror sheet were used of 2.007m x 1.062m. For collector`s stability and accuracy, a rigid supporting structure was designed made up of rigid iron strips. The structure was designed for easy manual tracking about the horizontal axis of the PTC.

Experimental Instrumentation

The setup consists of a parabolic trough collector assembly which includes a water container of 25 litres capacity located 2m high from PTC, to allow the water to flow naturally. The water flow from the container, passes through the absorber pipe where it was heated, and then recollected by a beaker to measure the flow rate. The water inlet and outlet temperature of the absorber tube, ambient temperature, reflector temperature were measured with the help of K type digital thermocouples, Solar intensity was measured by solarimeter and wind velocity was also measured continually with the help of Anemometer. The setup was oriented North-south to capture maximum solar radiation.

Testing

The testing was carried out from 10 am to 4:30 pm with a solar intensity in the range of 350-900 W/m^2. Inlet water was taken from a tank at a height of 2m from the base of PTC. Plastic pipe was used to connect the water tank and the inlet of the receiver of the PTC system, for controlling the flow of water a tab was used. At the outlet of receiver, a beaker was used to measure the mass flow rate of the water. Initial temperature of water in the tank was measured and it was 33^{0}c which flows naturally to the receiver tube and remains there for 30 minutes for solar heating, after 30 minutes the output of receiver tube was measured and the output temperature of water46.2^{0}c measured was recorded. Temperature of water was measured after every 30 minutes of interval at the inlet and outlet of receiver. To ensure that the incoming beam radiations should always remain normal to the reflector of PTC, parabolic trough was manually rotated after every 30 minutes along with the sun about the focal line of the parabola and it was held in that position for the next 30 minutes with the help of iron supporting strings.

Table 1. Observation Table For PTC

Time	Tinlet	Trec.	Tamb	Toutlet	SI	WV	Ta
10:00	28.8	34.9	34.5	36	320	1.2	33
10:30	30.9	38.2	38.5	39	380	0.9	38
11:00	32.1	48.9	45.5	43	450	1.2	38
11:30	35.8	48.5	50.5	49	530	1.8	39
12:00	37.3	48.1	50.2	52	600	1.4	40
12:30	38.3	45.4	48.2	55	670	1.6	41
01:00	38.5	46.6	45.6	55	790	0.6	41
01:30	38.3	47.5	46.9	55	820	0.3	39
02:00	39.1	47.1	47.3	54	780	0.5	39
02:30	40.2	46.6	48.4	53	670	1.6	38
03:00	39.9	43.3	47.2	51	580	1.5	38
03:30	39.5	43	46.6	50	520	0.6	38
04:00	38.6	43	43.3	47	460	0.8	38
04:30	37.9	43.1	40.4	43	350	1.4	38

RESULTS AND DISCUSSION

Thermal Evaluation

Calculation for thermal efficiency corresponding to maximum outlet temperature of water:

$\eta = Q*100/(A_a*H_b*\rho*R_b)$

Where,
Q= net useful heat gained by the fluid in Watt= $mC_p(T_6-T_1)$
m= mass flow rate of fluid in Kg/sec
C_p= Specific heat of fluid= 4180 J/Kg K
T_6= Outlet temperature of water in ^{0}C
T_1= Initial temperature of water in ^{0}C
A_a= Aperture area in m^2
H_b= Solar intensity in W/m^2
ρ= Reflectivity of collector material
R_b= Tilt factor for beam radiation
Mass flow rate(m)= 0.001756 Kg/sec
For, initial temperature of (T_1)=38.3^{0}C at 12:30 pm
And final temperature of (T_6)= 55^{0}C at 12:30 pm
Q= $mC_p(T_6-T_1)$= 122.57 W
$\eta = Q*100/(A_a*H_b*\rho*R_b)$= 10.67%

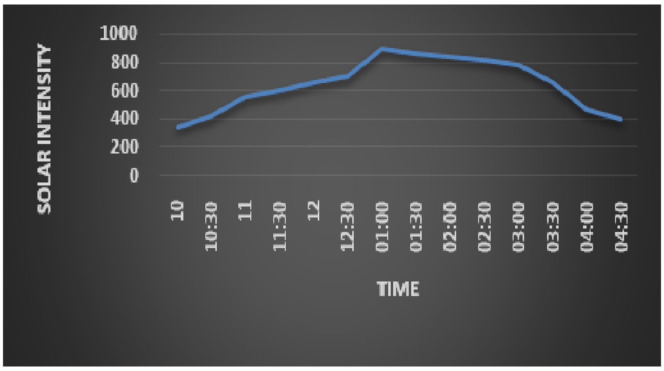

Fig. 1. Variation of Solar intensity with time of the day

Fig.1 shows the variation of solar intensity with time, as it was expected the maximum intensity of 700-900 W/m^{2}was observed between 12:30pm to 1pm

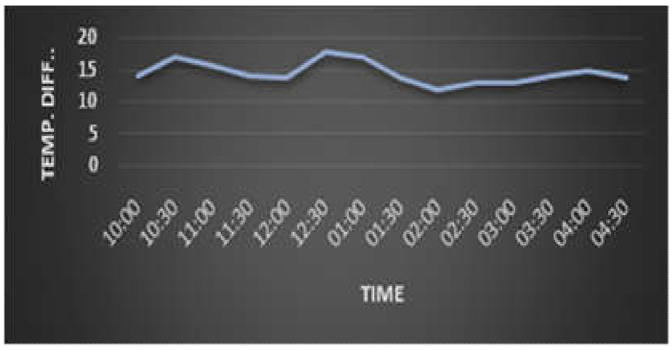

Fig. 2. Variation of temperature difference with time

Fig. 2 shows the variation of temperature difference between inlet and outlet temperature with time of the day and it was observed that the maximum temperature difference recorded at 12:30 pm of around 16.8^{0}C.

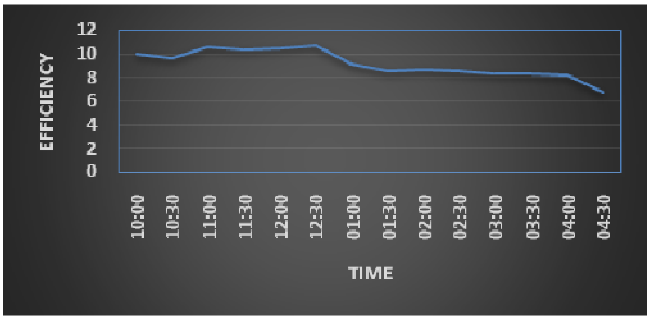

Fig. 3. Variation of Instantaneous thermal efficiency with time

Fig.3 shows the variation of instantaneous thermal efficiency of the system with time of the day and it was observed that the maximum instantaneous thermal efficiency calculated was at 12:30 pm of around 10.67%

Conclusion

The design, fabrication and performance evaluation of the PTC system were presented and it was found that the maximum outletwater temperature obtained from the PTC was 55^0C and corresponding to this maximum temperature the thermal efficiency calculated was 10.67% which is quite efficient. Finally, it is very important to mention that the thermal efficiency of the collector is strongly related to the atmospheric conditions like intensity of solar radiation, wind velocity and the cloudiness.

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