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Effect Of Unglazed Solar Flat Plate Collector On Thermal Efficiency And Outlet Temperature

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Abstract

The Present research article deals with the experimental investigation of an unglazed flat plate collector for the climatic condition of Dehradun, Uttarakhand, India. In the present study water is used as the working fluid, and the mass flow rate and temperature of inlet water was kept fixed at 0.0051kg/sec and 32˚C from the preliminary investigation. The experiment was carried out for two consecutive days and the outlet temperature of the unglazed flat plate collector was found to be 36˚C and 37˚C with the instantaneous efficiency of 11.11% and 13.79% for with the maximum solar intensity of 1140W/m^2 and 1145W/m^2 respectively for the day 1 and 2. The study shows without glazing material the outlet temperature was directly proportional to the solar intensity also the maximum heat gain during experimentation was found for day 2.

Keywords: Unglazed Flat Plate Collector, Instantaneous Efficiency, Heat Gain, Mass Flow Rate.

Nomenclature

FPC - Flat Plate Collector

DBT – Dry Bulb Temperature

ETC – Evacuated Tube Collector

INTRODUCTION

The consumption of the energy in each and every sector is increasing day by day which causes rapid increase in demand of the energy throughout globe. Few years back the conventional sources are the main sources of energy but due to limited in nature the interest shifted towards non-conventional sources of energies like solar energy, wind energy, hydro energy etc. Out of all the non-conventional sources of energy solar energy shows more promising compared to other energy sources like it is excess in nature and can be used for wide applications like generation of direct electricity from sun radiation with the help of PV modules and conversion of thermal energy by the help of different collectors[1], without any harm to nature[2]. There are different types of collectors but generally FPC as shown in Fig.1[3] is used for thermal conversion of solar radiations because of its simple working principle. FPC works on the principle of greenhouse effect in which glass surface acts as atmospheric layer which allows shorter wavelength radiations from sun to pass through it but does not allow longer wavelength radiation reradiated back from absorber plate to pass through it. So again, the longer wavelength radiations from glass strikes the absorber plate and this phenomenon goes on and increases the temperature of plate that was then passed to a high conductive pipe through which fluid passes. Some of the latest literatures are listed below in which authors and coauthors contributed in field of FPC to increases in thermal efficiency, outlet water temperature of the FPC.

Fig.1 Flat Plate Collector. 1,2. Cold Water Tank 3. Digital Indicator Display 4. Absorber Plate 5. External Radiation Panel 6. Hot Water Storage Tank [3]

M.K. Mansour[4] presented a numerical investigation over a mini channel based FPC and obtained results shows deviation less than 10% when compared to experimental work. The h_f (W/m^{2}K) and η_i was found to be 1517.8 W/m^{2}K and 66.4% for proposed solar still which was around 350% and 11% high compared to conventional collector respectively. Merzha et al.[5] experimented on FPC with twisted pipes under external radiation panels with variation in solar intensity from 200 to 1000W/m^2. The results shows that the performance was higher by 13.5% for twisted evaporator compared to thermosiphon type collector for maximum solar intensity. Unar et al.[6] performed a computational analysis with water and air as a working fluid with FPC. The simulation was performed for the climatic condition of Hyderabad, India. The maximum exit temperature of water and air at flow rate of 5×10^-^{6}kg/s was found to be 79.74˚C and 73.33˚C respectively. Due to low thermal conductivity of air the temperature outlet of air is less as compared to that of water. Junaid et al.[7] performed a simulation study with the help of Ansys fluent on SFPC at constant mass flow rate of the inlet water. The best results were obtained for 12:00pm with the outlet water temperature of 40.89˚C when the inlet water temperature was 25˚C. Kim et al.[8] performed an analytical study over FPC and ETC on thermal characteristics. Results shows less loss coefficient factor for ETC compared to FPC. Abuska et al.[9] performed an experimental investigation by modifying absorber plate of solar air collector with the help of conical springs to increase the heat transfer area. The mass flow rate of air was kept 0.06kg/s, 0.07kg/s in the study. The maximum output temperature of 43.2˚C was found for modified air heater at 0.06kg/s mass flow rate while for conventional heater the output temperature was found to be 40.6˚C. The maximum thermal efficiency was found to be 65.9% and 50.4% for modified and conventional solar air heater respectively. Dhaundiyal et al.[10] performed an experimentation to investigate the psychometry effect on the performance of the SC. The efficiency of SC at mass flow rate of 5.2g/s was found around 42% at average DBT of 26.4˚C. Wang et al.[11] performed a numerical investigation on SC U and Z type arrays. U denotes reverse flow of fluid inside manifold whereas Z denoted parallel flow of the fluid inside manifold. The results show irrespective of more pressure drop in Z array to be more compared to U array yet the efficiency was high in case of Z array. Chopra et al.[12] performed a theoretical investigation on designs, coatings on glazing surface, size of manifold, ways to decrease losses of FPC to make it suitable for wide applications. Qiu et al.[13] performed an experimental investigation over FPC coupled with reflectors. The polyline reflectors enhance the solar radiation on the collectors by 40.3% compared to parabolic and flat plate reflectors for summer season. Ammar et al.[14] performed a simulation study on FPC with different slats. The thermal efficiency was achieved to 81% when 6 slats at tilt angle of -45˚ and FPC tilted at 45˚. Subramanian et al.[15] performed an experimental investigation over MSS by integrating FPC to achieve maximum distillate output. The productivity of CSS was found to be 1610ml while MSS with FPC the output productivity was found to be 3100ml. Alwan et al. [16]conducted an experimental investigation for ambient condition of Yekaterinburg, Russia over solar water collector. The maximum outlet inlet temperature difference was found to be 7.99˚C for the July month when the maximum solar intensity was 1022W/m^2. Farhana et al.[17] performed an analysis on FPC with Al_2O_3, CNC nanofluids. The efficiency of FPC was enhanced by 2.48% and 8.46%

with 0.5% wt. concentration of Al_2O_3, CNC nanofluids. Moravej et al. performed an experimental investigation over FPC with different concentration of TiO_2 nanoparticles. The maximum efficiency gain was found for 5% concentration with 33.54% while in case of 1% and 3% the maximum gain was found to be 17.41% and 27.09% respectively.

From reviewing the above literature many authors have contributed to enhance thermal performance and outlet temperature of the water from FPC by introducing various nano particles, reflectors, design, varying glass angle etc. but from the best knowledge of the author no work has been reported on FPC without glazing material. In order to fill this gap an experimental study was performed at Graphic Era to be Deemed University, Dehradun.

Experimental Setup and Procedure

In this experimental setup the FPC was modified by removing glazing surface as shown in Fig.2 and table 1 shows materials used for fabrication. A wooden casing of dimensions (1.23m x 0.56m) was made for outer frame work of the collector. It surrounds and protects the foregoing components employed in the system. A thin layer of thermocol of 1inch thickness is placed at side and bottom of the casing. A thin sheet of aluminum of size 1.22m × 0.55m is coated with a black paint that is extremely efficient at absorbing, reflecting the sunlight and converting it into usable heat. The main function of absorber plate is to absorb the incident solar radiation to gain heat and allowing efficient transfer of heat to the working fluid. The flow tubes are the tubes used to facilitate the circulation of working fluid. Water is most commonly used working fluid in the solar flat plate collectors. Water enters the collector at inlet of the tube and leaves at outlet. The copper tube of 0.5-inch diameter was used in this work as flow tube. The water tank of 10-liter capacity is used to supply the water to the solar collector and thermometer is used to measure temperature of inlet and outer water.

Fig.2 Experimental Setup of Flat Plate Collector

Table 1 Materials Used for Fabrication of Setup

S NO.	COMPONENTS	MATERIALS	DIMENSIONS
1	Casing	Wood	1.23m × 0.56m
2	Insulation	Thermocol	1.22m × 0.55m
3	Absorber plate	Aluminum	1.22m × 0.55m
4	Flow tube	Copper	Length 1.3m, inner diameter 12.7 mm
5	Water supply tank	Plastic	10 liters
6	Pipes	Plastic hose	2 m
7	Temperature Measuring Device	Thermometer	-

Results and Discussions

The study has been carried for the climatic condition of Dehradun at Graphic era to be Deemed for latitude of 30.3165˚N and longitude of 78.0322˚E. The preliminary investigation was carried out a day on experimental setup and found 0.0051kg/s to be optimum mass flow rate of inlet water to the tubes of the FPC and table 2 shows the properties of working fluid.

Table 2 Properties of Working Fluid (Water)

Properties	Properties of Fluid
Density (kg/m$^{3)}$	998
Specific Heat Cp (J/kg.K)	4187
Thermal Conductivity k (W/mK)	0.6
Viscosity (Kg/m.s)	0.001003

The study was carried for two consecutive days for the total absorber area of $0.671m^2$. The instantaneous efficiency of the FPC was calculated by using eqn. 1.

$$\eta = \frac{Qu}{A.I(t)} \qquad (1)$$

Table 3 Shows Results Obtained

Days	1	2
Inlet temperature (Ti)	32	32
Outlet temperature (To)	36	37
Temperature Difference (Td)	4	5
Mass flow rate of water(kg/sec) (M_w)	0.0051	0.0051
Heat Gain (Q_u)	85.41	106.76
Solar Intensity W/m^2	1140	1145
Thermal Efficiency (η)	11.11%	13.79%

From the table 3 the results obtained for the experimental setup FPC without glazing the thermal efficiency of the setup for day 1 was found to be 11.11% while for the second day it was found to be 13.79% due to more solar intensity for 2nd day.

Conclusions

On the basis of above experimentation some conclusions were made:

1. By using black painted aluminum as the absorber plate the thermal efficiency was found to be 13.79% without glazing.
2. The maximum heat gain was found to be 106.76 W.
3. The outlet temperature of water was enhanced by 5°C for the solar intensity of $1145W/m^2$.
4. Solar Intensity directly effects the efficiency of the FPC more the intensity more will be the thermal efficiency and outlet temperature of water.

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