Available online www.ejaet.com

European Journal of Advances in Engineering and Technology, 2016, 3(12): 51-55

Research Article ISSN: 2394 - 658X

Experimental Investigation of Solar Flat Plate Collector with Double Glazing System

H Vettrivel and P Mathiazhagan

Department of Mechanical Engineering, Pondicherry Engineering College, Pondicherry, India
vettri9994@gmail.com

ABSTRACT

Solar energy is received from sun can be converted into useful energy in the form of heat energy. One of the most efficient method water is heated using solar flat plate collector. This heated water can be used for domestic as well as industrial applications. The efficiency of collector depends with many parameters such as area of the collector, number of glass cover, wind velocity and overall top heat loss coefficient. To reduce top loss heat transfer coefficient and improve heat transfer the conventional solar flat plate collector has modified with double glazing arrangements. The modified solar collector has installed at a latitude angle of 12 degree facing towards north-south directions. The experiments were carried out in thermosyphon principle from 10:00 to 16:00 hrs. The results show that over all top loss heat transfer coefficient has marginally reduced and collector efficiency 68% obtained. The flow pattern also studied using CFD analysis

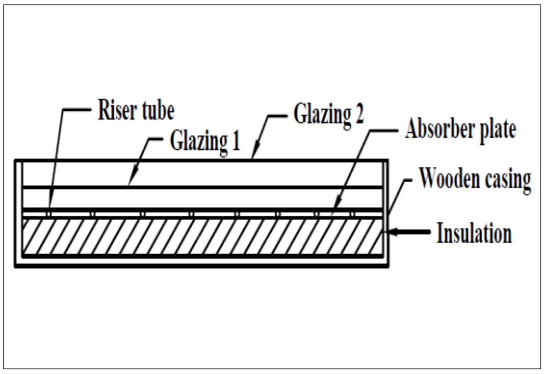
Key words: Solar collector, double glazing system

INTRODUCTION

The solar flat plate collector is an environmental friendly device which absorbed solar energy and convert into thermal energy, economically and reducing the fossil fuel energy [1]. Based on the literatures review [2] the solar flat plate collectors showing higher heat losses and hence lower thermal performance. The collector produced a hot water temperature around 50-70 ^{0}C depending upon the location, solar intensity, wind velocity and number of glazing. A large number of research investigations have been undertaken to modify the design such as spacing between absorber plate and glazing, working fluid etc [3, 4], to enhance the thermal performance of the flat plate collectors. The present work is focused toward the optimize space between absorber plate to glass (0.05 m), introduction of double glazing and considered wind velocity effect. Based on these factors over all top loss heat transfer coefficient (U_t) was calculated using thermal resistance concept. To identify the flow pattern CFD analysed also carried out and results were included.

EXPERIMENTAL SETUP

Fabricated solar flat plate collector and cross sectional view are shown in Fig. 1(a) and (b). It consists of absorber plate, riser tubes, header tubes and double glazing. The absorber plate is made up of aluminium and black painted to improve the absorption of solar energy. The riser and header tubes were used 0.01m and 0.012m diameter respectively. The distances between riser's tubes were arranged 0.05 m to minimize the heat loss and improve the heat transfer rate. The thickness of the glass was made with 3mm and to decrease the conduction resistances from top glazing to absorber plate. The six thermocouples were fixed in a collector and connected to digital temperature display unit to measure the temperature. The Pyranometer (PRY 300-3V) and anemometer (ambient air speed by accuracy ± 0.03 m/s.) used to measure solar intensity and wind velocity. Water from the storage tank enters the flat plate collector through header and riser tubes. Water gets heated in the riser tubes of the flat plate collector due to the solar radiation and its density will decrease the lighter density water move up and stored in the upper portion of storage tank. Higher density water from the bottom of the tank again enters the flat plate collector gets heated and moves up and stored in the water storage tank. Hot water from the storage tank can be used for domestic and industrial applications. The experiments have been carried out from 10:00 to 16:00 hrs. The specifications of collector and experimental values are shown in Table-1 and 2-4.



(a)

(b)

Fig.1 (a) Cross Sectional view of Solar Flat Plate Collector and (b) Experimental set-up of Solar Flat Plate Collector

Table-1Specification of Flat Plate Collector

Collector length	1	m
Collector width	0.6	m
Collector height	0.15	m
Absorber Plate material	Aluminium	-
Thickness of absorber plate	0.02	m
Riser tube diameter	0.01	m
Header tube diameter	0.012	m
Tube center to center distance	0.05	m
Plate -to -cover space	0.05	m
Cover -to -cover space	0.05	m
Number of tubes	8	-
Glass cover emmisivity (ε_g) /Transmittance (τ)	0.88	-
Absorber plate emmisivity (ε_p) /Absorbtance (α)	0.95	-
Diameter of header pipes	0.012	m
Insulating material	Glass –wool	-

Table-2 Experimental Values for the Flat Plate Collector- Day 1

T	I	T_P	Tg_{2-P}	Tg_1-g_2	T_o	V	h_w	Volume of water
10:00	746	79	72	67	51	2.4	10	1.5
11:00	900	88	75	63	65	1.9	8.5	3.2
12:00	960	93	86	80	71	1.7	7.9	5.6
13:00	1020	91	88	83	76	1.6	7.6	6.2
14:00	990	92	87	82	74	1.5	7.3	5.9
15:00	740	84	61	59	50	2.3	9.7	1.4
16:00	650	79	77	75	36	1.2	6.4	0.6

Table-3 Experimental Values for the Flat Plate Collector- Day 2

T	I	T_P	Tg_{2-P}	Tg_1-g_2	T_o	V	h_w	Volume of water
10:00	720	89	87	84	65	1.2	6.4	2.4
11:00	890	79	72	62	52	2.0	8.8	1.7
12:00	930	89	87	85	65	1.6	7.6	3.1
13:00	1000	85	81	77	73	1.9	8.5	5.8
14:00	780	84	82	79	54	1.7	7.9	1.6
15:00	640	73	72	69	56	1.5	8.8	1.3
16:00	580	74	71	68	54	0.8	5.2	1.0

Table-4 Experimental Values for the Flat Plate Collector- Day 3

T	I	T_P	Tg_{2-P}	Tg_1-g_2	T_o	V	h_w	Volume of water
10:00	726	87	85	60	65	1.5	7.3	1.9
11:00	840	72	67	62	61	2.2	9.4	1.5
12:00	970	88	82	79	80	1.7	7.9	2.2
13:00	1065	81	79	76	72	2.3	9.7	2.0
14:00	840	77	70	66	74	1.2	6.4	1.9
15:00	762	85	82	79	64	1.3	6.7	1.8
16:00	635	73	72	69	55	1.4	7.0	1.2

EFFICIENCY OF THE COLLECTOR

The efficiency of the collector can be expressed by useful heat and over all heat loss (Q_u and U_t). The experimental values were substituted and calculated using Eq (1-7), and obtained values are presented in Table-5.

$$U_t = \left\{ \frac{N}{(C/T_m)\left[(T_m - T_a)/(N+f)\right]^{0.252}} + \frac{1}{h_w} \right\}^{-1} + \frac{\sigma(T_m + T_a)(T_m^2 + T_a^2)}{\left[\varepsilon_p + 0.0425N(1-\varepsilon_p)\right]^{-1} + \left[(2N + f - 1)/\varepsilon_g\right] - N} \quad (1)$$

$$f = \left[(9/h_w) - (30/h_w^2)\right](T_a/316.9)(1 + 0.091N) \quad (2)$$

$$h_w = 2.8 + 3.0V \quad (3)$$

$$C = \frac{204.429(\cos\beta)^{0.252}}{L^{0.24}} \quad (4)$$

Useful heat gain from the collector can be described in the following equation

$$Q_u = A_c[S - U_t(T_{pm} - T_a)] \quad (5)$$

Solar flux absorbed by collector can be expressed

$$S = I_s(\tau_c \alpha_p) A_C \quad (6)$$

The instantaneous solar collector efficiency η is defined as:

η= Useful heat gain collected / solar energy incident on the collector

$$\eta = (Q_u / S\,A_c) \quad (7)$$

Table-5 Values of Overall Top Heat Loss Coefficient (U_t), Useful Heat Gain (Q_u), and collector Efficiency (η_c)

Day -1

S	U_t	Q_u	η
374	3.5	109	48
451	3.6	184	68
481	3.6	168	58
511	3.6	200	65
496	3.6	200	67
371	3.6	108	48
326	3.4	112	57

Day -2

S	U_t	Q_u	η
361	3.5	97	44
446	3.4	172	64
466	3.5	160	57
501	3.5	189	62
391	3.5	125	53
321	3.4	109	56
290	3.3	91	52

Day -3

S	U_t	Q_u	η
364	3.5	103	47
421	3.4	171	67
486	3.5	174	59
534	3.5	218	68
421	3.3	164	65
382	3.5	124	54
318	3.3	110	57

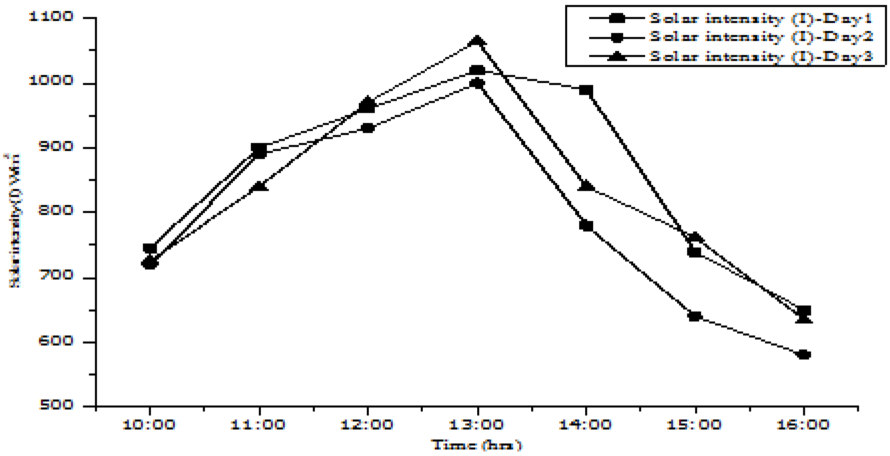


Fig.2 Solar Intensity Vs Time

RESULTS AND DISCUSSION

The graph plotted between solar intensity with time as shown in fig 2. The results show that higher intensity was obtained at 13:00 hrs for all three days. After that solar intensity reduced with respect to the time. The variation of solar intensity from the graph all three days due to clouds were noticed in the atmosphere.

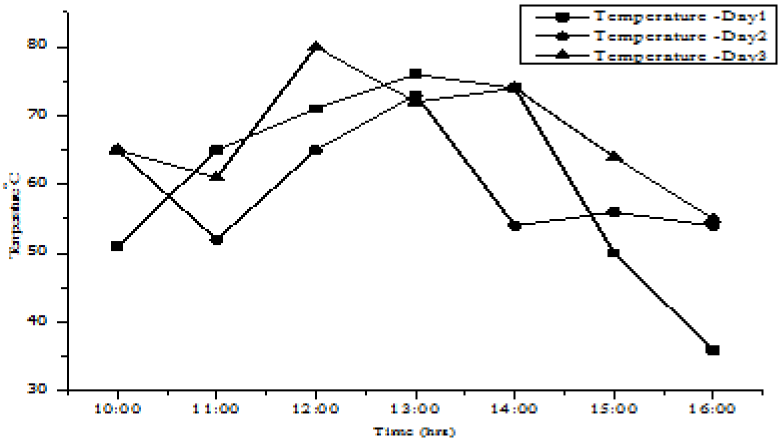


Fig.3 Outlet Temperatures of Water Vs Time

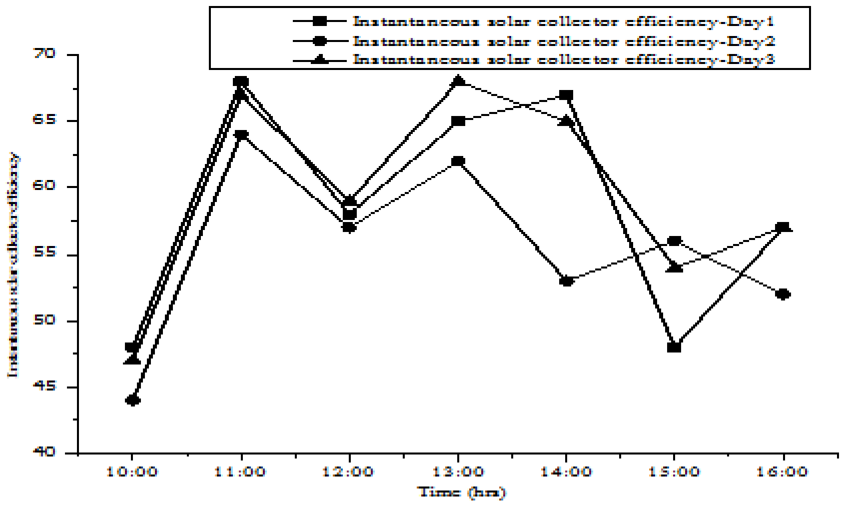


Fig.4 Instantaneous efficiency Vs Time

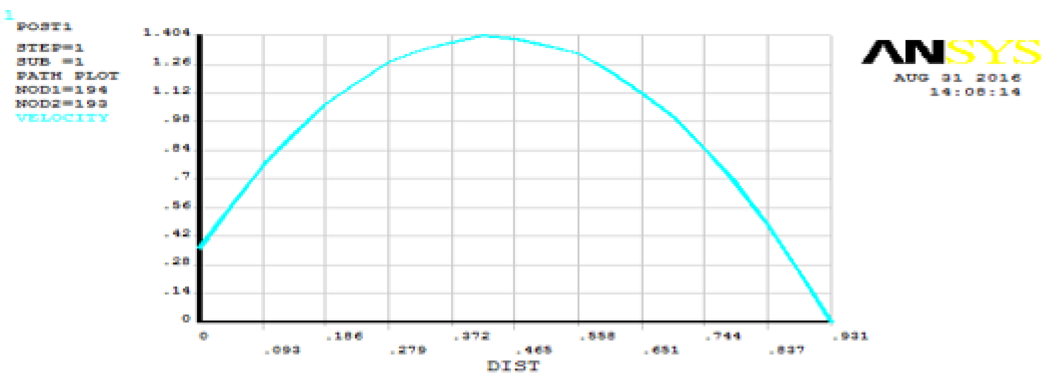


Fig.5 Velocity Variations within the Tube Length

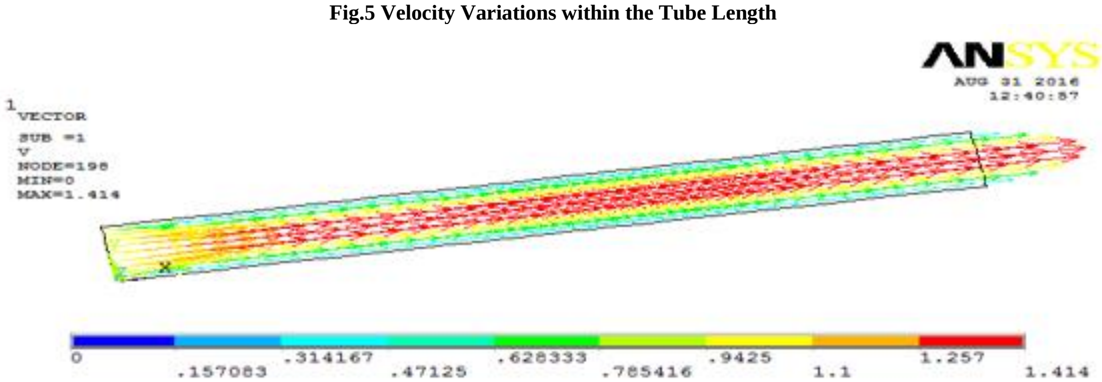


Fig.6 Flow Velocity Contours of Riser Tube Inlet to Outlet

From the graph Day-1 outlet temperature gradually increased up to 13:00 hr after that it is reduced due to solar intensity as shown in Fig 3. However, Day-2 at 10:00 hr outlet water temperature 65was obtained after that the temperature of water immediately reduced due to wind velocity effect at 11:00 hr. In Day-3 the maximum outlet temperature obtained at 12:00 hr due to less wind velocity. However, at 13:00 hr outlet temperature reduced even though there is high solar intensity this because of high wind velocity. Usually, during low wind velocities, heat-transfer takes place by free convection whereas forced convection takes over at medium and high wind velocities.

Fig. 4 shows the comparison graph between the instantaneous efficiency vs Time. The result shows that all the three days at 11 hr obtained higher compared to 12 hr, this due the temperature difference between mean plate and ambient temperature ($\Delta T=T_{pm} - T_a$) higher values that is higher loss from the collector. This also confirmed at 12 the instantaneous efficiency (η) was reduced as shown in fig. 4. CFD by using ANSYS (software version 11.4) used to identify the flow pattern of the water inside the tubes have analyzed. The boundary conditions are density of water, specific heat of water, thermal conductivity of water and volume of water taken from the experimental value (1.96 liters/hr) at initial conditions. The results show that bell shape curve has obtained this indicate that flow is fully developed laminar flow and maximum velocity also observed at centre as shown in fig.5 -6. The water is heated both surface of the tubes.

CONCLUSIONS

From the experimental results the following conclusion were obtained.

1. Using double glazing system, the maximum water outlet temperature 80^0C and efficiency 68% were achieved
2. The top heat loss coefficient (U_t) has reduced and obtained higher useful heat transfer rate (Q_u) this because of double glazing effect.
3. The wind velocity also affects the thermal performance of solar collector even though there is high solar intensity, therefore wind velocity not more than 2 m/s.
4. For the domestic applications double glazing solar collector is much more suitable than single glazing system. The Double glazing system has obtained higher outlet temperature.
5. The process industries or power generation the double glazing solar flat plate collector system with nanofluid may be considered as a future work.

NOMENCLATURES

S	Solar flux absorbed by collector W/m^2
A_c	Collector Area (m^2)
C_p	Specific Heat Capacity (J/kg-K)
I	Solar Radiation (W/m^2)
T	Time (hrs)
N	Number of glass cover
L	Spacing between plates (m)
m	Flow Rate per Unit Collector Area kg/m^2
η	instantaneous solar collector efficiency
U_t	Overall top heat loss coefficient (W/m^2K)
T_a	Ambient temperature ^{0}C
T_p	Absorber plate temperature^{0}C
T_{wi},T_{w0}	Water inlet and outlet temperature^{0}C
T_{g1},T_{g2}	First and second glass covers temperature ^{0}C
V	Wind speed (m/s)
h_w	Wind heat transfer coefficient (W/m^2K)
Q_u	Useful heat energy collected (W)

REFERENCES

[1] S Eswaran, M Chandru, M Vairavel and R Girimurugan, Numerical Study on Solar Water Heater using CFD Analysis, *International Journal of Engineering Sciences & Research Technology*, **2014,** 3, 1485–1489.
[2] Ruchi Shukla, K Sumathy, Phillip Erickson and Jiawei Gong, *Recent Advances in the Solar Water Heating Systems: Review* **2013,** 19, 173–190.
[3] Bukola Olalekan Bolaji and Isarel Abiala,Theoretical and Experimental Analysis of Heat Transfer in a Flat Plate Solar Collector, *Walailak Journal of Science and Technology*, **2012**, 9, 239–248.
[4] SC Mullick and SK Samdarshi, An Improved Technique for Computing the Top Heat Loss Factor of Flat-Plate Collector with a Single Glazing, *ASME Journal of Solar Energy Engineering*, **1988,** 110, 262–267.