ISSN: 2277-9655
(I2OR), Publication Impact Factor: 3.785
(ISRA), Impact Factor: 2.114

IJESRT

INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

EXPERIMENTAL STUDY ON SOLAR FLAT PLATE COLLECTOR WITH AND WITHOUT COATING

S. Anil Kumar*, Dr. K. Sridhar, G. Vinod Kumar

Department of Mechanical Engineering, KITS, Warangal, Telangana, 506015, India

ABSTRACT

Solar Flat Plate Collector is widely used for domestic hot-water, space heating and cooling, for applications requiring fluid temperature less than 100ºC. The main components associated with Flat Plate Collector are top cover, absorber plate with tubes. The objective of this paper is to make a comparative study of change in temperature, useful energy and thermal efficiency for two different collectors one with copper as absorber plate and another with black chromium coated copper as absorber plate. The absorber plate is selectively coated to have high absorptivity. The absorptivity of black chromium paint is about 0.92 to 0.96. It absorbs radiation energy emitted by the sun and converted into thermal energy of the fluid. For comparative study, the two flat plate collectors set ups are fabricated. It is established that the significance of coating the flat plate collector is technically and economically viable for gaining heat from radiation through flat plate solar collectors. From experimentation, it is observed that the change in temperature, useful heat gain and thermal efficiency are higher for coated absorber plate.

KEYWORDS: Flat plate collector, absorption coating, performance of solar collector.

INTRODUCTION

With the increasing in demand of energy for growing population and depletion of resources available for energy generation, a global movement towards production of alternative sources. Renewable Energy Sources are generated for mating the energy demands for present and future few sources such as solar, wind, biomass, tidal, etc. are renewable, economical and ecofriendly in nature. [1,2]

Solar energy is the radiation produced by nuclear fusion reactions in the core of the sun. This radiation travels to earth through space in the form of energy called photons. Even though only 30% of the solar power actually reaches the earth, every 20 minutes the sun produces enough power to supply the earth with its needs for an entire year. Unfortunately the atmosphere and clouds absorb a large amount of incident radiation from the sun. So the incident radiation that reaches any point on the groung depends on the time of day, month , year , the amount of cloud cover and latitude at that point.[7,8]

Solar energy collectors are employed to gain usefuel energy from incident solar radiation.Thermal energy could be stored in gerenal, in the form of either sesible or latent heat. Common systems used in storing thermal energy include water tanks or gravel beds, ground, sand, concrete etc., where energy is stored in the form of sesible heat. Latent heat thermal storage is also an efficient and suitable heat storage means.[3,9]

NOMENCLATURE

A_c – Collector area (m^2)
C_{pw} – Specific heat of water (kJ/Kg K)
I_t – Intensity of solar radiation on tilted surface (W/m^2)
m_w – mass flow rate (kg/sec)
$Q_{u,cu}$ – Useful heat gain of copper absorber plate collector (W)
$Q_{u,bc}$–Useful heat gain of coated absorber plate collector (W)
$T_{in,cu}$ – Inlet temperature of water for copper absorber plate (^OC)

ISSN: 2277-9655
(I2OR), Publication Impact Factor: 3.785
(ISRA), Impact Factor: 2.114

$T_{in,bc}$ – Inlet temperature of water for coated absorber plate collector (^{O}C)
$T_{out,cu}$ – Outlet temperature of water for copper absorber plate (^{O}C)
$T_{out,bc}$ – Outlet temperature of water for coated absorber plate collector (^{O}C)
$\eta_{c,cu}$ – Efficiency of copper absorber plate collector (%)
$\eta_{c,bc}$ – Efficiency of coated absorber plate collector (%)

DESCRIPTION OF EXPERIMENTAL SETUP

The primary function of the absorber plate is to absorb the possible radiation energy reaching the collector through the glazing. The setup consists of a collector element made of copper tubes and copper plate as an integrated element. Another setup is also made with same specifications and the collector element is coated with black paint which has the high absorptive in nature. Factors that determine the choice of absorber material are its thermal conductivity, its durability and ease of handling. Absorber plates are usually given a surface coating to increase the fraction of available solar radiation energy. Black paints, for which have absorptivity range between α = 0.92 to 0.96. Figure 1 show the two experimental setup for carrying the work with the necessary arrangements for fluid flow.

Fig. 1. Experimental Setups

ANALYSIS OF SFPC

Performance analysis on simple solar flat plate collector (SFPC) [4,5,6]

FOR COPPER ABSORBER PLATE

Efficiency, $\eta_{c,cu}=Q_{u,cu}/(I_t*A_c)$
Heat gain by water, $Q_{u.cu}= m_w*C_{pw}*(T_{out,cu}-T_{in,cu})$
$T_{in,cu}$ =Inlet temperature of water
$T_{out,cu}$, = Outlet temperature of water
Specific heat of water, C_{pw}=4.18kJ/Kg K
Useful heat gain, $Q_{u,cu}$, W

FOR BLACK COATED ABSORBER PLATE

Efficiency, $\eta_{c,bc}=Q_{u,bc}/(I_t*A_c)$
Heat gain by water, $Q_{u,bc}= m_w*C_{pw}*(T_{out,bc}-T_{in,bc})$
$T_{in,bc}$ Inlet temperature of water with coated plate
$T_{out,bc}$ = Outlet temperature of water with coated plate
Useful heat gain, $Q_{u,bc}$, W

RESULTS AND DISCUSSION

Table 1. shows the experimental values that are recorded and the results made. The experiment is carried out simultaneously on the two setups prepared for constant mass flow rate and environmental conditions. The

experimentation is conducted on sunny days and presented the averages values during experimentation period with respect to time.

Table 1: Performance of SFPC with coated absorber plate.

S.No	Time	Inlet Temp. $T_{in,bc}$ (°C)	Outlet Temp. $T_{out,bc}$ (°C)	Useful heat gain $Q_{u,bc}$ (W)	Intensity I_t (W/m²)	Efficiency $\eta_{c,bc}$ (%)
1.	10:00 AM	27	43	557.33	710.65	5.22
2.	10:30 AM	28.2	45	585.2	718.65	5.42
3.	10:45 AM	29	48	661.83	727.17	6.06
4.	11:00 AM	31	51	696.66	747.67	6.21
5.	11:15 AM	32	52	696.66	751.46	6.18
6.	11:30 AM	32.6	54	745.43	754.55	6.58
7.	11:45 AM	33.2	55	759.36	756.95	6.68
8.	12:00 PM	33.8	55	738.46	759.87	6.47
9.	12:15 PM	34	57	801.16	759.07	7.03
10.	12:30 PM	34.3	57.5	808.13	757.59	7.11
11.	12:45 PM	34.8	58.5	825.55	755.43	7.28
12.	1:00 PM	35.2	62	933.53	741.51	8.39
13.	1:15 PM	35.6	63	954.43	740.04	8.59
14.	1:30 PM	35.8	65	1017.1	736.04	9.21
15.	1:45 PM	36.1	67.5	1093.7	705	10.34
16.	2:15 PM	37	68.2	1086.8	668.14	10.84
17.	2:45 PM	38	69	1079.8	565.6	12.72
18.	3:10 PM	35	61	905.66	601.27	10.04
19.	3:25 PM	34	57	801.16	584.04	9.14
20.	3:40 PM	33.2	55.3	769.81	565.67	9.07
21.	3:55 PM	32	52	696.66	546.16	8.50

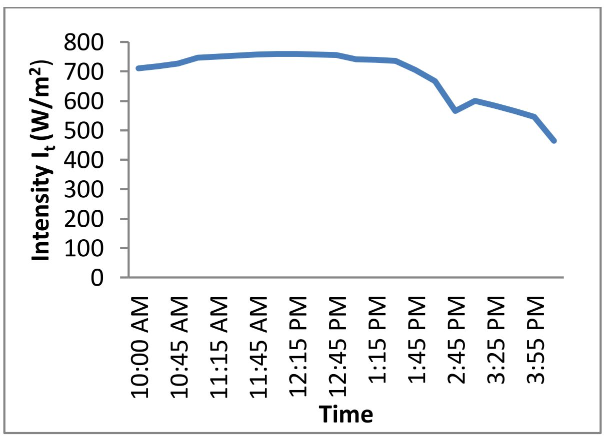

Fig. 2. Variation of intensity with respect to time

From the Fig 2. during the day progress the intensity slowly increases till midday and then starts decreases 3:00PM onwards.

ISSN: 2277-9655
(I2OR), Publication Impact Factor: 3.785
(ISRA), Impact Factor: 2.114

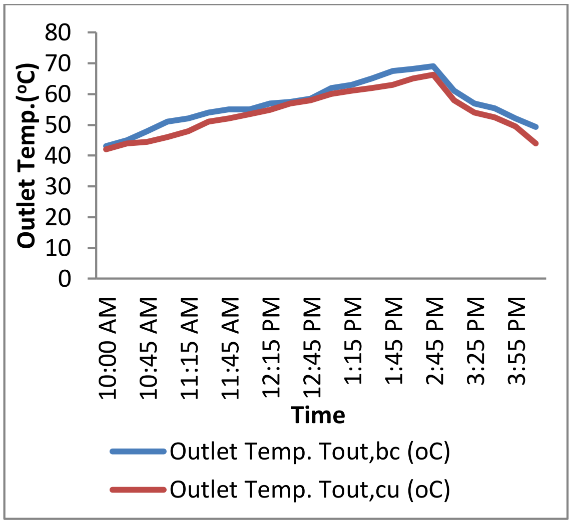

Fig. 3. Variation of outlet temperatures with respective time

Table 2: Variation of outlet temperatures of two collcetors.

S.No	Time	Outlet Temp. $T_{out,cu}$ (ºC)	Outlet Temp. $T_{out,bc}$(ºC)	Change in outlet temperature ΔT_{out} (ºC)
1.	10:00 AM	42	43	1
2.	10:30 AM	44	45	1
3.	10:45 AM	44.5	48	3.5
4.	11:00 AM	46	50	4
5.	11:15 AM	48	52	4
6.	11:30 AM	51	54	3
7.	11:45 AM	52	55	3
8.	12:00 PM	53.5	55	1.5
9.	12:15 PM	54.8	57	2.2
10.	12:30 PM	56.9	57.5	0.6
11.	12:45 PM	58	58.5	0.5
12.	1:00 PM	60	62	2
13.	1:15 PM	61	63	2
14.	1:30 PM	62	65	3
15.	1:45 PM	63	67.5	4.5
16.	2:15 PM	65	68.2	3.2
17.	2:45 PM	66.3	69	2.7
18.	3:10 PM	58	61	3
19.	3:25 PM	54	57	3
20.	3:40 PM	52.4	55.3	2.9
21.	3:55 PM	49.5	52	2.5

ISSN: 2277-9655
(I2OR), Publication Impact Factor: 3.785
(ISRA), Impact Factor: 2.114

From table.2 and fig. 3, it has been observed that the outlet temperatures of black coated plate collector is always higher than the copper tube collector. The maximum change in temperature is found between 11:00 AM to 3:00 PM.

From table. 3, it has been observed that the usefuel heat gain of black coated plate collector is always higher than the copper tube collector. The maximum change in useful heat gain is observed during 11:00AM to 3:00PM.

Table. 3. Variation of usefuel heat gain of two collectors.

S.No	Time	Useful heat gain Qu,cu (W)	Useful heat gain Qu,bc (W)	Change in useful heat gain ΔQu (W)
1.	10:00 AM	522.5	557.33	34.83
2.	10:30 AM	550.36	585.2	34.83
3.	10:45 AM	539.91	661.83	121.91
4.	11:15 AM	557.33	696.66	139.33
5.	11:30 AM	640.93	745.43	104.5
6.	11:45 AM	654.86	759.36	104.5
7.	12:00 PM	686.21	738.46	52.25
8.	12:15 PM	724.53	801.16	76.63
9.	12:30 PM	787.23	808.13	20.9
10.	12:45 PM	808.13	825.55	17.41
11.	1:00 PM	863.86	933.53	69.66
12.	1:15 PM	884.76	954.43	69.66
13.	1:30 PM	912.63	1017.13	104.49
14.	1:45 PM	937.01	1093.76	156.75
15.	2:15 PM	975.33	1086.8	111.46
16.	2:45 PM	985.78	1079.83	94.04
17.	3:10 PM	801.16	905.66	104.5
18.	3:25 PM	696.66	801.16	104.5
19.	3:40 PM	668.8	769.81	101.01
20.	3:55 PM	609.58	696.66	87.08

Table 4. Variation of efficiency of two collector with same intensity

Intensity (W/m^2)	Efficiency $\eta_{c,cu}$ (%)	Efficiency $\eta_{c,bc}$ (%)	Increase in efficiency with coated collector
710.65	4.901616	5.22839	0.326774
718.65	5.105561	5.428697	0.323136
727.17	4.949935	6.067663	1.117728
747.67	4.658918	6.211891	1.552973
751.46	4.944449	6.180561	1.236112
754.55	5.662831	6.586118	0.923287
756.95	5.767591	6.687951	0.92036
759.87	6.020474	6.478886	0.458412
759.07	6.363342	7.036388	0.673046
757.59	6.927523	7.11144	0.183917

755.43	7.131773	7.285475	0.153702
741.51	7.766734	8.393084	0.62635
740.04	7.97044	8.598034	0.627594
736.04	8.266157	9.212664	0.946507
705	8.860678	10.34295	1.482272
668.14	9.731826	10.84403	1.112204
565.6	11.61932	12.72788	1.10856
601.27	8.883049	10.04171	1.158661
584.04	7.952271	9.145112	1.192841
565.67	7.882099	9.072624	1.190525
546.16	7.440839	8.503817	1.062978

From table 4 the maximum increase in the efficiency of coated collector is observed at 705W/m^2

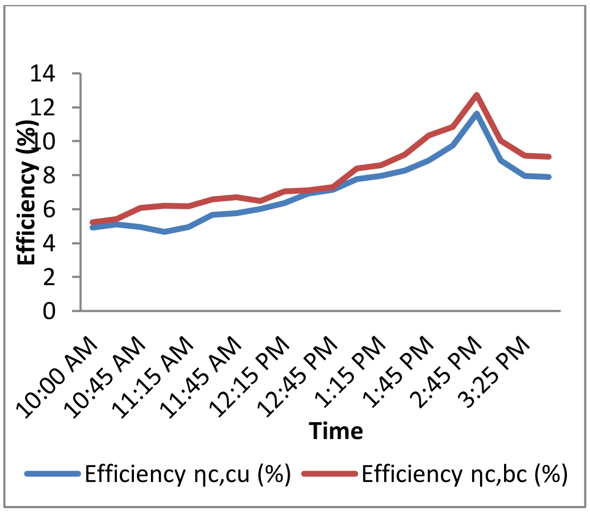

Fig. 4. Efficiency comparison of two collectors

Fig. 4. Shows the comparison between two collectors with respect to time and maximum efficiency for copper absorber plate collector is 11.6% where as for black coated absorber plate is 12.72%.

CONCLUSIONS

The significant conclusions of experimentation study are as follows:

1. As the intensity increases, the out let temperature, useful heat gain and efficiency of the collectors increases.
2. The maximum intensity is to be found at 12:00PM and the value obtained is 759.87 W/m^2.
3. The maximum temperature gained by copper absorber plate is 66.3^0 C where as for coated absorber plate is 69^0 C.
4. The maximum change in temperature is found to be 4.5^0 C at 1:45PM.
5. The maximum heat gained by copper absorber plate is 985.78 W where as for coated absorber plate is 1093.76 W.
6. The maximum change in heat gained is found to be 156.75 W at 1:45 PM.
7. The maximum efficiency for copper absorber plate is found to be 11.61%.
8. The maximum efficiency for coated absorber plate is found to be 12.72%.
9. The percentage increase in the efficiency of coated collector compared with copper collector is 1.48%.

ISSN: 2277-9655
(I2OR), Publication Impact Factor: 3.785
(ISRA), Impact Factor: 2.114

BIBLIOGRAPHY

[1]. Sunil.K.Amrutkar, SatyshreeGhodke, Dr. K. N. Patil, "Solar Flat Plate Collector Analysis", IOSR Journal of Engineering (IOSRJEN), Vol. 2 Issue 2, Feb.2012, pp.207-213.

[2]. Madhukeshwara. N, E. S. Prakash, "An investigation on the performance characteristics of solar flat plate collector with different selective surface coatings", Volume 3, Issue 1, 2012 pp.99-108.

[3]. B.K. Gond, M. K. Gaur, C. S. Malvi, "Manufacturing and performance analysis of solar flat plate collector with phase change material", ISSN 2250-2459, Volume 2, Issue 3, March 2012.

[4]. H. Vettrivel and Dr. P. Mathiaragan, "Experimental Study on a Flat Plate Solar Collector", ISSN 2249-0019, Volume 3, Number 6 (2013), pp. 641-646.

[5]. Alok Kumar, "Performance of Solar flat plate by using semi circular cross sectional Tube", ISSN 2091-2730, Vol.2, issue 2, Feb-2014.

[6]. F.F. Mammadov, "Estimation of flat plate solar collector productivity", ISSN 2077-3528, Vol.4, issue 10, No.1, Mar. 2012.

[7]. AnandBisen, P.P. Dass & Rajeev Jain, "Parameteric studies of Top heat loss coefficient of Double glazed flat plate solar collectors", ISSN 2230-7699, Vol.1, No.2, Aug.2011.

[8]. S. Anil Kumar*,Dr. K. Sridhar, G.Vinod Kumar "Effect Of Tilt Angle Of A Solar Air Heating System" Int. Conf. on Advanced Materials, Manufacturing, Management & Thermal Sciences (AMMMT 2013), May 03-04 ISBN-13 978-81-926304-0-3

[9]. G. Vinod Kumar*,Dr. K. Sridhar, S. Anil Kumar "Energy And Exergy Analysis Of A Solar Flat Platecollector"Int. Conf. on Advanced Materials, Manufacturing, Management & Thermal Sciences (AMMMT 2013), May03-04ISBN-13 978-81-926304-0-3

Author Biblography

	**S. Anil Kumar*** Assistant Professor MED,KITS, Warangal Research Scholar Pursuing the research in the area of solar energy and its applications.
	**Dr. K. Sridhar** Professor of MED & Dean, Student Affairs, KITS, Warangal Published more than 20 papers in the areas of Thermal Engg. and Energy Systems. Presently guiding 3 research scholars in the area of solar engineering , Exergy Analysis and one student awarded with PhD from NIT Warangal
	**G. Vinod Kumar** Assistant Professor MED,KITS, Warangal Research Scholar, KU, Warangal Pursuing the research in the area of solar energy and its applications.