Experimental Analysis of Parabolic Solar Dish with Copper Helical coil Receiver

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Abstract— Solar Parabolic Dish is currently used for the Water heating and cooking applications. Generally Solar Parabolic Dishes are fixed focus point concentrators, but in order to achieve higher thermal efficiency we tried to make it line focus concentrator by using a unique receiver (copper tube in the form of helical coil) mounted at focal point.This report presents experimental platform based on the design, development and performance characteristics of direct steam generation by non-tracking solar paraboloidal dish concentrating system. The performance of the concentrator is experimentally investigated with the water circulated as heat transfer fluid. The system is fabricated with highly reflective aluminium foil sheet (0.8 reflectance factor). The experimental setup is placed in open, and the tests were carried out. The collector's efficiency was noted. The results are encouraging to provide the data for developing steam generation for rural application. The concentrated heat is absorbed by a copper tube which is made up of coil in a curved shape (22cm diameter and length with 15 no of turns) and it is fixed on solar trace path in which, it is eliminates tracking the sun in the east west direction and optimal tracking of the sun in the north-south to obtain maximum solar energy. The experimental results are taken on summer and cloud free days. The test results were measured 215^{o}C with solar steam conversion efficiency is 60-70% measured.

Keywords— Point Concentrator, Focal Point, Coil Receiver

I. INTRODUCTION

Sun is the singular source of renewable energy that sits at the center of the solar system. This energy is released at the rate of 3.83 10^{26} W. The intensity of solar radiation per unit time on a unit surface outside the earth's atmosphere is known as "solar constant". Its value is 1353 W/m^2. The solar radiation as received on the earth's surface is composed of the following:

i) Beam radiation (I_b) is that solar radiation which is received directly from sun without change of direction.
ii) Diffuse radiation (I_d) is that solar radiation which is received directly from sun after its direction has been changed by reflection.
iii) Global radiation (I_g) is the sum of beam and diffused radiation

M. Mohamed, Auatf.S.Jassim, Yaseen. H. Mahmood [6], carried out design and fabrication of solar dish concentration with diameters (1.6) meters for water heating application and solar steam was achieved .The dish equipped with tracking system and measurement of the temperature and solar power. Water temperature increased up to 80 C^{O}, and the system efficiency increased by 30% at mid noon time. Ibrahim Laden Mohammed[1] carried out design and development of a parabolic dish solar water heater for domestic hot water application (up to100^{O}C) is described. The heater is to provide 40 litres of hot water a day for a family of four. Thermal efficiencies of 52% - 56% were obtained, and this range of efficiencies is higher than the designed value of 50%.

Meenakshisundaram Arulkumaran and William Christraj [2] experimentally investigated with the water circulated as heat transfer fluid. The concentrated heat is absorbed by a copper tube which is made up of coil in a curved shape and it is fixed on solar trace path in which, it is eliminates tracking the sun to obtain maximum solar energy. The test results were measured 215^{o}C with solar steam conversion efficiency is 60-70% measured.

Joshua Folaranmi [5] carried out design, construction and testing of a parabolic dish collector, where heat from the sun is concentrated on a black absorber located at the focus point of the reflector in which water is heated to a very high temperature to form steam. The whole arrangement is mounted on a hinged frame supported with a slotted lever for tilting the parabolic dish reflector to different angles so that the sun is always directed to the collector at different period of the day. On the average sunny and cloud free days, the test results gave high temperature above 200°C.

Adel M. Al-Nasser [4] said that Hourly values of useful energy gain are calculated after considering the optical and thermal losses of the collector. The months of April and August offer the largest irradiation and useful solar energy rates compared to other months. The prediction hours starts from 5 a.m. to 8 p.m. to account for variation in sunrise and sunset times of different months. It is observed that thermal losses provide low proportion to the absorbed radiation predicted at 3.5%.

Cédric Philibert [3] studied present and future use of solar thermal energy. The main technologies belong to either "passive" and "active" solar energy forms. Passive solar energy relates to the design of buildings collecting and transforming solar energy used for day lighting and natural ventilation. Active solar energy relates to the use of solar collectors for water or space heating purposes, active solar cooling, heat pumps

Lifang Li and Steven Dubowsky [7] developed new design approach for solar concentrating parabolic dish based on optimized flexible petals. The dish mirror is formed from several optimal-shaped thin flat metal petals with highly reflective surfaces. Attached to the rear surface of the mirror petals are several thin layers whose shapes are optimized to have reflective petals form into a parabola when their ends are pulled toward each other by cables or rods.

II. Experimental Set-Up

The experimental setup consists of a solar parabolic dish system, absorber, and heat transfer fluid as water which is circulated through the system from water tank. A galvanized steel pipe is used to carry the water from tank to the absorber tube and absorber tube is a coiled tube made up of copper. It is located in the focal point on the solar trace of parabolic dish.

When the sunlight rays are incident on the reflective surface they are reflected and conveyed to the surface of the tube at the curve to heat the water and to take change phase. The parabolic dish made with highly reflective panels with 0.8 of reflectance factor. The reflector cut into small shapes and fixed parabolic which can be turned conveniently.

Fig 1 Parabolic dish concentrator experimental setup.

The out let pipe is connected to the other end of the absorber tube and generated steam is delivered to the application. The circulating fluid flow measured by collecting in a vessel with respect to the time. The reflection surface can be deteriorated when exposed to the open atmosphere, and it can be cleaned by rubbing polish and can be washed. It can be maintained with good environment stability and weather ability to be monitored during the test. Many methods have been developed to study the focal image characteristic of heat flux and heat flux on the absorber.

III. Experimental Procedure

Expected Thermodynamic Performance of Parabolic Dish Concentrator [1]

- ✓ The estimated useful energy for one cycle of the designed PDSWH is given by
  $\dot{q}_{use} = \eta I_b A_a$
- ✓ The efficiency range of most solar concentrators is 40% - 60% (Magal,1993)
- ✓ Avg value of solar beam radiation at Pune in first quarter of 2014 is 714 W/m^2
- ✓ Hence $\dot{q}_{use}$ = 0.55(average of 0.4 and 0.6) x 714 x 1.56 =604.75W
- ✓ For four cycles total useful energy is Q_{use}= 4 xq_{use} = 4 x 604.75 = 2419W

Useful energy is also given by $\dot{q}_{use} = \dot{m}_w C_{pw} (T_w - T_a) = \eta . I_D . A_a$

$$\dot{m}_w = \frac{\eta\, I_D\, dish^2}{4 \times c_{pw} \times (T_w - T_a)} = 0.13 \text{ litres per minute.}$$

$\dot{m}_w$ is also given by $\dot{m}_w = \dfrac{\rho_w \times V_w}{t}$

Where t= time required to heat the water . ρw at 30°c = 995.7 kg/m^3

Therefore t = 45 min to heat 6 liters of water.
For four cycles total time required is =180 minutes to heat 24 liters of water.
The energy, P_{abs}, absorbed by the absorber is obtained from:

$\eta_o = \dfrac{P_{abs}}{A_a I_D}$, $P_{abs} = n_o \times A_a \times I_D$, Divide and multiply by n, we get

- ✓ $P_{abs} = \dfrac{n_o}{n}(nA_aI_D)$
- ✓ $n_o = 0.65$ (average of 0.6 and 0.7)
- ✓ Also we know $\dot{q}_{use} = \eta I_D A_a$ put in equation we get,
- ✓ $P_{abs} = 0.65/0.55\ \dot{q}_{use} = 1.18\ q_{use} = 1.18 \times 604.75 = 714W$

IV. Results

The objectives of the present investigation may be stated as,

- ✓ To understand theoretical analysis of parabolic dish concentrator.
- ✓ To find out efficiency of concentrator.
- ✓ To test by varying pitch of receiver and find out optimum receiver length.
- ✓ To fabricate copper helical coil tube receiver of 0.22M diameter and length.
- ✓ To compare performance of PDC with point focusing and line focusing

Validation of Experimental Set up

Testing was done during the summer and clear sky with cloud free days during the month of April 2014 for about seven days. The tests were taken between 10 am to 4 pm in data were taken on each hour for 7 hours. The k type thermocouple with digital indicator used to measure temperature.

Table 1 Receiver temperature variation with Time- Results on 5th April 14

Time	*T_a ambient temperature ^{o}C*	*T_g receiver temperature ^{o}C*
10 am	32	90
11 am	32	115
12 am	34	130
1pm	35	145
2pm	34	170
3pm	33	150
4pm	32	130

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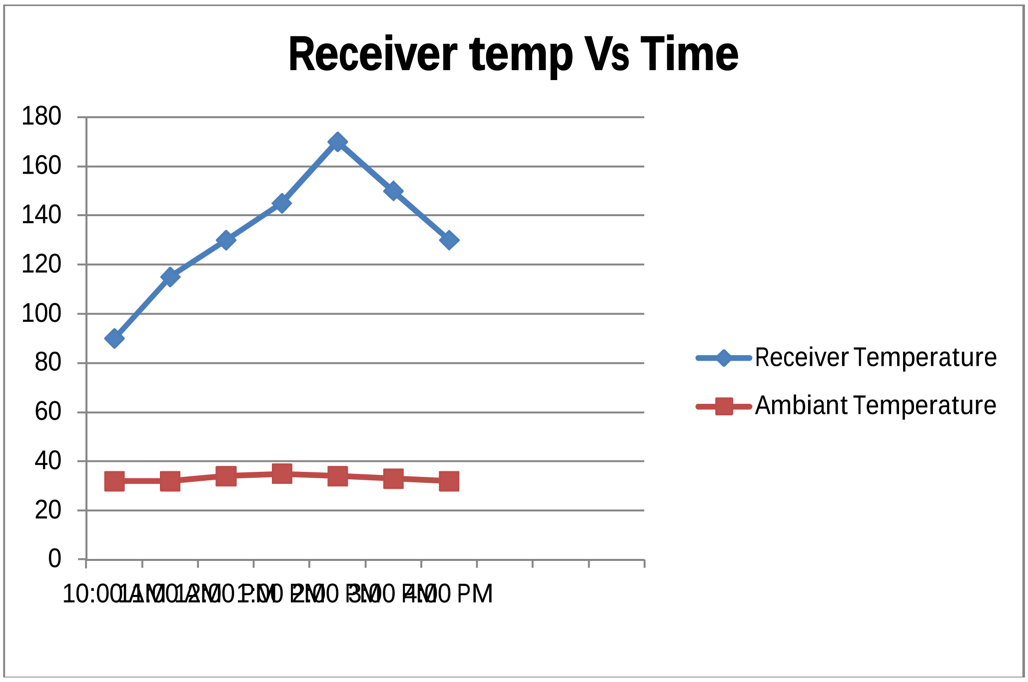
Table 2 Temperature variation with mass flow rate in kg/sec

Sr.No.	Mass flow rate Kg/sec	Temperature of receiver in ^{0}C
1	0.0013	140
2	0.0014	138
3	0.0015	136
4	0.0016	133
5	0.0017	130
6	0.0018	128
7	0.0019	125

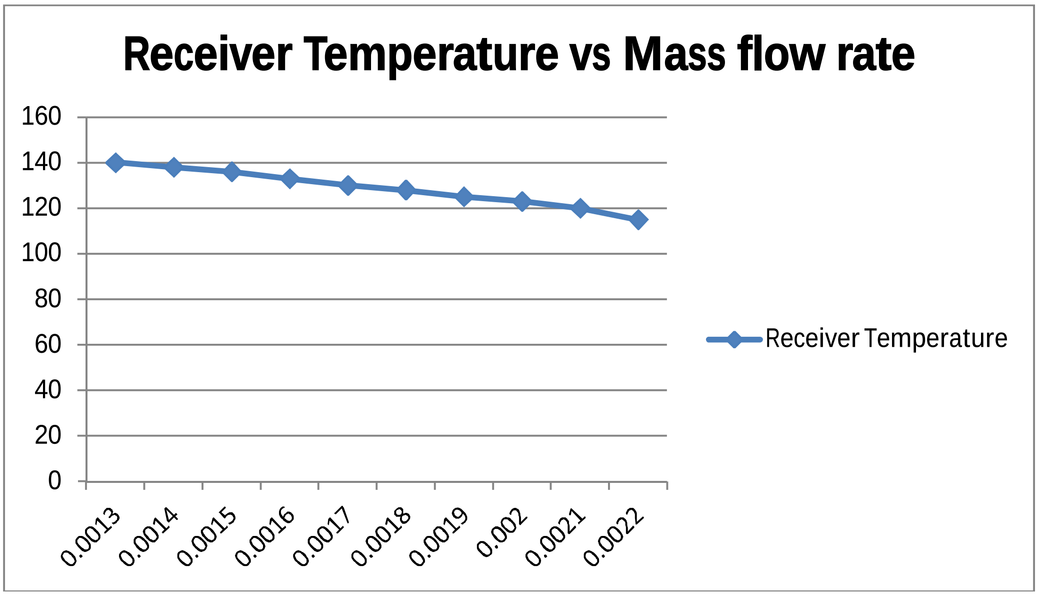
Table 3 Comparison of Helical coil and cavity receiver

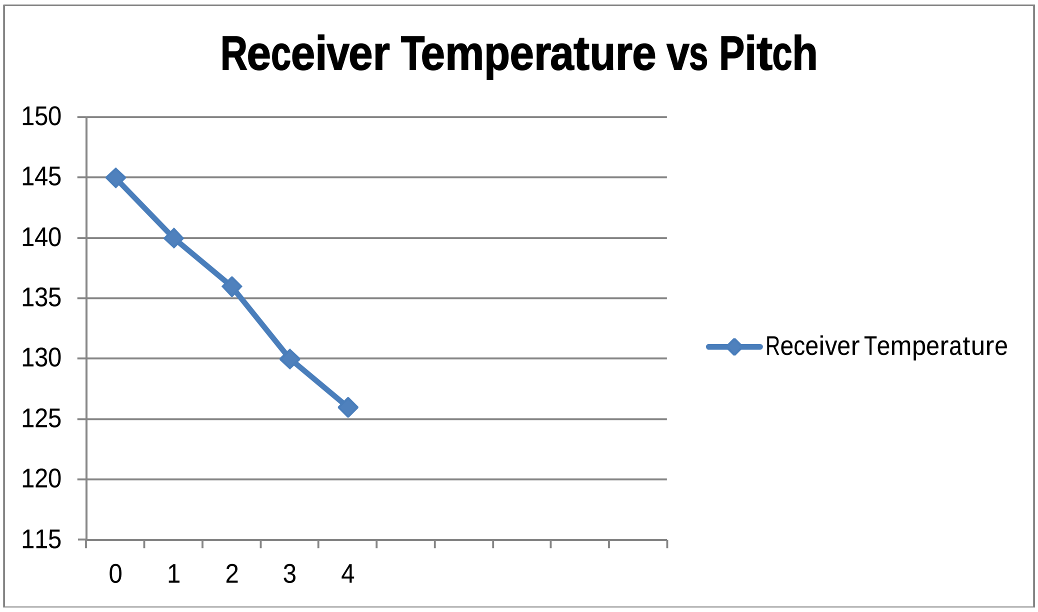
Time	P F concentrator temp(^{0}C)	LF concentrator temp.(^{0}C)	% Rise
10 am	58	101	57
11 am	66	120	55
12 am	72	140	52
1pm	78	155	50
2pm	80	185	43
3pm	86	176	48
4pm	60	145	41

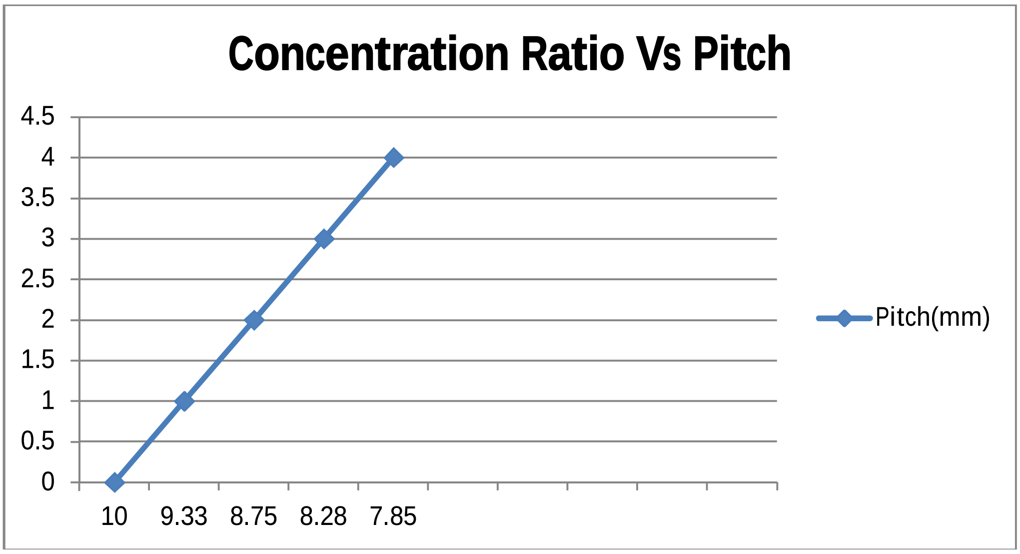
Based on the results obtained during the test of PDC steam generator the temperature above 190^{o}C was recorded with the ambient temperature, the maximum value reaches at about 2.00 pm and temperature varies along the solar trace on the absorber tube .The average soar beam radiation measured during testing as 714 w/m^2.

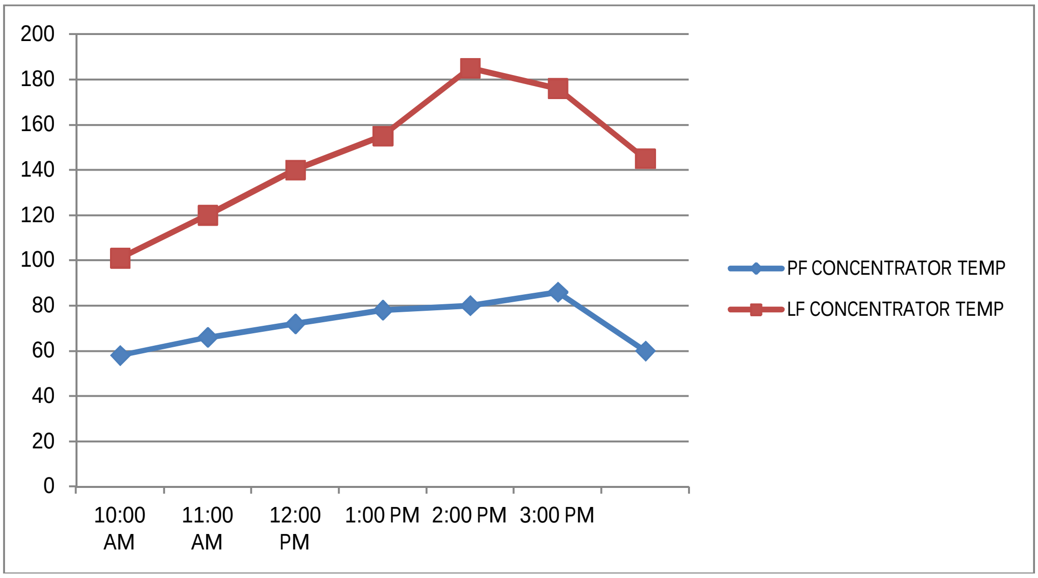


From above three figure it is clear that the temperature increases up to 2pm after which it gradually decreases.


Receiver Temperature vs Mass flow rate
160
140
120
100
80
60
40
20
0
0.0013
0.0014
0.0015
0.0016
0.0017
0.0018
0.0019
0.002
0.0021
0.0022
Receiver Temperature


Receiver Temperature vs Pitch
150
145
140
135
130
125
120
115
0
1
2
3
4
Receiver Temperature


Concentration Ratio Vs Pitch
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
10
9.33
8.75
8.28
7.85
Pitch(mm)



Comparison of Point and Line focus concentrator

V. CONCLUSION

- The experimentally calculated maximum temperature of coil receiver is 190 ^{0}C which is double than obtained from cavity receiver using point focusing.
- The experimentally calculated outlet temperature of water increases by average 50% as compared to cavity receiver.
- It is found that heat loss from the coil receiver (considering convective and radiative loss) will decrease by 20-25% compared with cavity receiver.

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