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Performance Evaluation of Parabolic Solar Water Heater

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Abstract*—this paper was concerned with an experimental study of parabolic trough collector designed and manufactured. A parabolic trough solar collector uses GI sheet in the shape of a parabolic cylinder to reflect and concentrate sun radiations towards an absorber tube located at the focus line of the parabolic cylinder. The receiver absorbs the incoming radiations and transforms them into thermal energy, the latter being transported and collected by a fluid medium circulating within the absorber tube. The Designing and Fabrication of parabolic trough solar water heater for water heating was executed, the procedure employed includes design, construction and testing stages. The model which is made up of reflector surface, reflector support, absorber pipe and a stand with manual tracking arrangement was fabricated using locally sourced material for rural applications point of view. Performance evaluation of this system has been done during the months of February, at Gorakhpur 29° 27' 0'' N, 75° 41' 0'' E. Latitude and Longitude*

Key Word *- Absorber, Parabolic Trough, Receiver, Solar Water Heater*

I. Introduction

Solar water heaters are simple solar thermal applications that alteration solar radiation into heat that is use to warm water for swim, wash, clean-up, and food preparation solar water heating is at the present recognized as a dependable practice that save considerable amount of electricity or other conventional fuels, lead to peak load decrease and avoid release of carbon dioxide. A domestic solar water heating structure can give close to 58% of the energy necessary annually for water heating in a family. Solar water heaters generally go down into two broad categories: concentrating type and non-concentrating type. Flat plate collectors and evacuated tube collectors be the two most commonly used no concentrating type of solar water heaters. The concentrating type of heaters normally employs parabolic/concave mirrors/reflectors to concentrate the whole solar energy incident on the collector surface. So the collector surface is usually very broad and the heat achieve is very high. Some of the collectors in this category are parabolic trough, compound parabolic concentrator, parabolic dish, and cylindrical parabolic concentrator. Parabolic dish has the most efficiency in terms of the use of the reflector area as in a fully steerable dish system there are no losses due to aperture projection effects. Also radiation losses are little because of the small area of the absorber at the focus.

We are blessed with Solar Energy in great quantity at no cost. The solar radiation incident on the surface of the earth can be expediently utilized for the benefit of human society. One of the usual devices that harness the solar energy is solar hot water system (SHWS).The solar energy is the nearly all capable of the option energy sources. Due to rising Demand for energy and increasing cost of fossil type fuels (i.e., gas or oil) solar energy is measured an attractive source of renewable energy that can be used for water heating in both home and commerce. Heating water consume nearly 25% of total energy use for a regular family. Solar water heating systems are the cheapest and mainly without difficulty reasonable fresh energy presented to homeowners that may give most of hot water required by a people.

Solar heater is a machine which is used for warm the water, for produce the steam for home and industrialized purposes by utilizing the solar energy. Solar energy is the energy which is approaching from sun in the form of solar radiations in never-ending amount, when these solar radiations falls on absorbing surface, then they gets changed into the heat, this heat is used for heat the water. This type of thermal collector suffers from heat losses due to radiation and convection. Such losses grow rapidly as the temperature of the working fluid increase

Rukenzlan [2001] has done their investigation on the topic optimization of the geometry and material of solar water heaters. It was observed that thickness of the absorber plate, spacing between pipes, diameters of pipes are the determining factors for the efficiency of the collectors.

Xiao Gang [2007] a closed parabolic trough solar collector is calculated in which a hermetic box with a transparent cover and the parabolic reflector form the back parabolic trough concerted solar collector. And the track of the sun is done by turning the box about the receiver tube which is set with respect to the argument. The absorber is make by two concentrating tube such that outer glass tube and an evacuated annular gap between the working fluid and outer glass tube, for the reason of thermal inclusion with analuminium inner tube conducting the and an external tube for air tightness. The centre of the boxes can be filled to a minor overpressure with air or gas supplied by central apparatus due to prevent the dust from the atmosphere and succeeding harm to the optic surfaces. Active carbon can be used to take away mainly of the gaseous pollutants. Accept an optical loss of a few percentages owing to reflection by the cover, this set up offer some reward over the present open model, in particular a possible of significant cost reduction

Joshua Folaranmi [2009] designed, constructed and testing of a parabolic solar steam maker mechanism on solar energy and prepared concentrating collector, heat from the sun was concerted on a black absorber placed at the focal point of the reflector in which water is heated to a extremely high temperature to form steam. It also describes the sun tracking system element by manual oriented of the lever at the base of the parabolic dish to imprison solar energy. The full arrangement is mounting on a hinged frame support with a slot lever for tilting the parabolic dish reflector to different angles so that the sun is all the time directed to the collector at different period of the day. On the usual sunny and cloud free days, the test results give high temperature more than 200°C.

Valentina A. Salomoni [2010] New Trends in design Parabolic trough Solar Concentrators and Heat Storage Concrete arrangement in Solar Power Plants This design give a common vision related to the last experience R&D in the field of new technologies for solar energy use within the Italian context, directly exportable abroad due to the follow design and study methodologies.

II. System Description

The parabolic trough solar collector uses aluminium foil sheet in the shape of a parabolic cylinder to reflect and concentrate sun radiations towards an absorber tube located at the focus line of the parabolic cylinder. The receiver absorbs the incoming radiations and transforms them into thermal energy, the latter being transported and collected by a fluid medium circulating within the absorber tube. The absorber tube is made of stainless steel tube. A schematic sketch of the test setup of the constructed parabolic trough concentrator for domestic hot water application is shown in Figures 1 The test setup it consists of a solar collector, absorber tube.

Figure1: parabolic solar water heater

III. Fabrication of the Parabolic Trough

The material for the manufacture of the device was measured strength, suitability and general availability. For building of the parabolic trough GI sheet is use. Aluminium sheet has been chosen as material for collector. Initial, the structure was prepared of a GI. Sheet material. On top of this parabolic form reflector-surface Aluminium sheet was set with sticky materials. The absorber tube was prepared of stainless steel tube is surrounded by a concentric glass cover. The sun tracking agreement was providing to the system which is yourself operate.

Table 1: Experimental set up dimension

Parameter	Dimension
Aperture of the concentrator (W)	0.63m
Inner diameter of absorber tube (Di)	0.026m
Outer diameter of absorber tube ()	0.03m
Length of parabolic trough	0.55m
Concentration ratio	6 collector
aperture area	0.35
Focal distance	0.13m
Collector orientation	Axis N-S direction
Mode of tracking	- E-W (manual)
Reflectivity of concentrator	0.85
Absorber tube emissivity/emissivity (α)	0.9

IV. Thermal Performance Calculations

The theoretical useful energy from parabolic trough solar collector calculated by equation writing

$$Q_{u,th} = A_{ap} F_R \left[H_{ab} - \frac{A_{r,ext}}{A_{ap}} U_l (T_{fi} - T_{amb}) \right] \quad (1)$$

$$A_{r,ext} = \pi D_r ext^L \quad (1a)$$

$$A_{ap} = (W - D_{r,ext}) L \quad (1b)$$

$$H_{ab} = I_b \alpha \rho \quad (1c)$$

Where: ρ =Reflectivity of the reflector

The overall heat loss coefficient is one of the most important parameters and can be found out through the following equation

$$U_l = h_w + h_{r,r-a} (2)$$

The convection heat transfer coefficient h_w between receiver and ambient air due to wind can be calculated as

$$h_w = \frac{N_{Ua} K_a}{D_{r,ext}} (2a)$$

$N_{Ua} = 0.4 + .54 * Re_a{}^{0.53}$

for.01< Re_a 1000(2a1)

$N_{Ua} = .03 * R_{ea}{}^{.6}$

for1000< Re_a 50,000(2a2)

$$Re_a = \frac{V D_{r,ext}}{V_a}$$

The radiation heat transfer coefficient between absorbed tube and can be writing in equation as

$$hr,_{r-a} = \varepsilon \sigma (T_r - T_a)(T_r{}^2 + T_a{}^2) (3)$$

The temperature of the absorber surface can be calculated from the written equation as

$$T_r = T_f + \frac{Mc_p (T_{f,o} - T_{fi})}{h_{ci} \pi D_r ext^L} (4)$$

$$T_{fm} = \frac{T_{fi} + T_{fo}}{2} (5)$$

$$T_{fo} = T_{fi} + \frac{Q_u}{Mc_p} (6)$$

The heat removal efficiency factor is given as

$$F_R = \frac{Mc_p}{A_{r,int} U_l} \left[1 - exp\left(-\frac{A_{rint} U_l F^-}{Mc_p} \right) \right] \quad (7)$$

For a tubular absorber with inside diameter and $D_{r,int}$ outside diameter D_{rext} having h_{ci} the convective heat transfer coefficient between absorbed and the fluid the collector efficiency factor is given as

$$F^- = \frac{\frac{1}{U_l}}{\frac{1}{U_l} + \frac{D_{rext}}{h_{ci} D_{rint}} + \frac{D_{r,ext} \ln\left(D_{r,ext} / D_{r,int} \right)}{2k_r}} (8)$$

The convective heat transfer coefficient is given as

$$h_{c,i} = \frac{K_w}{D_r} \left[3.6 + \frac{.0668 \left(D_{r,int} / L \right) Re_w Pr_w}{1 + 0.04 \left[\left(\frac{D_{r,int}}{L} \right) Re_w Pr_w \right]^{2/3}} \right] (9)$$

Where

$$Re_w = \frac{U_W D_{r,int}}{V_w}$$

$$U_w = \frac{M}{\rho_w A_{c,r,int}}$$

$$A_{c,r,int} = \frac{\pi D_{r,}{}^{int}}{4}$$

The actual useful energy obtained from parabolic trough solar collector is given as;

$$Q_{u,exp} = Mc_p (T_{f,o} - T_{fi}) (10)$$

The theoretical thermal efficiency is writing as

$$\eta_{th} = \frac{Q_{u,th}}{I_b A_a}$$

The experimental thermal efficiency is given as;

$$\eta_{exp} = \frac{Q_{u,,exp}}{I_b A_a}$$

Table 2: Obtained during Experimental and Theoretically observations of February 25, 2016

S. No	Time (hr)	Solar Intensity (W/m^2)	Inlet Water Temp(	Outlet water Temp (	Inlet-outlet Temp (	Ambient Air Temp (	Wind speed m/s	Theoretically result	Experimentally Result
1	9	220.11	19	29	10	15.59	3	26	22.6
2	10	369.89	22	44	20	18.19	3.6	31	26
3	11	516.81	24	51	27	21.55	3.8	32	26
4	12	582.89	26	61	35	22.99	2.5	34	29.8
5	13	593.04	27	65	38	24.88	2.3	36	31.8
6	14	599.08	27	70	41	24.47	2.4	41	35.7
7	15	480.7	29	60	31	24.79	3.1	36	32
8	16	233.16	28	40	12	24.72	3.5	29	25
9	17	146.51	28	34	6	23.55	3.4	26	20.3
10	18	110.12	26	32	6	22.08	4.1	14	9.6

Figure 2: Show the variant of radiation with respect to time.
It increase with time and reach a maximum range between 12.00 PM and 2.00 PM and then decrease. Radiation received during this study has been record in the range of 369.89 W/m^2 to 599.04 W/m^2.

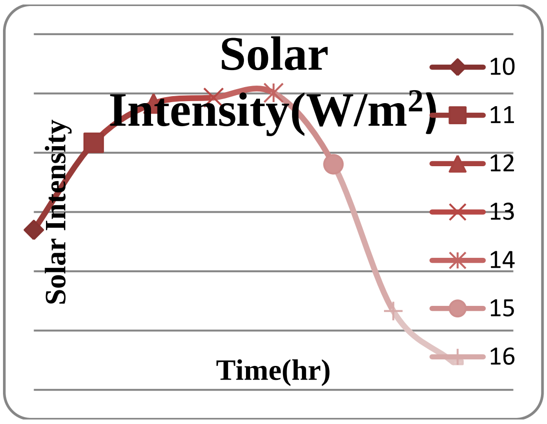
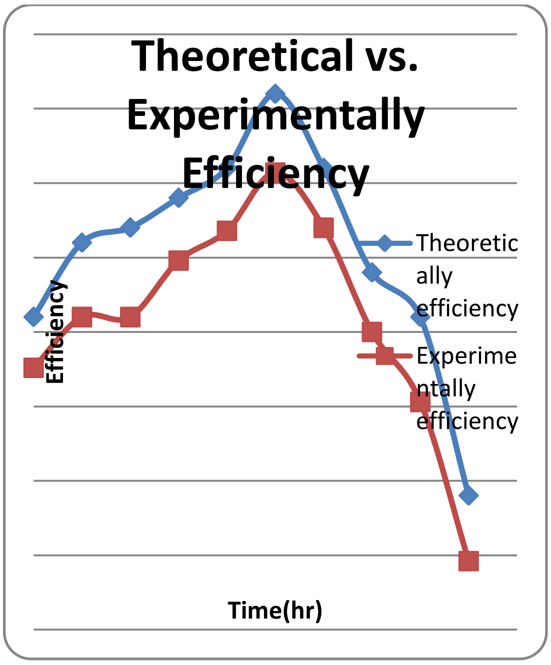


Figure3Show the variation of efficiency for theoretically and experimentally with respect to time.



V. Conclusion

In the present work, the performance of a new parabolic trough collector with hot water generation system is investigate through experiment over one full day. The highest value of each of those parameters is experiential around midday, when the incident beam radiation is at its peak. The fabrication and design of a solar parabolic trough with close by available materials is feasible hence low temperature trough will be a improved solar thermal device for the rural and remote area. From the result it has been seen that the parabolic trough is better alternative during winter season to dropping the water heating cost. This do research has its own special features Maintenance cost is minimum and hence economical, running cost is nil, the labor cost is minimized on account of its easy design. As other forms of energy are fast deplete and polluting the atmosphere, non-conventional energy resources like solar energy are best suitable to use. The solar Parabolic Trough is among the best way to use solar energy efficiently due to its advantages to convert in abundance available solar energy into effective and convenient form of heat energy which can be used for various reason.
We observed that, experimental thermal efficiency and the theoretical thermal efficiency is theoretical results always higher than experimental results. We also measured still output 25 February. Fig 5 shows the comparison between the experimental results of the thermal efficiency and the theoretical results of the thermal efficiency was the figure shows that the experimental thermal efficiency is less than the theoretical thermal efficiency.

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