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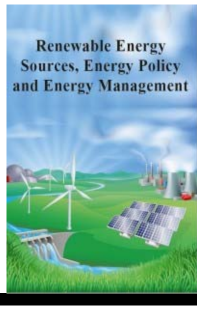

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Original Research Article

Experimental analysis of a flat plate solar collector in Benin City metropolis

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ABSTRACT

In this study, the heat transfer in a flat-plate solar collector with water tubes was analyzed. The performances of the system both theoretically and experimentally were evaluated and compared. The theoretical results obtained agreed well with the experimental results, except that a slight higher deviation of heat loss was obtained in the experimental analysis and low solar radiation in the morning and evening affects the system. An overall heat loss coefficient of 7.82 W/m^2 °C was obtained in the theoretical analysis. The collector efficiency was high around the mid-day when the collector receives the highest energy and the useful heat rate was at its maximum. The results also reveal that the performance of the solar collector depends much on the heat rate. The collector efficiency increases as the heat rate increases at an output temperature of 78^{o}C.

Keywords: Experimental, flat-plate, heat transfer, performance, solar collector

1. Introduction

Improvements in quality of life and rapid industrialization in many countries are increasing energy demand significantly, and the potential future gap between energy supply and demand is predicted to be large as demonstrated [1]. Therefore, the issue of sustainable development is gaining steady momentum. The renewable energies being inherently sustainable and environment-friendly are gaining popularity.

Among the various type of clean energy, special attention has been given to solar energy because it is freely available. As worldwide energy reserves have continued to diminish, the incentive to develop solar energy systems has increased. Research on applications of solar energy technologies have as a consequence expanded rapidly, exploiting the abundant, free and environmentally benign characteristics of solar energy. The utilization of solar energy is important in developing nations where electrical energy is expensive and energy production is too low to meet requirements.

Some studies have been performed on flat-plate solar water heating systems. Rommel and Moock [2] investigated a flat-plate solar collector of rectangular narrow ducts absorber type. In their consideration of the thermal heat gained by the collector, they concluded that considerable improvement in thermal performance of the collector can be achieved with rectangular ducts absorber, but also with extra cost for its increased consumption of electric pumping energy.

Ismail and Abogderah [3] carried out a comparative study between theoretical predictions and experimental results of a flat-plate solar collector with heat pipes. The theoretical model for the heat pipe solar collector was based upon the method by Duffie and Beckman [4], but modified to use heat pipes for energy transport. This results revealed that the instantaneous efficiencies of the

heat pipe solar collector are lower than the conventional collector in the morning and higher when the heat pipes reach their operating temperatures.
Facao and Oliveira [5] analyzed the thermal behaviors of a flat-plate heat pipe solar collector experimentally. The major simplification was that the temperature in the heat pipe was considered to be uniform and equal to the saturation temperature. The results showed a collector optical efficiency of 64 % and overall loss coefficient of 5.5 W/m^2 K, for a non-selective surface coating.

2. Material and Methods

The study was aim at defining at what time and solar radiation can a high temperature be obtained with significant efficiency from the designed and fabricated flat plate solar collector system achieved for usage. This experimental set up also helped to validate the model developed.

The experimental procedure which was followed during this article is as follows:
All the components of the Flat Plate Solar Collector were gathered and assembled together. The arrangement is placed in an open place on clean sky days of the mid-months. Cleaning of the absorber plate, flow tube and glazing cover is done to remove dust particles and moisture content.
The cold water supply tank is filled with fresh and clean water and is placed at a height of one and half meter (0.5m) from the collector inlet as shown in Figure 1, to create necessary pressure head for the flow of working fluid through copper tube.

The collector is exposed to the sun from 8am to 12noon, this process of exposing the flat plate solar collector to the sun before passing water through it was termed preheating the collector system. Preheating the solar collector was done from 8am to 12noon for January, February, March as dry season and June, July, September as raining season respectively. While the water is passing through the collector the inlet temperature and the outlet temperature of water are noted down using a mercury thermometer. The solar radiation is also recorded down using a solar meter.
Mass flow rate of water is measured by observing the time taken for the collection of 600ml of water using measuring jar and stop watch (45 seconds), the various materials and dimensions of the components for the experimental prototype setup is shown in Table 1.
Each experiment is conducted for 1 hour duration by maintaining constant flow rate of water. The readings are taken after every hour and a mass flow rate of 0.0133kg/s gotten after 45sec.

Table 1. Materials and dimensions for design

S/N	COMPONENTS	MATERIALS	DIMENSIONS
1	Casing	Wood	0.84m × 0.79m × 0.08m
2	Insulation	Fiber (Polyurethane)	0.80m × 0.75m × 0.004m
3	Absorber plate	Aluminium painted black	0.80m × 0.75m
4	Flow tube	Copper	0.012m in diameter
5	Glazing cover	Transparent glass	0.80m × 0.75m × 0.005m
6	Water supply tank	Plastic	300 liters
7	Hot water collecting tank	Plastic	20 liters
8	Pipe	Plastic hose	h =1m , d=0.008mm

Figure 1. Experimental setup of the flat plate solar collector

3. Results And Discussion

Table 2. Temperatures from experimental installation with preheat

2019 Day	Inlet temp (K)	12:00NOON outlet temp (K)	1:00PM outlet temp (K)	2:00PM outlet temp (K)	3:00PM outlet temp (K)
17th Jan	302	337	341	345	351
16th Feb	301	338	339	341	348
16th Mar	301	335	336	339	346
11th Jun	297	307	318	305	303
17th Jul	297	321	321	324	325
15th Sep	299	331	331	333	337

Three months were considered for dry season and three months were also considered for raining season. Table 2 shows the temperature of solar radiation from experimental installation, the inlet water was allowed to flow into the system after the flat plate collector was preheated to 12noon. It was also observed that the temperature was highest for January and lowest for June.

Table 3. Solar radiation from experimental installation

2019 Day	10am Solar rad (w/m^2)	11am Solar rad (w/m^2)	12:00 N Solar rad (w/m^2)	1:00PM Solar rad (w/m^2)	2:00PM Solar rad (w/m^2)	3:00PM Solar rad (w/m^2)
17th Jan	1095	1115	1263	1440	1489	1581
16th Feb	1055	1185	1202	1415	1420	1537
16th Mar	980	1008	1190	1340	1355	1522
11th Jun	540	548	610	520	512	620
17th Jul	670	675	680	650	655	770
15th Sep	830	848	875	920	925	890

Table 3 shows the solar radiation from experimental installation for each hour of the day from 10am to 3pm, it was found that the solar radiation was high for January and it was lowest for June. Indicating how solar radiation changes with both dry and rainy season.

3.1. Results

The developed model was used to estimate the output of the simulated results and experimental results to see how it affects or relates with its performance.

Table 4. Predicted and experimental efficiency and output temperature

Months	Day number	Eff(RSM predicted)	Eff(Exp)	To(RSM pred)	To(Exp)
January	17	0.889	0.75	343	337
February	47	0.869	0.74	338	338
March	75	0.854	0.75	333	335
June	162	0.828	0.70	320	307
July	198	0.827	0.81	321	321
September	258	0.839	0.72	330	331

The result shows a relation between the predicted outputs gotten from the modelled equation and the experimental output from the experimental installation as seen in table 4.

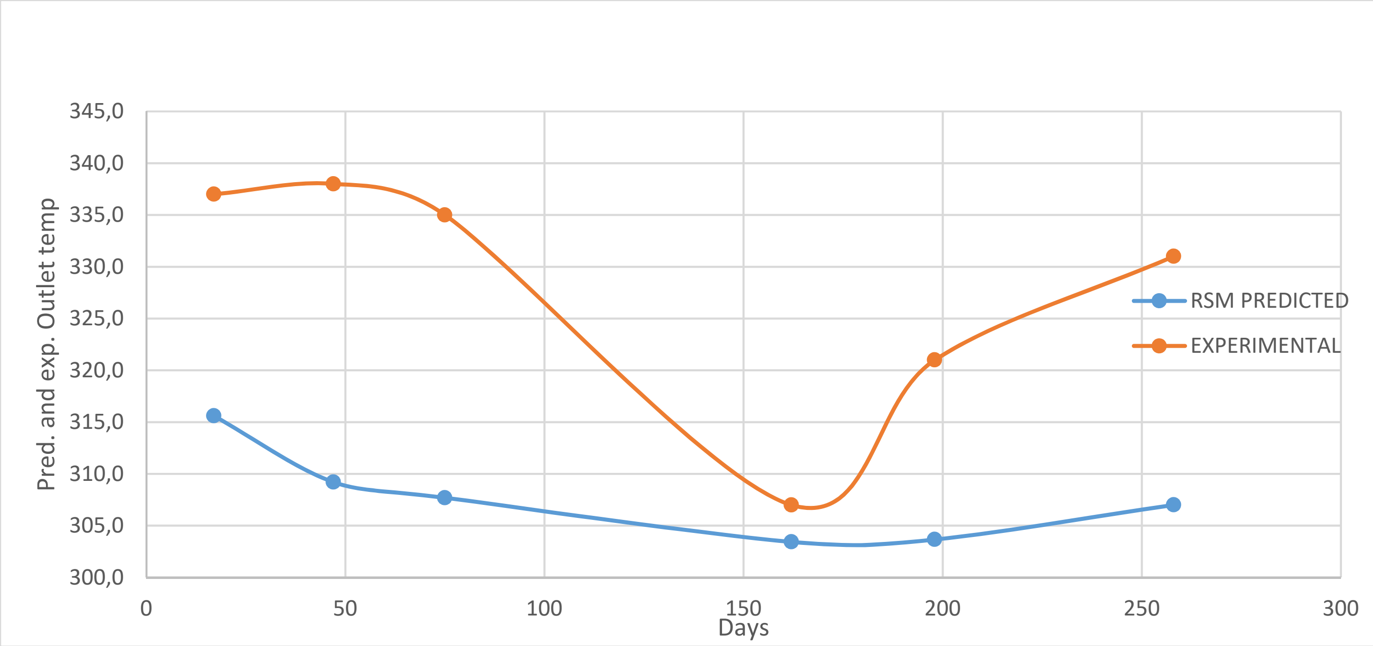

Figure 2. Experimental outlet temperature predicted by days

The analysis shows that there is an increase in the outlet temperature for both predicted and experimental setup within the first few months of the year and it experiences a fall at the middle and rise towards the end as shown in figure 2.

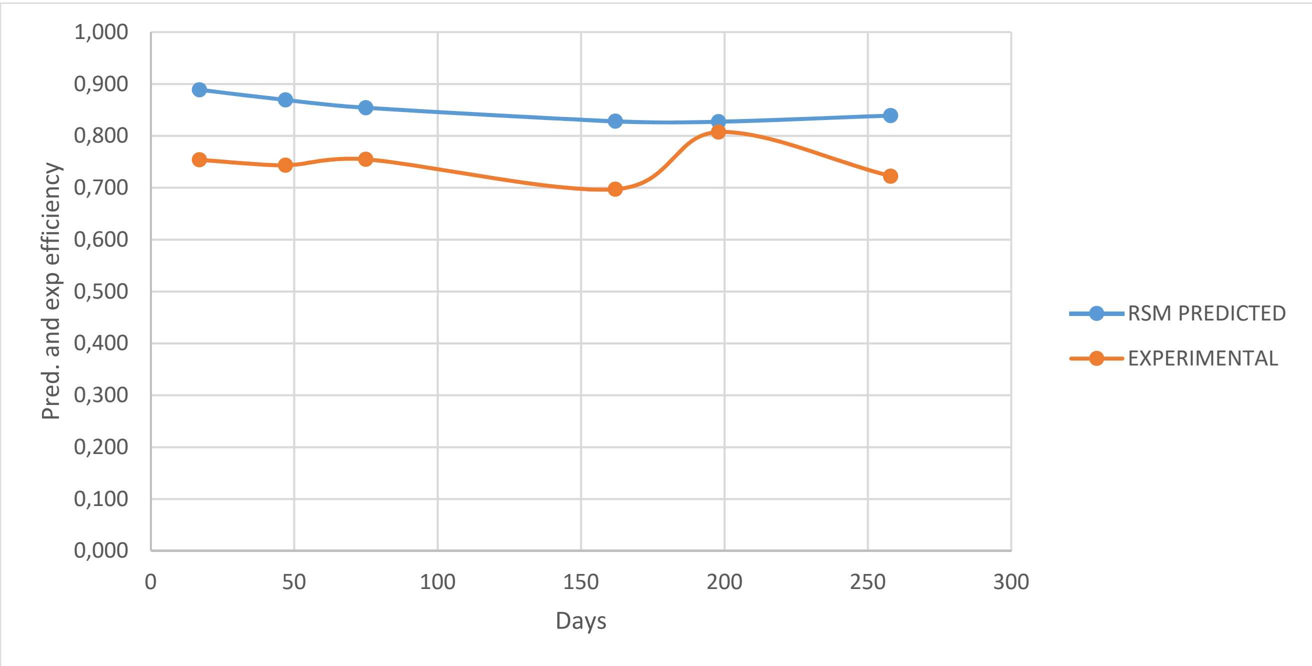

Figure 3. A graph of predicted and experimental efficiency against days

The analysis shows that there is an increase in the efficiency for both predicted and experimental setup within the first few months of the year and it experiences a fall at the middle and rise towards the end as shown in figure 3.

4. Conclusion

In this study, the experimental results show that the solar flat plate collector has a great potential and this is due to the fact that the temperature was reasonably high and efficiency respectively. In this study rainy and dry season was considered, January, February and March were considered as dry season respectively. June, July and September were considered as rainy season. 351K was achieved as the highest temperature output and this temperature can be used for both domestic and some industrial applications. The solar radiation gotten shows that the site used during this study has a great potential for solar energy availability.

5. Reference

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