

A Performance Measurement of Double Glass Solar Flat Plate Collector Using Corrugated Absorber Plate Having Twisted Tape Inserted In Tubes With Packed Bed Materials Around The tubes

Bhavik.J. Patel¹ Dr.K.V.Modi²

¹M.E Student ²Associate Professor

¹Department of Energy Engineering ²Department of Mechanical Engineering

^{1,2}Government engineering college, Valsad

Abstract— Solar energy is the better alternative source due to its availability all over the world. A number of systems are developed those replace conventional energy sources by the solar energy in many applications. One of the methods is developed to improve the performance by double glass solar flat plate collector using corrugated type absorber plate having twisted type inserted in a tube with packed bed material around the tubes. The experiment is carried out with different mass flow rate by forced circulation and natural circulation and also compares the efficiency of forced circulation and natural circulation by various mass flow rates. The result shows that the maximum efficiency is observed at 15:30 in all three flow rates as 84.03%, 86.50% and 87.14% respectively by forced circulation and during natural circulation the maximum efficiency is observed at 15:30 in all three flow rates as 35.26%, 54.54% and 76.39% respectively. It is also conclude that the efficiency is increased with the increasing mass flow rate and temperature is increased with decreasing the mass flow rate. It can also concluded from this present work that the daily collector efficiency increase slowly with respect to the mass flow rate except for small value of mass flow rate. The solar water collector of modified design of corrugated surface has good potential for harnessing solar radiation and also it's gradually increase the efficiency by the effect of packed bed materials.

Key words: Solar energy, Solar Flat Plate Collector

I. INTRODUCTION

The flat plate collectors are the commonly used device for residential water and space-heating applications. Solar collectors have potential to fulfill the industrial process heating demands which helps in the saving of electric energy. Basically, solar collectors are used for the low temperature application due to its operating simplicity. From the non-concentrating collectors liquid flat plate solar collector (LFPSC) is much preferable because of its design simplicity and more reliability. The use of corrugated absorber is in the place of flat absorber obviously provides a large surface area for heat transfer. The increase in surface area enhances solar radiation collection, mainly by increasing the capture of diffuse radiation and reflected radiation from the collector surface. The modified surface has a higher characteristic length, which affects the convective heat transfer coefficient from absorber surface to water, in addition to having more surface area exposed to solar radiation.

II. LITERATURE REVIEWS

There are number of various parameters influence the performance of a liquid flat Plate collector. These parameters could be classified as Design parameters, operational parameters, meteorological parameters, Environmental parameters.

R.Sivakumar,V.Sivaramkrishnan, M.Vivekanandan [1]has developed the batch type solar water heater by CFD model with different size of fins and dimples; V-grooves type absorber surface was utilized. They observed that the temperature of water with that of V-groove absorber surface is maximum when compared to other models and minimum for dimpled surface. Among all these models, the model with V-groove is advantageous for hot water usage in the evening, because it gains maximum heat and hence temperature when compared with other fins.

Deepak.P, Adhichelvan.B [2] was carried out an experimental work using pebble stone as a porous medium for packing of absorber surface and agitator used in the riser tube. They found that the temperature is increasing using combination of agitator and porous medium. A pebble stone is used as a porous medium as it has high heat energy absorbing properties, so it has highest temperature in comparison with agitator and ordinary solar water heater.

Sethuraman Ramasamy, Pakkirisamy Balashanmugam [3]presented the analysis of solar water heater carried out with circular and rectangular fins used in the riser tube. They obtained that the efficiency of circular finned tubes is higher than that of rectangular finned tubes and without tubes. They have concluded that the radiation, energy gain and the efficiency are high when the fin is used.

Mahesh. Kulkarni, Dr.D.S.Deshmukh [4] developed a flat plate collector using aluminum material as an absorbing surface. The absorbing surface made of rectangular aluminum pocket with aluminum pipes. They found that the temperature of water obtained at outlet of a new collector is about 690C and efficiency of the collector is 35.47% as compared to that of conventional collector efficiency is around 40.05%.they also detected that the solar collector with aluminum pocket, the cost is reduced to that of solar collector with copper.

Rakesh kumar,Mark.A.Rosen [5] has performed ingrated solar water heater with corrugated absorbe and concluded that the corrugated surface has good potential for harnessing solar energyat reasonably high temperature.

S.vijaykumar,R.vinoth [6] has developed heat transfer rate in a solar flat plate collector using twisted tape and wire coiled turbulators. they concluded that the use of twisted tape along with wire coils causes a high pressure drop providing considerable augmentation. twisted tape

generate turbulence superimposed with swirlness inside the flow tube and consequently result in enhanced heat transfer.

III. DEVELOPMENT OF SOLAR FLAT PLATE COLLECTOR

In order to measure the performance a new design based novel type solar flat plate collector is fabricated. Fig.3.1 shows the 2D model of actual experimental set up.

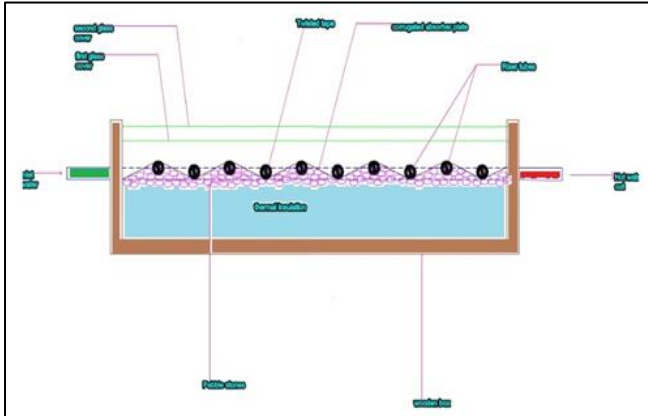


Fig. 1: 2D model of actual experimental set up.

A simple rectangular shape of flat plate collectors are fabricated having black paint coated having corrugated shape copper absorber plate is used. The copper tubes with twisted tape are welded or soldered to the absorber plate and arranged parallel tubes as shown in fig.5.1. a five riser tubes are connected above the absorber plate with the header pipes located on inlet and outlet sides and other riser tubes are connected at the bottom of the absorber plate and pebble stones are used as a packed bed material which is provided below the absorber surface around the tubes. two transparent glass sheet are placed on the upper side of the absorber plate to reduce the thermal losses. Glass wool is used as a thermal insulation provided between the absorber plate and the casing .the whole body is installed on a support structure.

| Description | Material | Size (mm) |
|--|--------------|-----------|
| Length of collector | Wood | 780 |
| Width of collector | - | 490 |
| Thickness of collector | - | 140 |
| Absorber sheet (corrugated type) | Copper | 440 x 600 |
| Sheet thickness | | 0.4 |
| Absorber or riser tube diameter | Copper | 12 |
| Twisted tape | Copper | 4 |
| Header tube diameter | Copper | 22 |
| Tube spacing | - | 40 |
| Insulation material | | - |
| Insulation thickness(bottom) | Mineral wool | 60 |
| Insulation thickness(sides) | | 12 |
| Transparent glass cover | Window glass | 4 |
| Space between absorber plate and First transparent cover | - | 20 |
| space between first transparent cover to second cover | - | 20 |
| Packed bed material | pebbles | to 25 |

Table 1: Technical specifications of solar liquid flat plate collector are:



Fig. 2: Actual Experimental Set up

IV. EXPERIMENTAL PROCEDURE

Fabricating of various parts of solar collector and assembling together and whole set up is installed properly at an suitable angle facing due south located on building of government engineering college Valsad (20.63°N, 70.93°E). This collector box is fixed to the stand which is made of mild steel.

The inlet of cold water is connected to the bottom header pipe and the outlet is connected to the top header pipe. Cold water from the overhead tank enters directly in the collector through bottom header pipe. And outlet hot water pipe is connected to the exit channel pipe.

Water is circulated with the help of forced circulation and thermo syphon action throughout the pipe and tank arrangement.

For measuring the various temperatures, a number of thermocouples are connected in the collector such as two for absorber plate, one for packed bed material, two thermocouple are placed in first glass cover and second glass cover, one for ambient temperature, one for inlet water and one for outlet hot water. Run the experimental set up with measuring instrument throughout the day and measure the various temperatures, wind velocity, solar radiation, and mass flow rate from 09:30 am to 18:30 pm.

V. EXPERIMENTAL INVESTIGATION AND RESULT ANALYSIS

The results are presented here after performing the measurement of important operating parameters of the experimental set up at selected location as per the specified procedure during the experimental work. The present experiments are performed during period from 9:30 to 6:30 in winter season in the month of October 2016.

A. Performance Measurement with Different Mass Flow Rate by Forced Circulation

In the present experimental work is performed with mass flow rate of 60 kg/hr., 70 kg/hr. And 80 kg/hr. respectively and results are analyzed with graphically presented.

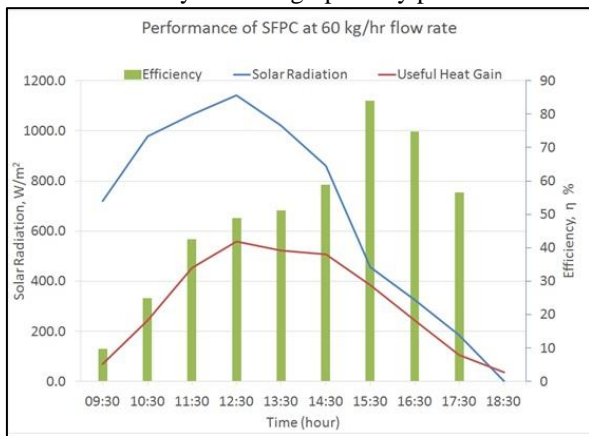


Fig. 3: Variation of efficiency, solar radiation and useful heat gain throughout the day

Figure 5.1 shows the representation of solar flat plate collector with mass flow rate of 60 kg/hr. It is observed that the efficiency of solar flat plate collector is increased up to 51% by increasing the solar radiation at 13.30 pm and temperature reaches 43°C. After that solar radiation is decreasing but temperature is going to decreased very slowly and system efficiency is increasing due to the effect of packed bed material and maximum efficiency is achieved at 15:30 pm is 84.03%.

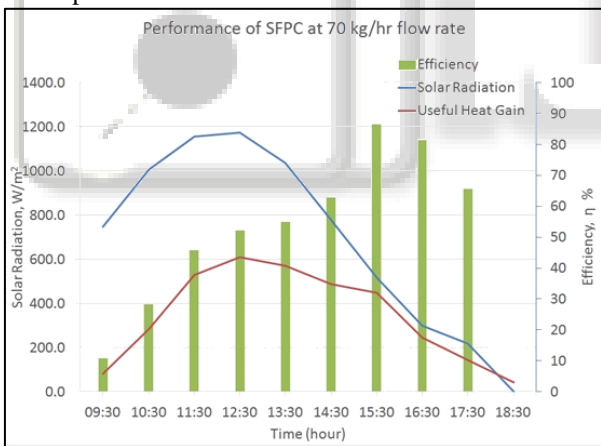


Fig. 4: performance of solar flat plate collector with mass flow rate of 70 kg/hr.

Figure 5.2 shows the performance of solar flat plate collector with mass flow rate of 70 kg/hr. It is observed that the maximum temperature 43°C is achieved and the maximum efficiency is 85.50% observed during 15:30.

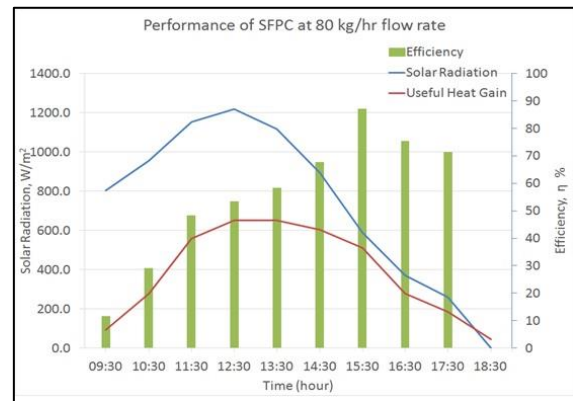


Fig. 5: Performance of solar flat plate collector with mass flow rate of 80 kg/hr.

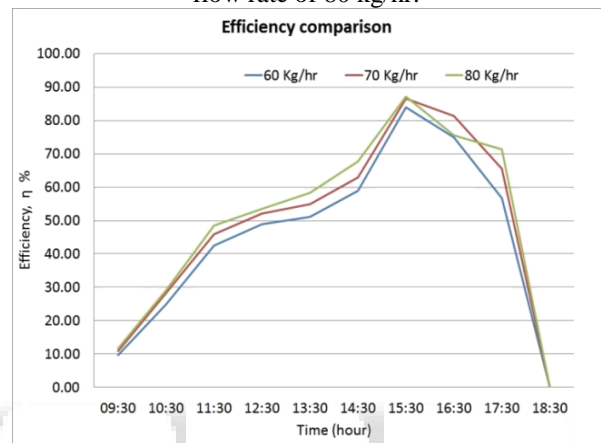


Figure 6.4 represents the comparison of efficiency of solar flat plate collector with mass flow rate of 60kg/hr., 70 kg/hr. and 80 kg/hr. respectively. The collector efficiency at 9:30 hours is 9.69% at 60kg/hr., 10.88% at 70 kg/hr. and 11.56% at 80 kg/hr. the maximum efficiency is observed at 15:30 in all three flow rates as 84.03%, 86.50% and 87.14% respectively. The collector efficiency is decreasing after 16.30 hour till 18.00 hour in the same manner.

B. Performance Measurement with Different Mass Flow Rate by Natural Circulation

In the present experimental work is performed with mass flow rate of 20 kg/hr., 30 kg/hr. and 40 kg/hr. respectively and results are analyzed with graphically presented

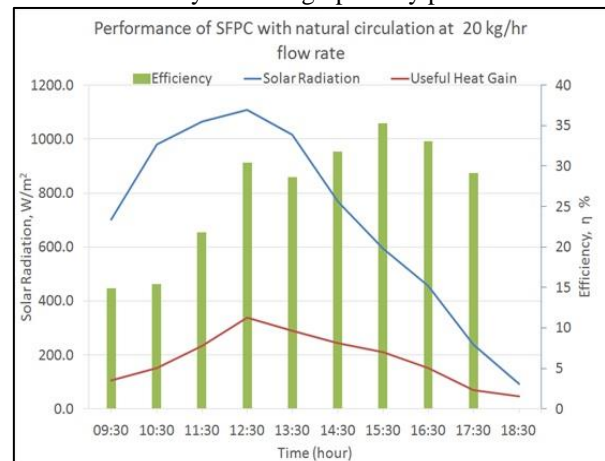


Fig. 7: Performance of solar flat plate collector with mass flow rate of 20 kg/hr.

From the figure 5.5 it is clearly observed that the temperature is increasing up to 58°C and this may be due to the reason that at lower mass flow rate more amount of heat is being absorbed by water.

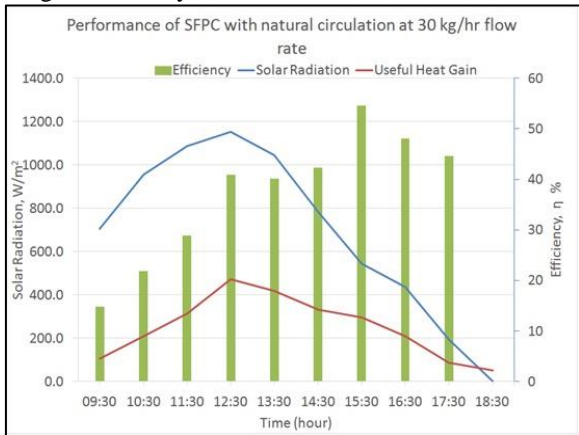


Fig. 8: Performance of solar flat plate collector with mass flow rate of 20 kg/hr.

Figure 5.6 shows the variation of efficiency, useful heat gain and solar radiation with time at a flow rate 30 kg/hr. The temperature increased up to 55°C at 12:30 pm with maximum solar radiation.

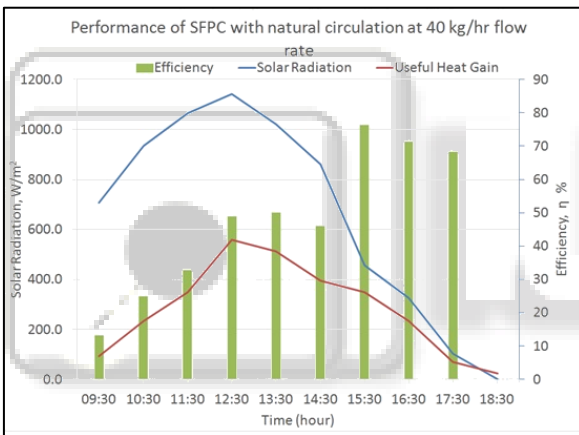


Fig. 9: Performance of solar flat plate collector with mass flow rate of 20 kg/hr

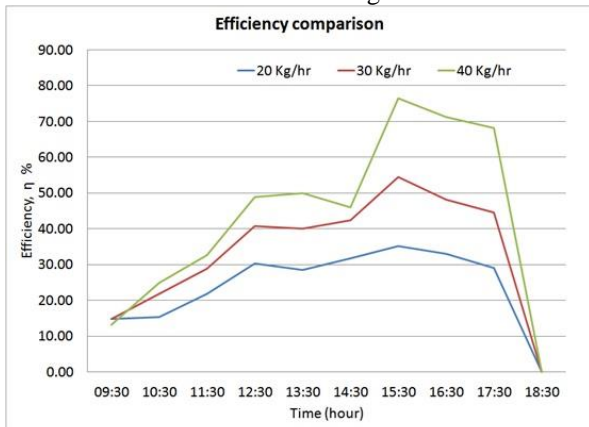


Fig. 10: Efficiency comparison with various mass flow rate

Figure 6.8 represents the comparison of efficiency of solar flat plate collector with mass flow rate of 20, 30 and 40 kg/hr respectively. The collector efficiency at 9:30 hours is 14.90% at 20kg/hr., 14.85% at 30 kg/hr and 13.16% at 40 kg/hr. the maximum efficiency is observed at 15:30 in all three flow rates as 35.26%, 54.54% and 76.39%

respectively. The collector efficiency is decreasing after 15.30 hour till 18.00 hour in the same manner. The collector efficiency is shown in Fig 6.8. The graph reveals that the maximum efficiency is at 15.30 hour in the three different cases. It is also observed that the efficiency is increased with the increasing mass flow rate and temperature is increased with decreasing the mass flow rate.

C. Effect of Absorber plate on the performance of SFPC

The performance of the solar flat plate collector with corrugated absorber surface is carried out. For most of the day the outlet temperature of water is increased 3°C to 8°C with up to high solar radiation in all cases of mass flow rate. Due to its corrugated grooves, increase the surface area so that enhance the collection of diffuse radiation and capturing of the reflected radiation from the absorber plate surface. The solar water collector of modified design of corrugated surface has good potential for harnessing solar radiation.

D. Effect of twisted tape on the performance of SFPC

The performance of SFPC is also carried out with twisted tape which is inserted in the riser tube. In the present study twisted tape ratio is taken as 4, where twist is define as the (P/Di) ratio of pitch to inner diameter of the tube and the width is 0.8. by using this twist ratio during forced circulation pressure drop and friction factor is increased so that swirl flow is generated. The maximum efficiency is obtained during mass flow rate of 80 kg/hr.

E. Effect of packed bed material on the performance of SFPC

Pebble stones are used as packed bed material is provided below the absorber plate around the tubes which is used to store the thermal energy. During the experimental work it is clearly observed that the outlet temperature of water increased with increasing the solar radiation up to 13:30 hours. After that the continuous reducing the solar radiation ,but temperature of water is marginally stable and increased from 28°C to 31°C, 29°C to 32.5, and 28°C to 29°C at the mass flow rate of 60,70 and 80 kg/hr. respectively due to the pebble stones which transfer the storage heat to the water .

In the case of natural circulation, it is observed that the temperature of water at 17:30 is 33°C, 31°C and 29°C at the mass flow rate of 20,30 and 40 kg/hr.so that overall performance shows that the packed bed material is highly affected with low mass flow rate.

During natural circulation of water, the tape is much affected because of low mass flow rate, pressure drop is decreased and so much amount of radiation is captured by twisted tape which is increase the heat transfer to the water. The maximum temperature is 58°C achieved at low mass flow rate of 20 kg/hr.

VI. CONCLUSION

During force circulation, the maximum efficiency is observed at 15:30 in all three flow rates as 84.03%, 86.50% and 87.14% respectively. This efficiency is achieved by packed bed material during the reducing of solar radiation. In the case of twisted tape during force circulation is not much effective.

During natural circulation, the maximum efficiency is observed at 15:30 in all three flow rates as 35.26%, 54.54% and 76.39% respectively. The collector efficiency is decreasing after 15.30 hour till 18.00 hour in the same manner. From the result it is conclude that the efficiency is increased with the increasing mass flow rate and temperature is increased with decreasing the mass flow rate. The maximum temperature is obtained at 18:30 is 33°C with low mass flow rate of 20 kg/hr.

It can also concluded from this present work that the daily collector efficiency increase slowly with respect to the mass flow rate except for small value of mass flow rate.

REFERENCES

- [1] R.Sivakumar, V.Sivaramakrishnan, M.Vivekenandan, "CFD Study of an Integrated Collector – Storage Type Flat Plate Solar Water Heater Without and with Fins, Dimples and V-grooves in Absorber Surface". IJMME-IJENS Vol:15 No:02, April 2015
- [2] Deepak.P, Adhichelvan.B. "Fabrication & Performance Analysis of Solar Water Heater Using Porous Medium & Agitator".IJCEM Vol:2, April-2015
- [3] Sethuraman Ramasamy, Pakkirisamy Balashanmugam "Thermal Performance Analysis of the Solar Water Heater with Circular and Rectangular Absorber Fins".IJSET Vol:2, January-2015
- [4] Mahesh.Kulkarni, Dr. D.S. Deshmukh, "Investigation of a New Flat Plate Collector Performance for Solar Water Heating System".ICGTETM, ISSN:2231-5381, 2016
- [5] Rakesh kumar, Mark.A.Rosen, "thermal performance of integrated solar water heater corrugated absorber surface. Researchgate.net/publication/281113150, June 2010
- [6] Dr.K.Sridhar,G.VinodKumar,S.AnilKumar, "performance analysis of integrated packed bed solar flat plate collector". IJESRT-May 2015, ISSN: 2277-9655
- [7] S.vijaykumar,R.vinoth, "Enhancement of Heat Transfer Rate in a Solar Flat Plate Collector Using Twisted Tapes and Wire Coiled Turbulators, International Journal of Mechanical, Aerospace, Industrial, Mechatronic and Manufacturing Engineering Vol:8, No:2, 2014
- [8] Hussein Chaji, Yahya Ajabshirchi, "Experimental Study on Thermal Efficiency of Flat Plate Solar Collector Using TiO_2 /Water Nano-fluid, Modern Applied Science; Vol. 7, No. 10; 2013,ISSN 1913-1844 E-ISSN 1913-1852
- [9] Siddhartha Roy, Deepak Kunhappan, "Heat transfer performance of silver/water Nano fluid in a solar Flat-plate collector" - Research Article – JTEN – 2014-7
- [10] Raj Thundil Karuppa R,Pavan.P, "experimental investigation of a new solar flat plate collector", journal of engineering science, volume 1(4),October 2012,ISSN 2278-9472
- [11] J.S.khatik,S.V.Yeole, "comparative experimental study of simple absorber plate with absorber plate having concavities", international journal of research in engineering and technology,eISSN:2319-1163