Fabrication and Performance analysis of Solar Cavity Collector

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ABSTRACT

Solar Energy is radiant energy and heat coming from the sun is used in a range of evolving technologies such as solar heating and solar thermal energy. Solar energy has become an alternative approach for the limited fossil fuel resources. One of the simplest and most direct applications of solar energy is the conversion of solar radiation into heat that can be used in water heating system. It will increase countries energy security through inexhaustible and mostly import-independent resource, enhance sustainability, reduce pollution, lower the costs of mitigating global warming and keep fossil fuel prices lower. For converting sun radiant energy into heat energy, it is required to use a flat plate collector for exchanging the heat using the greenhouse effect.

Several studies were carried out by scholars in order to improve the performance of the flat plate collector in recent years. The concrete objective of this paper is to design performance analysis of solar cavity collector in order to improve the efficiency of the flat plate collector. In this paper I have analyzed the performance of flat plate cavity collector. In order to verify the proposed method, an experiment was designed and fabricated. Four numbers of cavities are placed in rectangle metal box with equal distance. The size of the collector is width 550mm, length 350mm and height 30mm. The tubular absorber with an outer radius of 5mm was positioned concentrically with the cylindrical cavity. A glass plate mounted on top serves as protective shield for spilled radiation. All the joints are metal box are well sealed. The collector sides and bottom were properly insulated to reduce heat losses. The collector was kept in open yard facing south and exposed to solar radiation.

Keywords *– Atmospheric Temperature (T_a), Temperature of water at inlet (T_{in}),Temperature of water at outlet (T_{out}), Temperature of glass cover (T_g).*

I. Introduction

Solar energy is becoming an alternative for the limited fossil fuel resources. Solar Energy is radiant light and heat from the sun that is used in a range of evolving technologies such as solar heating and solar thermal energy. Active solar include the use of photovoltaic systems, concentrated solar power and solar water heating to harness the energy. One of the simplest and most direct applications of this energy is the conversion of solar radiation into heat that can be used in water heating system. The International Energy Agency said that "the development of affordable, inexhaustible and clean solar energy technologies will have huge longer-term benefits". It will increase countries energy security through reliance on an indigenous, inexhaustible and mostly import-independent resource, enhance sustainability, reduce pollution, lower the costs of mitigating global warming, and keep fossil fuel prices lower. In 2003 11.4 million sq. ft. of collector area were delivered by 27 manufacturers. Most of these were unglazed collectors for swimming pools, a very cost-effective application. The installation of solar water heating system can be done on the near-south-facing roof or nearby un-shaded grounds for installation of collector.

For converting sun radiant energy into heat energy it is required to use a flat plate collector for exchanging the heat using the green house effect. Solar flat plate collectors are more than capable of delivering the necessary quantity of hot water at the required temperature. A lot of research has been done in order to analyze the flat plate operations and improve its efficiency.

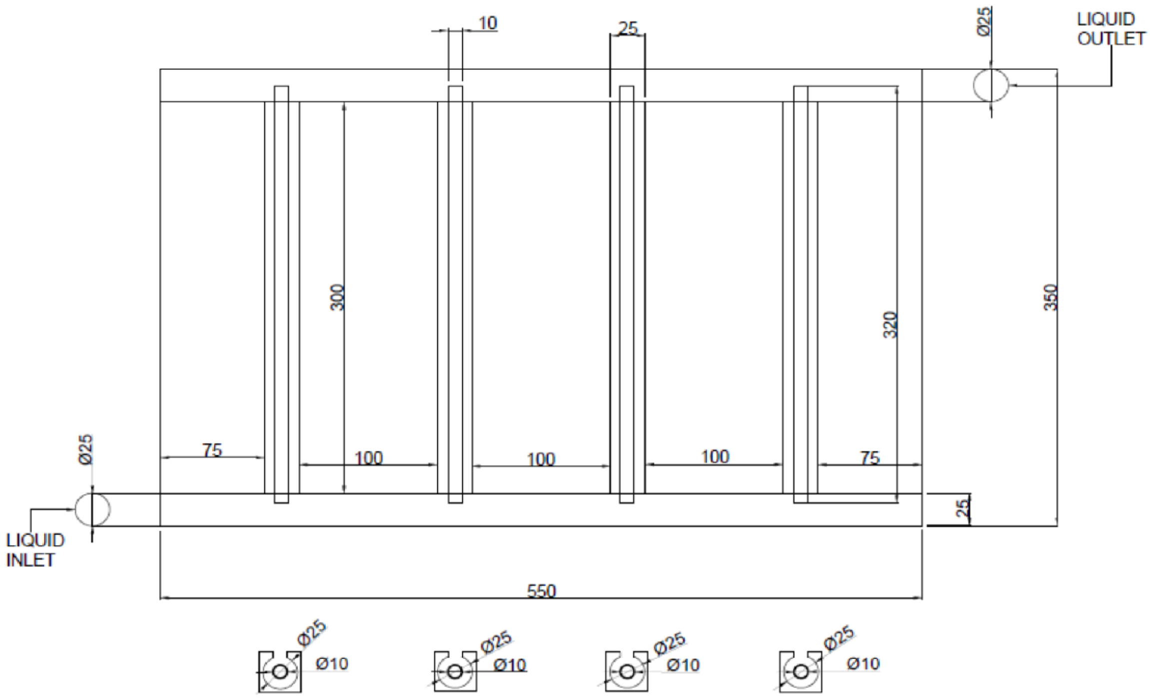
Therefore, the thesis include the solar water based heating system having a cavity collector for trapping the heat inside the system for heating the water by the use of solar energy. The system on the top has one transparent glass that can penetrate the solar radiation within the system and can be absorbed by the cavity collector to producing heat. . This system of cavity collector can be installed anywhere onto the roof of any building or in the open area where sun light can reached. In this system, there are tubes or channels that can allow water to pass through it and can be heated because of the solar radiation. The solar collector collects the heat from the transparent cover onto the top which created more heat when the sun light enteron the top of it, then the black color painted walls of the system creates more heat to get the warm water. Water heating is a sustainable portion of energy that can be uses at many residential, commercial, institutional, and federal facilities. Solar water heating system can provide efficiently 80 % hot water needs without fuel cost or pollution and minimal operation which use the sun's energy rather than the electrical energy for heating water.

II. EXPERIMENTAL INVESTIGATION

Specifications of Proposed Work

- Collector size : 550 mm x 350 mm x 40 mm
- Number of cavities : 4
- Diameter of each cavity : 25 mm
- Length of each cavity : 30 mm
- Diameter of each tube : 10mm

- Length of each tube : 320mm
- Thickness of glass plate : 2mm
- Tube material : Copper



All dimensions are in mm

Fig. 1 Schematic of Flat plate cavity collector

Description

The flat plate solar cavity collector consists of four cylindrical cavity absorbers coated with black paint.1cm copper pipe has been placed concentrically within the cavity. The cavities were connected in parallel type through pipes. Top and bottom ends of the unit were connected with outlet and inlet headers respectively. The total setup was tilted at an angle of 11degree to the horizontal. The collector sides and bottom were properly insulated to reduce heat losses. The collector was kept in open yard facing south and exposed to solar radiation.

The experiment was conducted from 10.00 am to 4.00 pm on different days with different flow rates. The instantaneous efficiency of the collector was estimated. Based on the observed data graphs were drawn.

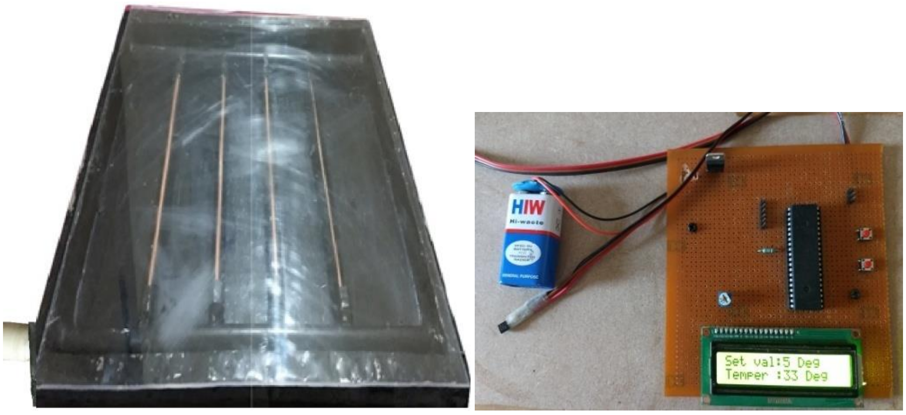


Fig. 2 The experimental arrangement of the solar cavity collector

The diagram shows the experimental arrangement of the cavity collector. The solar cavity consists of a cylinder with the diameter of 2.5 cm and lined with glass wool insulation. Four numbers of cavities are placed in rectangle metal box with equal distance. The size of the collector is width 55 cm, length 35cm and height 4cm.The tubular absorber with an outer diameter of 1 cm was positioned concentric with the cylindrical cavity. A transparent plate mounted on top serves as protective shield for spilled radiation. All the joints are metal box are well sealed. Global solar radiations were measured by the Temperature sensor with the use of LCD .The ambient temperature was recorded by the same temperature sensor.

III. RESULT AND DISCUSSION

Solar cavity collector has a set of cylindrical cavities to receive and capture the solar radiation. Experiments were carried out for various fluid flow rates to determine the optimum performance parameter. The experiments were conducted from 9.00 am to 4.00 pm on different days with different flow rates. The instantaneous efficiency of the collector was estimated. It shows that the efficiency of the cavity collector increases even in the late afternoon hours. It is evident from the graph; the temperature goes on increasing even in afternoon hours when solar intensity is very low. Also, the result shows that the efficiency of the cavity collector is better than the conventional type even on cloudy days or part cloudy days. The cavity collectors having more capacity to hold heat for a long time. Copper tubes are giving better result when comparing to the G.I pipes. The efficiency is increased due to copper can withstand or hold the heat for a long time. From the graph we know that the flow rate of water at 0.0025 kg/sec gives better result as an outlet temperature of water at 71℃ was achieved. The average efficiency of 55% was achieved at a water flow rate of 0.00416 kg/sec.

EXPERIMENTAL INVESTIGATION FOR SOLAR FLAT PLATE CAVITY COLLECTOR

1. Flow rate: - 0.00375kg/sec. Date: - 25/05/2018

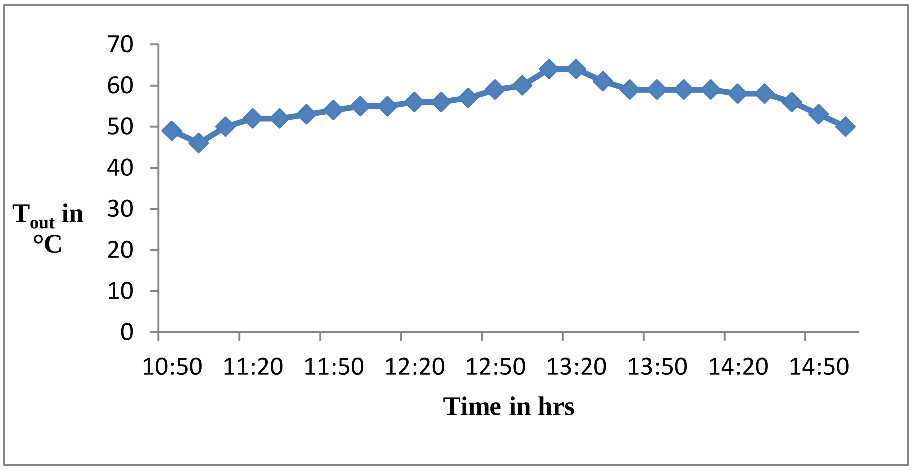


Fig. 3 Variation of Outlet temperature w.r.to Time

2. Flow rate: - 0.0075kg/s Date:-26/05/2018

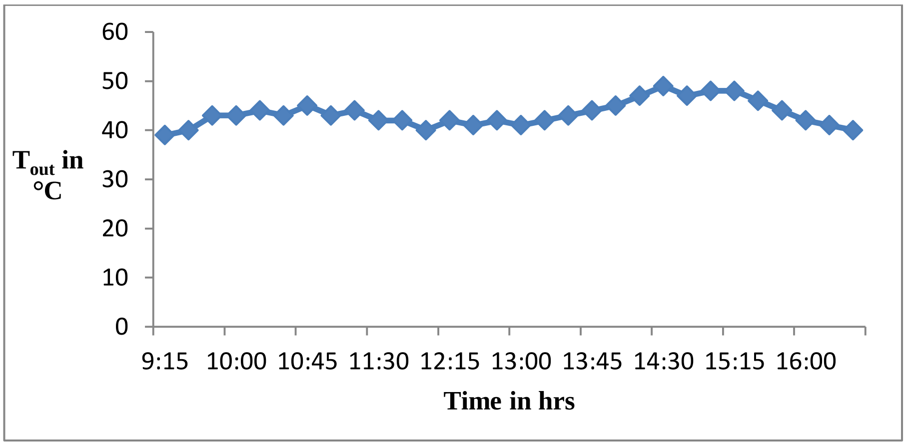


Fig. 4 Variation of Outlet temperature w.r.to Time

3. Flow rate: - 0.00275kg/s Date: - 27/05/2018

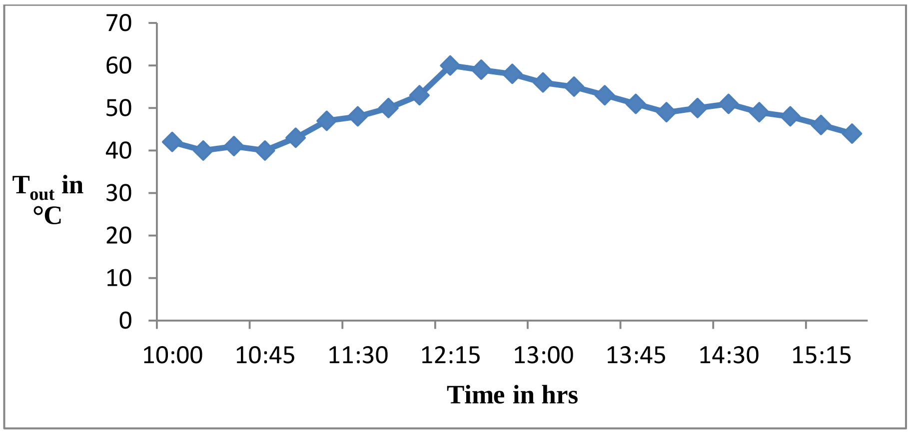


Fig. 5 Variation of Outlet temperature w.r.to Time

4. Flow rate: - 0.0033kg/s Date: - 28/05/2018

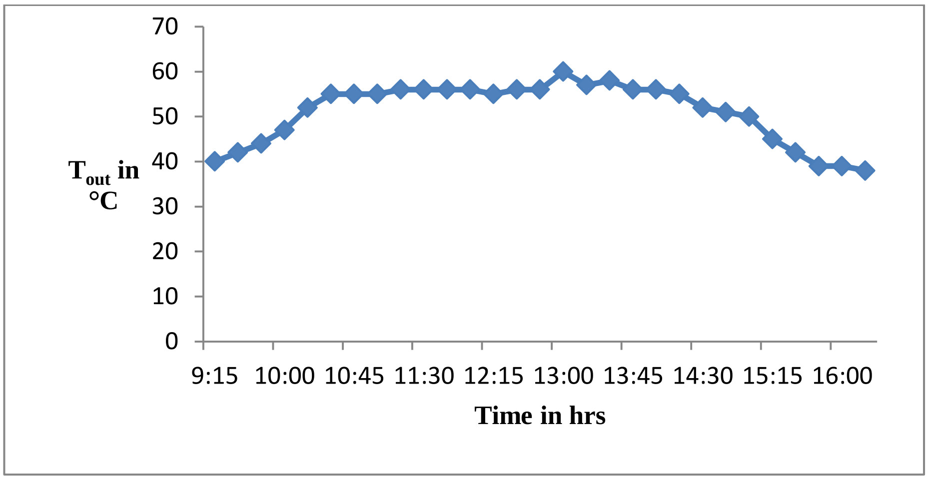


Fig. 6 Variation of Outlet temperature w.r.to Time

5. Flow rate: - 0.0025kg/s Date:- 29/05/2018

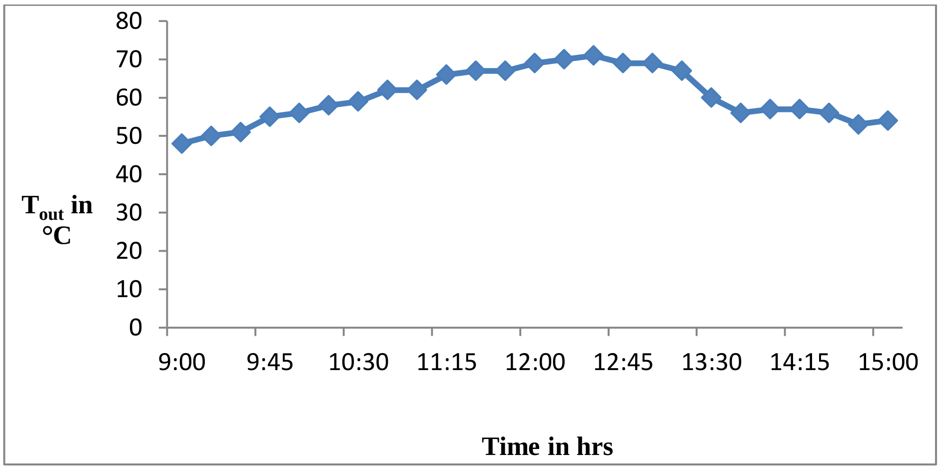


Fig. 7 Variation of Outlet temperature w.r.to Time

6. Flow rate: - 0.002kg/s Date: - 30/05/2018

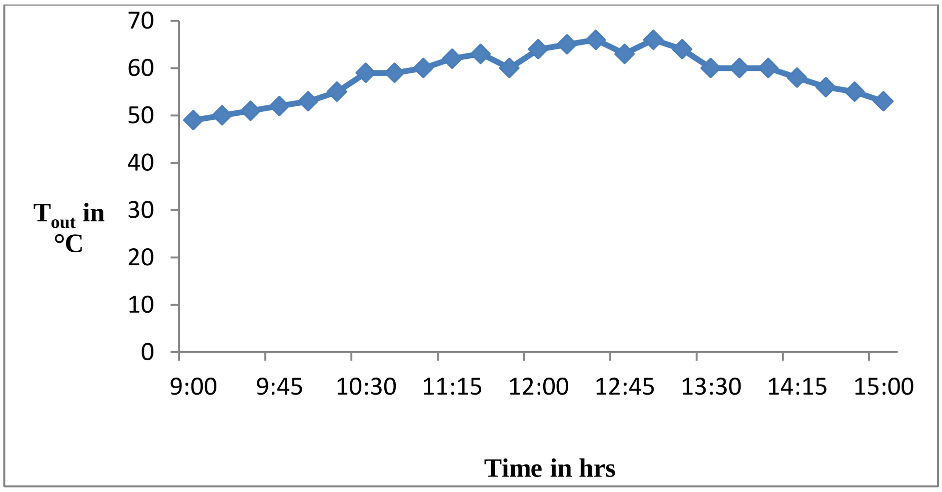


Fig. 8 Variation of Outlet temperature w.r.to Time

7. Flow rate: - 0.00416kg/s Date: - 31/05/2018

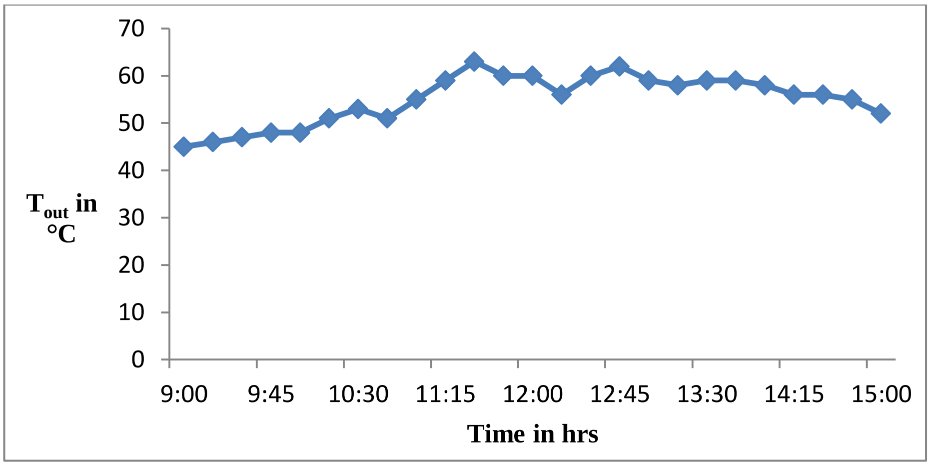


Fig. 9 Variation of Outlet temperature w.r.to Time

8. Maximum outlet Temperature w.r.to Flow rate

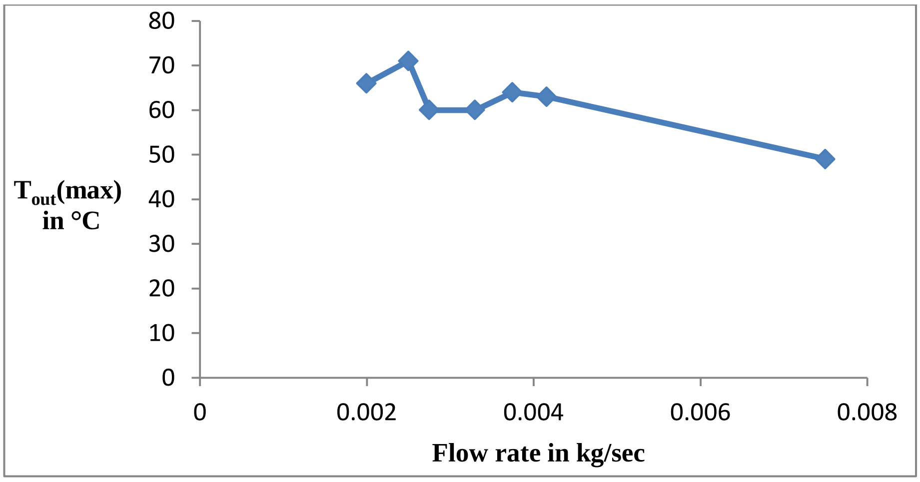


Fig. 10 Variation of Maximum Outlet temperature w.r.to Flow rate

TABLE 1 OBSERVATION TABLE

Flow rate: - 0.00416kg/s Date: - 31/05/2018

Sl. No	Time Hrs	Heat Available w/m^2	T_a °C	T_{in} °C	T_g °C	T_{out} °C
1	10:30	527		34	57	53
2	11:00	727	38	34	57	59
3	11:30	752		34	57	63
4	12:00	752	40	34	56	60
5	12:30	752		34	54	62
6	13:00	727	38	34	52	59
7	13:30	652		34	58	59
8	14:00	652	38	34	58	58

SPECIMEN CALCULATION: -

(For the value given in table , time 12:00)

1. Heat available = 752 w/ m^2
2. Total heat gained by water= mcp⌂t

   Where, m= mass flow rate of wate= 0.00416 kg/sec.

   Cp= Specific heat of water= 4186 J/kg-k

   Q=0.00416 x 4186 x [60-34]

   = 452.75 w

3. Efficiency =total heat gained by water/heat available

   = 452.75 x 100/752

   = 60.20%

TABLE 2 RESULT TABULATION

Date: - 31/05/2018 Tin: - 34 °C

Sl. No.	Time hrs	Total heat gained by water W	Efficiency %
1	10:30	330.86	62.78
2	11:00	435.34	59.88

3	11:30	504.99	67.15
4	12:00	452.75	60.20
5	12:30	452.76	64.83
6	13:00	435.34	59.88
7	13:30	435.34	66.76
8	14:00	417.93	64.09

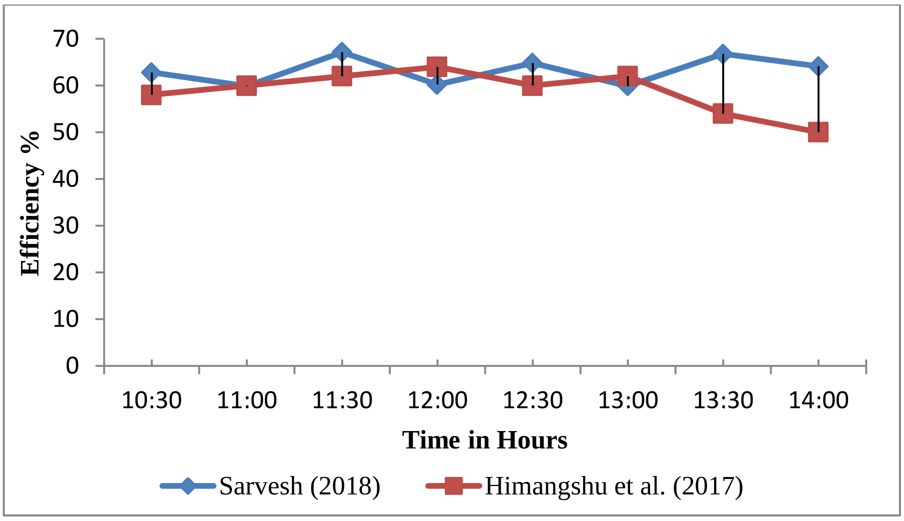


Fig. 11 Comparison and Variation of collector efficiency w.r.to time

IV. CONCLUSIONS AND FUTURE SCOPE

Conclusion Solar collectors usually can employ the cavity-type configuration for highly concentrated solar applications. The cavity receiver has an advantage of multiple reflection of radiative energy inside the cavity itself. That-is, a proper design of the cavity makes effective capture of solar radiation entering through a small opening called aperture. Cavity-type collectors are also well suited for the solar radiation of intermittent type. The radiative energy once absorbed by the air inside the cavity can withstand the temperature and distribute it to the surrounding working fluid either air or water. It is however useful to point out that the multi-reflection effect is considered through the cavity and thus increases the heat holding capacity for a long time, particularly inside the cavity.On the basis of the results obtained in this study, the following conclusions can be drawn:

- To improve the efficiency of the flat plate solar cavity collector, the collector tube was replaced by copper tubes and was designed, fabricated and tested for its performance. Experiments were carried out at different flow rates on different days.

- All the thermo-physical properties of the air gap, the absorber plate, and the working fluid are computed in time dependent mode. The transient heat transfer coefficients are also computed in real time.

- The proposed method allows the transient processes occur in the flat-plate solar collector to be simulated. The time dependent flow rate, variable ambient temperature, and variable solar irradiance have been taken in consideration.

- The efficiency of the proposed method was confirmed by experimental verification. The analysis shows a very good agreement between the measured and the numerically predicted values for different running conditions and flow rates.

- It is found from the observed data that the flat plate cavity collector having copper tubes performance was better than the collector having galvanized iron tube specially during the late afternoon hours and cloudy times. The efficiency of the collector is of increasing trend even.

Future Scope

Solar water heater performance is a topic of never-ending discussion in the solar renewable energy field. While the performance of solar water heater systems is at par, still there is scope of performance improvement. In order to assure certain quality for solar water heater systems, it is necessary to design standards, conduct tests to verify compliance of these standards. In this project solar water heater performances parameters are discussed which would be useful to optimize and compare various solar water collectors. It would provide information to consumers regarding performance of the solar water heater. There is wide scope in research and development of solar water heater to enhance performance by increase transmission of energy through the collector to the working fluid also reduces thermal losses, few of them are as follows:

- More experimental investigations are needed to improve the efficiency of the proposed model, by testing the performance for different cases.

- To improve the cavity collector performance. It can be tested with changing the tilt angle, position, etc.

- The performance of solar cavity collector can be improved by increasing the size of the collector.

- The performance of solar cavity collector can be improved by increasing the number of cavity.
- Performance can also improved by the use of solar tracker in solar cavity collector.

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