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Fabrication & Performance Analysis of Solar Water Heater Using Porous Medium & Agitator

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Abstract

The aim of the present study is to improve the thermal performance of flat plate solar collector using a cheap cost energy absorbing materials. The present work focuses on the process of energy conversion from the collector to the working fluid. Here the system follows passive solar system so the circulation of water will be natural. This experimentally accomplished by using agitator in the riser tube, packing of collector's surface with porous medium such as pebble stone. The basic purpose of agitator in the riser tube is to improve heat transfer , packing of collector surface with pebbles stones is for longer heat retention and enhanced heat capture respectively .In this project temperature of water is being measured with different combinations such as with agitator, pebbles stone is measured, and also combination of both agitator and pebbles stone is also measured. Here collector is made with aluminium plate so that there will be a good heat transfer process, and here storage tank had capacity of 15 litres and it also had a valve which it acts as an outlet. As the flat plate has low efficiency because of poor convective heat transfer and consequent thermal loss, in this project both factor is being considered and by placing agitator and pebble stones can increase convective heat transfer and reduce thermal loss and thereby efficiency is being gradually increased.

Index Terms— Porous medium, pebbles, agitator, solar water heater etc

I. Introduction

The solar energy is the most capable of the alternative energy source. Due to increasing demand for energy and rising cost of fossil fuels like gas or oil solar energy is considered an attractive source of renewable energy that can be used for water heating in both homes and industry. Heating water consumes nearly 20% of total energy consumption for an average family. Solar water heating system is classified into three types namely (A) Active system (B)

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Passive system (C) Batch system

Active system:

Active system use electric pumps, valves and controller to circulate water. It is again classified into two categories (A) Open loop (direct) active system.(B) Closed loop(indirect) active system.

Passive system:

Passive system simply circulates water or heat transfer fluid by natural convection between collector and elevated storage tank. Thermosiphon and evacuated tube collector is one of the best example for this type of system.

Batch system:

Batch system also known as integral collector storage system are simply passive system consisting of one or more storage tank placed in an insulating box that has a glazed side facing the sun

[1]An active solar water heating system requires an external source such as pump or motor. In this study less than 1 m2 area of solar collector was fabricated by using indigenous materials. The temperature in moderate weather by this collector was observed as 76°C with inlet temperature of 25°C. r. The overall efficiency of this system was found as 26.28% as compared to 23% (with tracking system) and 19% (with non-tracking system) observed by other researchers. In this study a passive solar water heating system was also fabricated, by using indigenous and locally available materials. The maximum temperature achieved by this system in moderate weather was 90.5°C with the inlet temperature of 28.1°C. The overall efficiency of this system was found as 31.07% as compared to 19% which is higher than the system studied by other researchers.

[2]Batch type solar water heater with integrated collector storage tank, deliver 30L of 60°C water by 5:00pm this domestic BSWH system with a capacity of 100 litter per day is capable of achieving significant energy savings in hot climate countries.

[3] Two small box type solar water heaters are designed and fabricated size of 24”×16”×4”. One has conventional tube-in-sheet flat plate collector and another is modified by using Phase Change Material (PCM) as short term heat storage media, It is observed that water could be heated to 90℃ by mid afternoon in simple water heater where as PCM filled collector keeps water warm even after sun-set. It has been found that 40°C temperature of water is available till 10 pm in winter conditions. It can be concluded that a ½ kg of PCM with some pipe work in the flat plate collector can improve the efficiency as well as dependability of cloudy or short-term Sun off period.

[4]Study of solar water heater based on exergy analysis, Exergy is the expression for loss of available energy due to the creation of entropy in irreversible systems or processes. The exergy loss in a system or component is determined by multiplying the absolute temperature of the surroundings by the entropy increase, Exergy efficiency of solar systems is highly dependent on the daily solar radiation and radiation intensity. To improve the exergy efficiency, we must select the material and design the number layer of transparent cover and a

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judicious choice of the length of pipe is necessary. It is a good way to find out to design a new style of storage tank, because large exergy losses in the storage tank.

[5] The automated system would allow the user to get hot water from the solar water heater as long as the solar water heater can supply hot water above a set temperature. If the solar water heater is unable to supply water above the set temperature, then only will the electric water heater come into action. It is efficient because our controller ensures that the solar water heater is used to supply hot water 80% of the time, and the rest 20% will be supplied by the electric water heater. It is cheap because, our system runs on solar energy which is abundant and free. It uses very small amount of electricity and therefore, reduces the expenses for the user.

Flat Plate Collector:

- Reason for low efficiency of flat plate collector

(A) Poor convective heat transfer between the collector working fluid and the absorber tubes.

(B) Collector plate temperature increases consequently the thermal loss increases.

- Method to improve the efficiency

(A) Factor affect on convective heat transfer

(B) Commercial known method to improve the efficiency(area of heat exchanger, mass flow rate).

(C) Working fluids.

[6]Tube-side enhancement passive techniques can consist of adding additional devices which are incorporated into a smooth round tube (twisted tapes, wire coils), modifying the surface of a smooth tube (corrugated and dimpled tubes) or making special tube geometries(internally finned tubes).Based on previous studies from the authors, wire coils were selected for enhancing heat transfer. This type of inserted device provides better results in laminar, transitional and low turbulence fluid flow regimes.

[7] Reverse Flat Plate Collector which increases the efficiency of solar water heating system. Major losses being convection losses from absorber plate to glass which is 20 to 30 %.RFPC eliminates this loss and also we have used the same area for producing electricity using the solar voltaic plate. Experimental result is found to be that RFPC is better in efficiency. . **[8]**Enhancement of Flat-Plate Solar Collector Thermal Performance with Silver Nano-fluid, In this study, water mixed with 20 nm silver nano with concentrations at 1,000 and 10,000 ppm were undertaken as the working fluid in three identical closed-loop flat-plate solar collectors each of 0.15 x 1.0 m2. The flow rate of working fluid was between 0.8 - 1.2 litre/min m^2 and the inlet temperature were controlled in a range of 35-65 degree Celsius. The results showed that as the concentration of the nano particles increased the thermal performance increased. The solar collector efficiency with the nano-fluid was still high even the inlet temperature of the working fluid was increased.

[9]Concentrated solar power (CSP) systems use mirrors or lenses to concentrate a large area of sunlight, or solar thermal energy, onto a small area. Solar radiation

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concentration using optical lens arrays make possible to achieve high temperature using conventional flat plate collector will provide cost effective performance.

[10]The present work concentrates on the incorporation of porous medium to improve the thermal performance of a dual purpose solar collector. Dual purpose solar collectors can be used for heating air and water simultaneously using incident solar radiation resulting in optimum usage of energy and space. A simulation study is undertaken to investigate the integration of a porous matrix to dual purpose collectors. The porous matrix is incorporated below the absorber plate of the collector to improve the thermal performance of the overall system. The total thermal efficiency of the modified collector is found to vary from 34.60% to 46.03% over inlet water temperature range of 30°C to 90°C.

Flat plate solar water heater efficiency is improved by placing additional device around flow path of hot water carrying pipes like twisted tapes, wire coil and by using nano fluids like silver nano fluids and some porous medium is also used. But in flat plate solar water heater, temperature loss of water occurs suddenly due to high convection loss, and this factor is prevented by placing agitator and porous medium.

II. Experimental Setup

The basic parts of the working models are - Flat plate water heater, Insulated Water Storage Tank, Instruments used are Digital Thermometer, Agitator using Aluminium Wire with copper coating, Packing Media such as Pebbles, Stainless Steel chips. The purpose of agitator in the riser tube is to intensify heat transfer and packing of collector surface with porous medium is for longer heat retention and to enhance heat transfer respectively. The frame of solar collector is made with aluminium and circulation pipe is made with plastic pipe. Inside flat plate collector pipes are made with copper tubes of 15mm dia. The length of riser tube is 55cm and the length of header tube is 48 cm, and the number of riser tube is 6 and the number of header tube is 2 solar collector frame length is 70 cm and width of collector is 62 cm. Storage tank capacity of about 15 litres. Frame of solar flat collector is covered with 3mm thickness glass. Copper sheet metal is placed below copper pipes for heat capture respectively. Stand is usually made with stainless steel. Following are the part of the project namely body of collector, support for tank, two valve one for storage tank outlet and another one for inlet flow of water. Valve which is made for outlet is made with mild steel and valve for inlet is made with plastic. In construction of flat plate collector insulation that are made with glass wool to prevent heat escaping radiation. Copper pipes are welded with help of gas welding. Storage tank inlet and outlet are made by collar of 18 mm dia. The top surface of the collector was left open for the glass cover plate. Flat plate collector along with storage tank, valve and copper pipes were painted black to increase absorption of heat.

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Figure 1: Ordinary Solar Water Heater

Figure 2: Solar Water Heater With Agitator

Figure 3: Solar Water Heater With Porous Medium

Figure 4: Solar Water Heater With Agitator, Porous Medium & Transparent Cover

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III. Result & Discussion

The following results are obtained and presented in tabular form

Case 1: Ordinary Solar Water Heater

On by using Ordinary Solar Water Heater without using any absorbing medium there is a gradual increase of temperature but however there is a decrease in temperature after certain time. Reading values and graph are tabulated below.

Table 1: Ordinary Flat Plate Water Heater Only (6th October)

Time	Global Radiation (W/sq.m)	Diffused Radiation (W/sq.m)	Ambient Temperature (deg.C)	Temperature Of Water (deg.C)
09:00 AM	526	122	22.24	23.26
10:00 AM	640	137	24.37	25.32
11:00 AM	655	169	26.97	27.46
12:00 PM	681	198	28.83	27.92
1:00 PM	713	163	30.25	29.24
2:00 PM	698	151	29.79	30.17
3:00 PM	620	126	28.63	29.21
4:00 PM	522	111	26.78	28.59
4:30 PM	421	81	24.66	28.29
5:00 PM	401	65	24.09	27.99

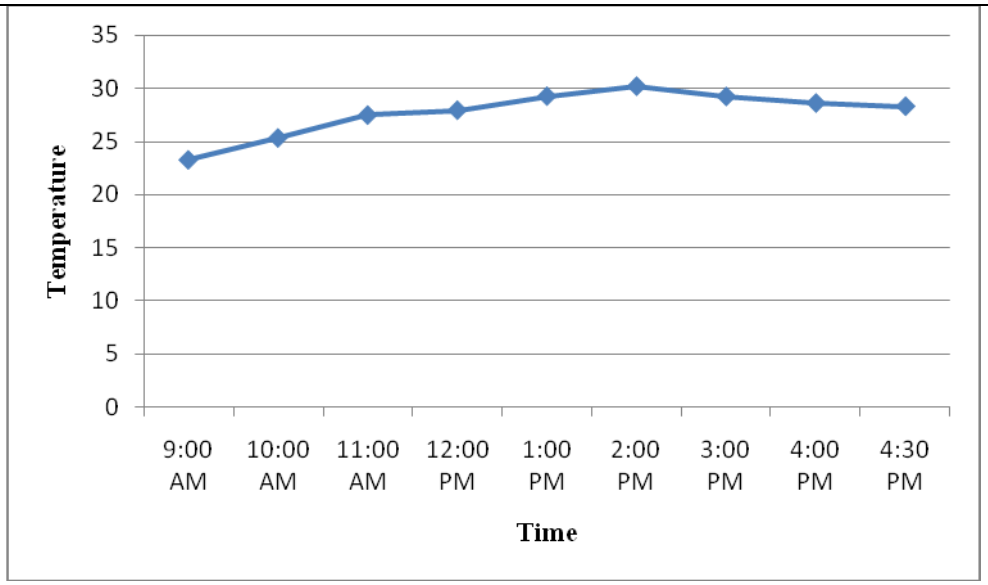

Figure 1 ordinary solar water heater

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Case 2: Agitator in the riser tube

On by using Agitator in the riser tube of solar water heater there is a gradual increase of temperature but however there is a decrease in temperature after certain time. Reading values and graph are tabulated below

Table 2: Flat Plate Collector with Agitator only

(7^{th} October)

Time	Global Radiation (W/sq.m)	Diffused Radiation (W/sq.m)	Ambient Temperature (deg.C)	Temperature Of Water (deg.C)
09:00 AM	530	136	23.24	24.16
10:00 AM	642	149	24.37	26.33
11:00 AM	599	200	26.47	27.06
12:00 PM	683	239	28.89	28.85
1:00 PM	710	247	30.15	30.14
2:00 PM	698	152	29.96	31.15
3:00 PM	623	110	27.63	29.29
4:00 PM	530	86	25.78	28.88
4:30 PM	429	71	23.06	28.69
5:00 PM	412	67	23.00	27.96

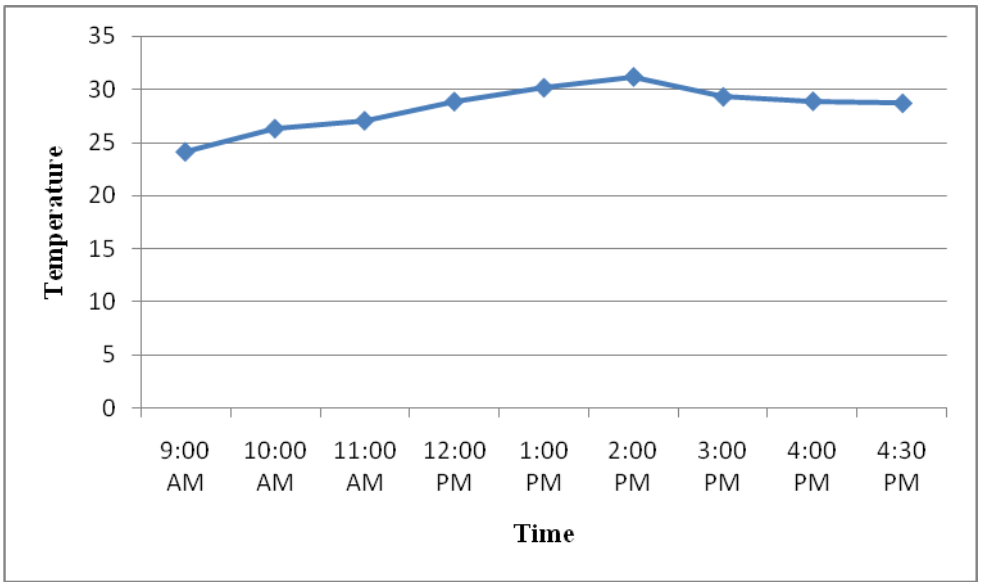

Figure 2 temp Vs time with agitator

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Case 3: Agitator and porous medium in collector

On by using Agitator and porous medium in the collector temperature rise as well as temperature is being maintained constant. Reading values and Graph are tabulated below

Table 3.Flat Plate Water Heater with Porous Medium
(8^{th} October)

Time	Global Radiation (W/sq.m)	Diffused Radiation (W/sq.m)	Ambient Temperature (deg.C)	Temperature Of Water (deg.C)
10:15 AM	567	97	24.47	27.39
10:50 AM	596	112	25.56	29.96
11:20 AM	613	121	26.71	30.14
12:00 PM	650	179	28.14	31.24
12:30 PM	697	194	28.49	31.49
01:00 PM	716	204	30.14	31.97
02:00 PM	681	191	29.69	29.36
03:00 PM	622	170	28.36	28.85
04:00 PM	593	130	26.74	28.68
05:00 PM	490	99	25.57	28.47

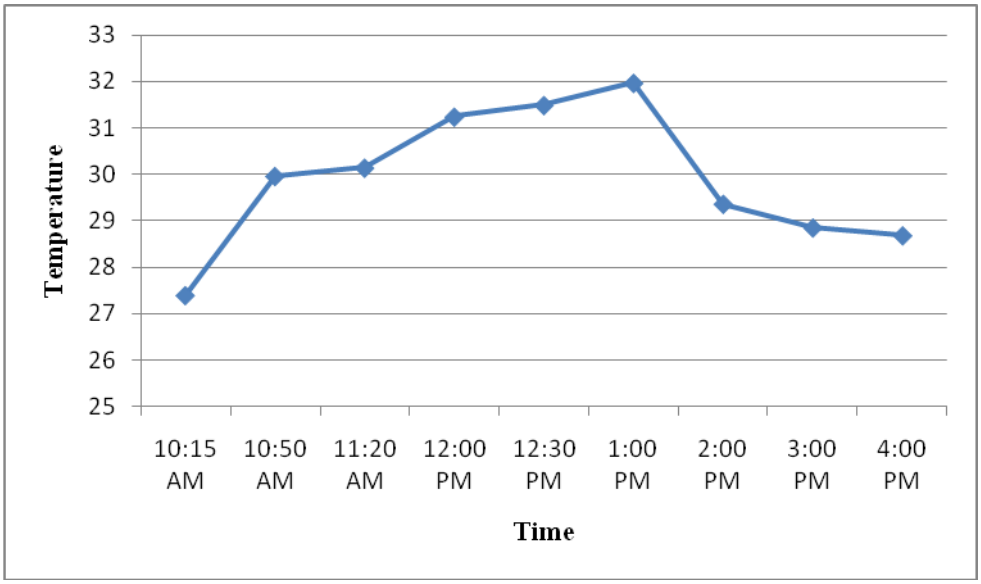

Figure 3 temp Vs time with porous medium

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Case 4: Agitator, porous medium and transparent cover in collector.

On by using Agitator, porous medium and transparent cover in the collector high temperature is being achieved and as well as temperature is being with stand for longer time. Reading values and graph are tabulated below.

Table 4.Flat Plate Water Heater with Agitator & Porous Medium& Transparent Cover (8^{th} October)

Time	Global Radiation (W/sq.m)	Diffused Radiation (W/sq.m)	Ambient Temperature (deg.C)	Temperature Of Water (deg.C)
10:15 AM	476	136	23.74	26.87
10:40 AM	513	147	24.11	27.74
11:15 AM	496	139	24.76	28.98
12:00 PM	567	167	25.74	29.99
01:00 PM	674	196	28.74	31.47
01:30 PM	714	204	29.96	32.45
02:00 PM	654	178	27.41	32.01
03:00 PM	622	147	26.54	31.67
04:00 PM	556	109	24.89	30.47

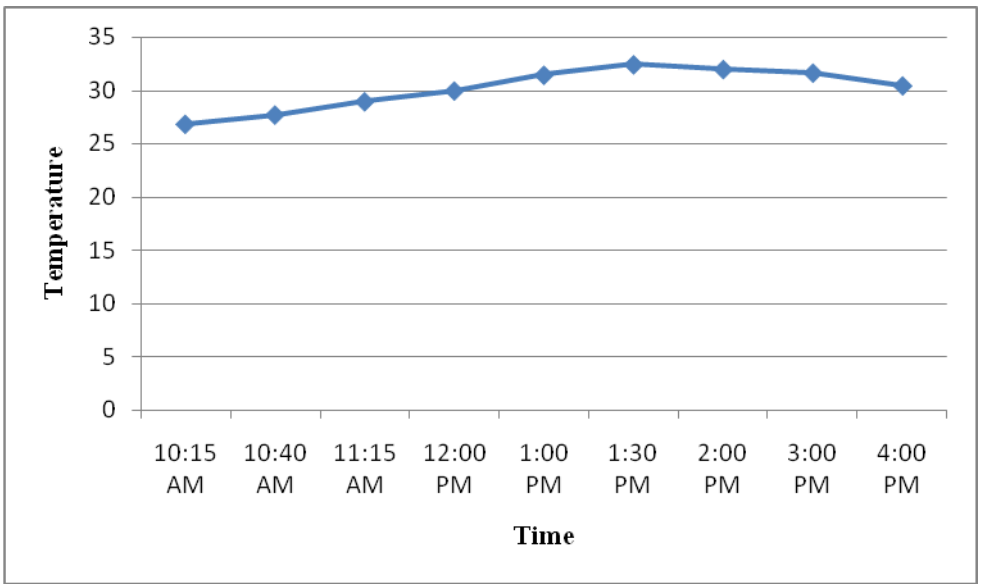

Figure 4 temp Vs time with agitator, porous medium

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IV. Conclusion

Flat plate solar water heater is being fabricated with low cost, as flat plate collector has low efficiency because of convection heat transfer loss. In this thesis this factor is considered and prevention of this loss is done by porous medium and agitator.

Following are the maximum temperature attained by solar water heater:

- Ordinary solar water heater ----------**30.55**
- Solar water heater with agitator----------**31.15**
- Solar water heater with porous medium----------**31.97**
- Solar water heater with agitator and porous medium---**32.01**
- Here porous medium used is pebble stone as it had high heat energy absorbing properties, so it has highest temperature in comparison with agitator and ordinary solar water heater.

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