Investigation of solar water heater by using flat plate collector and evacuated tubes

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Abstract. Collection, storage and utilization of solar energy by solar water heating by flat plate collector and evacuated tube is cheapest and effective renewable energy technologies. This solar water heater design uses a nonconventional source of energy which can be used for house hold applications. The cost of production will be comparatively low in cost and high in capacity. The G.I. sheet collector boxes are replaced by copper tube, stainless steel water tank, thick costly PUF insulations and toughened glass etc. Pebbles are used as a medium of heat storage this increases the capacity of solar water heater.by using this method natural source of energy can be used instead of depending on electric water heaters.

1. Introduction

The solar water heater uses the incident solar radiation for generating heat and it converts the radiation energy in to thermal energy. The heat generated by the thermal energy source is used for different application. There is a rapid growth in the world of solar water heater market which accounts for an annual growth rate of 15%. Major market share for solar energy water heater are India China and Europe. Overall the cost of unit is expensive so there is a need to develop a low cost construction of this water heater. Government of India has a target of 20 million units to be produced by the end of 2022 for Solar Water Heater collectors. It is being implemented in different phases the first phase with 7 million units for the year 2010 to 2013, the second phase with a target of 15 million units for the year 2014 to 2017 and the target for 2022 is 22 million units. The solar water heating system has the following components solar thermal collectors, water storage tanks, connecting pipelines, and the water to be heated and circulated within the solar water heating system. The source of heat is used by heat falling on to the surface which generates the heat source. The heat source can be generated by either a flat plate collector or a evacuated tube collector. The sun rays falls directly over the collector tube which results in the heating of tube. The water is passed to flow through the heated tube which results in change in temperature of the water. Now the water gets heated up and the temperature starts increasing.

Ahmet Samanci[1] concluded that the efficiency of the closed system is lower than the two phase system and also by using two phase SWHS heat is transferred by the process of evaporation & condensation as a result of quick response to change in solar radiation. Sanjay Kumar Sharma et al[2] suggested that the system is designed for 5 litres water inside & outside of the tank for per hour and 30 litres water capacity tank. The research work focuses upon the process of energy conversion from the collector to the working fluid. This is accomplished by employing an aluminium sheet placed at the base within the system to induce a gradient of heat capacitance and the Flat Plate Collectors (FPC) and Evacuated Tube Collectors (ETC) are more popular devices used in the solar water heater system. This domestic V- Through flat plat collector system with a capacity of 100 litters per day is capable of achieving significant energy savings in hot climate countries. Particularly, in the present situation of acute energy short age and most suitable to supply the needs as a family of four persons.The evacuated tube collector method is more popular in the last decade which has a great impact in the solar water heater industry. There are more manufactures and suppliers for the Evacuated Tube Collectors because of this there is greater expansion in the solar water heating businesses. Due to this the cost of manufacturing came down which resulted in reduction in costs of the domestic solar water heater systems. Rajakrishnamoorthy P [3]suggested that the efficiency of the conventional collector is lesser when compared to the Integrated collector storage solar. Pankaj Kumar Mongre[4] suggested that increase in the instantaneous efficiency 55.24 % due to increase in glazing area. Morrison et al[5] has identified that during high temperature operations the evacuated tube solar collectors has a good performance than the flat plate collector. The U-tube glass evacuated solar collector is being used widely when compared to a heat pipe method. Some experimental investigation has resulted that U-tube welded inside a circular fin has a good result in thermal efficiency, which has a benefit over other different shapes of the absorber tube. The parts which are used for the fabrication of this evacuated U-tube solar water heater are discussed in the components and description section.

2. Components and Description

The components used to fabricate physical setup of this work are Acrylic Fiber, Copper Tube, Water Flow Controller, and Mild Steel.

2.1 Acrylic Fiber

The Acrylic fibres are synthetic fibres which are made from a polymer called polyacrylonitrile. This polymer has an average molecular weight of ~100,000, which about 1900 monomer units. The first acrylic fibres were created in 1941by DuPont. The DuPont then created the trademark under the name orlon. The Acrylic is called as acrilan fabric. The acrylic fibre are used as lining in boots, gloves, sweaters and tracksuits and it is also used in furnishing fabrics and carpets. The manufacturing of acrylic is made as filaments and then it is cut into short lengths as staple which is similar to wool hairs and then it is spun into yarns.

2.2 Copper Tube

Copper tubes are generally used in HVAC system as a refrigerant line and it is also used transport hot and cold water. The copper tube is of two types one is soft copper tube and other is rigid copper tube. To join the copper tubes we use flare connection or compression connection or solder method. The purpose of using copper is due to its property of having higher corrosion resistance but it is becoming expensive. The soft or ductile copper tubes can be easily bent, so that it can be easily fixed around the path which has obstacle in the path of tubing. The copper tubes can be bent for more exposure to the sun rays which improves the heating method and easy to carry water.

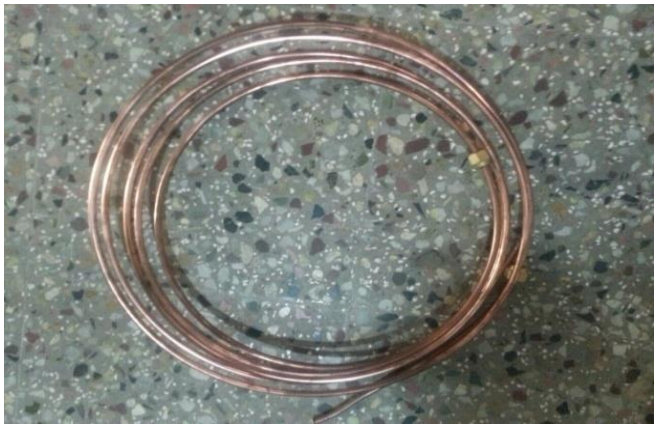

Figure 1. Copper tube

2.3 Water Flow Controller

The flow of water should be controlled to achieve a linear flow rate so that the water flowing through the tube will have even heating through the thermal conductivity achieved through the copper tube. A self sealing latex tube is used for the extra medication and easy flushing highly kink resistant tubing roller clamp is used for the flow controller with special beveled extra strong spike disc filter in drip chamber facilitating rapid adjustment of fluid at 23G needle for smooth flow drop size which is reduced to 60 drops / ml.

Figure 2. Water flow controller

2.4 Mild Steel

The propertied of the mild steel and its usage in different fields are compiled here. The mild steel has a density of 7861.093 kg/m3. This is the calculated value for industrial grade mild steel. The Young's modulus of mild steel and the measure of its stiffness is around 210,000 MPa. The value can be changed based on the amount of carbon that is being added to the steel, which makes this steel different from other types. Carbon atoms get affixed in the interstitial sites of the iron lattice, making it stronger and harder. But if the hardness is increased then the ductility is being decreased.

A passive system is considered as the basis for the design work. The passive systems do not need any electricity or relay to work on it. It works based on natural circulations of hot water in the system through the tube with some applied gravity feed and the pressure flow from water. The solar water heater is designed for the Community Resources centre where the product has to be made cost effectively. The design of solar water heating system is made based on the following need:

- Daily water consumption(by assumption): 25 litres/day
- Water inlet temperature = 34°C

- Design the water heater based on the parameter.
    - Atmospheric temperature = 34°C
    - Collector Inclination angle = 30^0
- Fluid to tube heat transfer coefficient is 205 W/m^2 °C

The following design parameters are considered for the solar flat plate collector.

Collector length	= 77cm
Collector breadth	= 46cm
Collector height	= 11cm
Absorber plate thickness	= 0.5cm
Storage tank length	= 59cm
Storage tank breadth	= 29.5cm
Storage tank height	= 29.5cm
Outer dia. of copper tube	= 0.9cm
Inner dia. of copper tube	= 0.7cm
Copper tube length	= 458cm

2. Experimental Setup

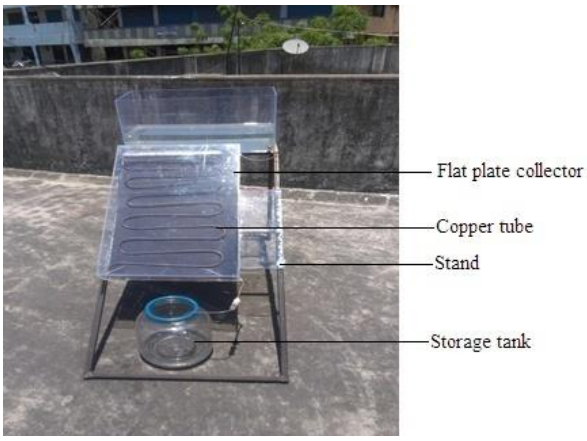

Figure 3. Experimental setup

The figure shows the designed solar water heater which is going to provide hot water for bathroom. The required operating temperature range of 55°C to 65°C can be achieved.

3.1 Collector setup

The collector is designed with a dimension of 77cm x 46cm. G.I. sheet is used for the fabrication of the collector. Two HDPE pipe is used in the design of 32mm diameter at the header and baser at the top and bottom, drip pipe of diameter 12mm.in the HPDE pipe 12 holes in are made. The holes are made to insert the drip pipe. Once the preparation hole in header and baser pipe is made, the drip pipe is connected between headers and baser and rest flow is connected by using T-joint as a lateral pipe.

3.2 Stand setup

Based on the collector angle the stand is fixed with the support of MS angle camp. The collector should face at the required angle so that maximum efficiency can be achieved. The considered values for the stand are as follows

Angle	= 30°C
The height of stand	= 73cm
The base length of stand	= 112cm

3.3 Storage Tank structure

The storage tank has a capacity of 25 litres in drum shape is fabricated. For providing insulation to the drum. Another drum is prepared using G.I. sheet for the outer. In between inner tank and outer tank Polystyrene is inserted and glass-wool is also used between the two drum. Then sawdust and glass wool is also used to retain the heat. Multilayer packing is given in between the two drum structures.

3.4 Experimental Connections

The construction setup has three holes in the storage tank. One is used at the bottom and the other two holes used at top of the setup. The top hole is used to connect through headers of the collector. The top hole used to extract hot because the hot water remains at the top of the storage tank. The lower hole is connected through the HDPE-pipe to the baser. The lower hole also connect inlet pipe for incoming water. One side of the collectors is joined by using T-joint and another side in closed using MT cap. This way the connections are established and ready for testing.

4. Results And Discussions

Water was allowed to flow through the SWH continuously with the help of the pump and the temperature of water in the insulated tank was noted down at regular intervals of time.

4.1 Calculation of collector efficiency (complete cycle)

The efficiency of the SWH is calculated for the trial-1 for the given period of heating time

Total duration of heating = 100 minutes
ΔT achieved = (50-34) = 16°C
Mass of water = 25 kg
Cp of water = 4187 J/kg°C
Q heater= m*Cp = 1674.8 KJ
Wattage heater= Q/t = 279 Watts
Average solar power in India is 5 KW/meter^2
Surface area of the collector = 0.3542 meter^2
So net solar power incident on collector surface = [5 * 0.3542 * cos 30°]
{Cos 30° gives the projection of the collector on the ground, as it is tilted at an angle of 30° with the horizontal surface}
So Efficiency of the collector = [W heater/W solar] * 100 = 18.19 %

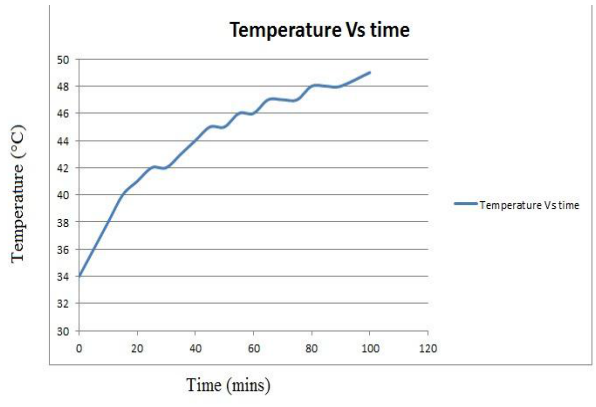

Figure 4. Temperature Vs time trial run-1

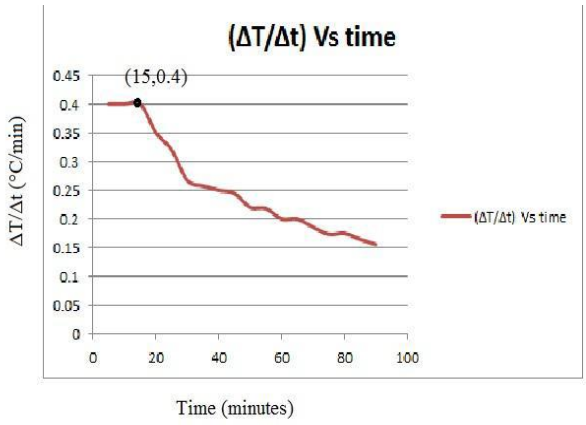

Figure 5. Graph ΔT/Δ t Vs time trial-1

4.2 Calculation of efficiency for the first 15 minutes

The graph [Fig 5] shows that the $\Delta T/\Delta t$ is maximum and steady for the first 15 minutes. So the maximum efficiency of the collector comes, if it is operated for this duration only.

ΔT is 8 degrees in 15 minutes.

Calculation of efficiency in the same procedure we have

Wattage heater = $(m*Cp*\Delta T/\Delta t)$

$= (25* 4187 * 8) /(15 * 60) = 930$ Watts

So efficiency = $(0.930/1.53)*100= 60\%$

5. Conclusions

The hybrid solar collector thus fabricated was put to test under the sun, while circulating water through it at different flow rates. The SWH efficiency was as high as 60 %. These types of solar water heaters can easily be used to heat pool water. A flow rate comparable to that of .2lpm is best for heating. The heaters are to be used intermittently for heating a batch of water till 15-20 minutes until the efficiency drops down and then fresh water be circulated through it. A cycle like this would give us the maximum output in minimum time.

6. References

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