Experimental Analysis of Evacuated Tube Solar Water Heater Using Twisted Tape

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Abstract:*Alternative energy sources possess ample amount of energy which is available at free cost and it is pollution free too. The solar energy is one such energy which can be used for cooking, heating, for other household purposes and for industrial purposes like power generation purpose. The objective of present work is to develop evacuated tube solar water heater and analyse thermal performance using twisted tape insertion. Fabrication of two evacuated tube solar water heater is done and observation under same conditions are noted one without twisted tape and other with twisted tape and all observation are compared. Result of comparison shows that using twisted tape inserts, heat transfer in the tube is more and thus the water at the outlet has more the temperature compared to evacuated tube without twisted tape insert.*

Index Terms- **Alternative Energy Sources, Solar Energy, Evacuated Tube Solar Water Heater, Twisted Tape.**

I. INTRODUCTION

Energy is the primary and universal measure of all kinds of work by mankind and nature. Everything that happens in the world is the expression of flow of energy in one of its forms. Most people use the word energy for input to their bodies or to machines and thus think about crude fuels and electric power.The increasing need of energy consumption, shrinking resources and rising costs of fossil fuel will have significant impact on our standard of living for future generations. In this situation, the development of alternative, cost effective sources of energy has to be a priority. One of the major renewable energy resources is the solar energy which sun emits to the earth. Since ancient time, the solar energy is always remaining prime source of our uses. The solar energy is the most capable of the alternative energy sources. Due to increasing Demand for energy and rising cost of fossil type fuels (i.e., gas or oil) solar energy is considered an attractive source of renewable energy that can be used for water hearing in both homes and industry. Heating water consumes nearly 20% of total energy consumption for an average family. Solar water heating systems are the cheapest and most easily affordable clean energy available to homeowners that may provide most of hot water required by a family. Solar heater is a device which is used for heating the water, for producing the steam for domestic and industrial purposes by utilizing the solar energy. Solar energy is the energy which is coming from sun in the form of solar radiations in infinite amount, when these solar radiations falls on absorbing surface, then they gets converted into the heat, this heat is used for heating the water. This type of thermal collector suffers from heat losses due to radiation and convection. Such losses increase rapidly as the temperature of the working fluid increases.

1.1 SOLAR WATER HEATING SYSTEM [1]

SWH systems are generally very simple using only sunlight to heat water. A working fluid is brought into contact with a dark surface exposed to sunlight which causes the temperature of the fluid to rise. This fluid may be the water being heated directly, also called a direct system, or it may be a heat transfer fluid such as a glycol/water mixture that is passed through some form of heat exchanger called an indirect system. These systems can be classified into three main categories:

(A) Active Systems:

Active systems use electric pumps, valves, and controllers to circulate water or other heat-transfer fluids through the collectors. So, the Active systems are also called forced circulation systems and can be direct or indirect. The active system is further divided into two categories:

- Open-loop (Direct) Active System
- Closed-loop (Indirect) Active System

(1) Open-Loop Active Systems

Open-loop active systems use pumps to circulate water through the collectors. This design is efficient and lowers operating costs but is not appropriate if the water is hard or acidic because scale and corrosion quickly disable the system. These open-loop systems are popular in non-freezing climates.

(2) Closed-Loop Active Systems

These systems pump heat-transfer fluids (usually a glycol-water antifreeze mixture) through collectors. Heat exchangers transfer the heat from the fluid to the household water stored in the tanks. Closed-loop glycol systems are popular in areas subject to extended freezing temperatures because they offer good freeze protection.

(B) Passive Systems

Passive systems simply circulate water or a heat transfer fluid by natural convection between a collector and an elevated storage tank (above the collector). The principle is simple, as the fluid heats up its density decreases. The fluid becomes lighter and rises to the top of the collector where it is drawn to the storage tank. The fluid which has cooled down at the foot of the storage tank then flows back to the collector. Passive systems can be less expensive than active systems, but they can also be less efficient. Thermo siphon system is the best example of passive systems.

(C) Batch systems

Batch System (also known as integral collector storage systems) is simple passive systems consisting of one or more storage tanks placed in an insulated box that has a glazed side facing the sun. Batch systems have combined collection and storage functions. Depending on the system, there is no requirement for pumps or moving parts, so they are inexpensive and have few components in other words, less maintenance and fewer failures.

1.1.1Evacuated-Tube Collectors

Evacuated-Tube Collectors are usually made of rows of parallel and transparent glass tubes. In which each of tube consists of a outer glass tube and an inner tube, or absorber, which is covered with a selective coating which can absorb solar energy well but also inhibits radiative heat loss. The air is withdrawn ("evacuated") from the space between the tubes to form a vacuum, which eliminates conductive and convective heat loss. They are most suited to extremely cold ambient temperatures or in situations of consistently low-light. They are also used in industrial applications, where high water temperatures or steam need to be generated where they become more cost effective.

Sharad B. Parekh et al [2] aims behind performance evaluation to find new material as solar thermal absorber and develop the feasible technology. The collection system consists of polycarbonate sheet with relatively low mass flow rate. S. Sadhishkumar et al [3] summarizes the previous works on solar water heating systems with various heat transfer enhancement techniques include collector design, collector tilt angle, coating of pipes, fluid flow rate, thermal insulation, integrated collector storage, thermal energy storage, use of phase change materials, and insertion of twisted tapes. The enhancement of heat transfer in the solar collector with twisted tape is found to be better than the conventional plain tube collector. In solar water heating systems twisted tape has been used as one of the passive techniques to augment the heat transfer. Twisted tape has been used in heat exchangers but their applications are limited in solar water heating systems. S.Rajasekaran et al[4] prepared three experimental set up. One of set up was by replacing copper tubes with epoxy –polyether coating stainless steel and aluminium tubes with copper oxide coating material pipes in the flat –plate solar collector, the cost of the system is found to be reduced by 30%. Result recorded that the collector outlet temperature is the function of solar irradiance and time. The maximum collector efficiency was obtained at 13.00 hour in all three experiments. The experimental results revealed that the performance of the solar water heater by using all materials produced the efficiency of around 40 % to 47 %.Budihardjo,G.L.Morrison [5] studied the thermal performance of water-in-glass evacuated tube solar water heaters and is evaluated using experimental measurements of optical and heat loss characteristics and a simulation model of the thermo syphon circulation in single-ended tubes. Raj ThundilKaruppa R., Pavan P and Reddy Rajeev D. [6] studied the performance of sandwich type solar water heater in which pipes through which water is flowing placed in the cavity of absorber plates to enhance the rate of heat transfer. N.M. Nahar [7] focused on effect of selective surface on the performance of solar water heater the overall efficiency of the heater is 57%. The predicted performance at various Indian stations revealed that hot water is required at most places for domestic use only during winter season and it can provide 100 l of hot water at an average temperature of 50–70 ^{0}C, which can be retained to 40–60 ^{0}C.

II Experimental Set up

In the present work from glass material evacuated tube is fabricated having inner diameter of 47 mm and 58 mm with length of 1800 mm having storage tank of 50 lt capacity with 500 mm diameter and 580 mm length made of GI coated material. Twisted tape made of copper strip 1 mm thick 1200 mm long with 180 mm pitch and 25 mm width.

Fig. 1 evacuated tube

Fig. 2 storage tank

 

Fig. 3 twisted tape inserted inside the tubeFig 4 twisted tape inside the tube

Fig. 5 twisted tube and evacuated tube

Fig. 6 experimental set up

III Equation used for Calculation of Efficiency of evacuated tube solar water heater

m = mass flow rate =0.018 kg/s
C_p = 4.187 KJ/ KgK

Surface area = πdl =3.14×0.058×1.8 =0.328 m^2

The collection efficiency is defined as the ratio of the energy absorbed by the fluid to the total flux incident on the tilted surface of the collector

$$\eta = \frac{mC_p(T_{fo} - T_{fi})}{IA}$$

Where,

I = input solar energy

m = mass flow rate of water
Cp = specific heat of water

$T_{fo} - T_{fi}$= temperature difference (outlet fluid temperature – inlet fluid temperature)

IV Result and Discussion

Table :3.1 Observation table

TIME	I (W/m^2)	T_{fo}(^{o}C) (without twisted tape)	ΔT (^{o}C) (without twisted tape)	T_{fo}(^{o}C) (with twisted tape)	ΔT (^{o}C) (without twisted tape)
9.00	686	31.1	2.1	31.2	2.2
9.30	795	33.3	2.2	33.6	2.4
10.00	903	36.7	3.4	37.3	3.7
10.30	974	39.3	2.6	40.2	2.9
11.00	1044	41.8	2.5	43	2.8
11.30	1081	44.8	3	45.8	2.8
12.00	1119	47.8	3	49.1	3.3
12.30	1120	50.5	2.7	52.4	3.3
01.00	1122	53.2	2.7	55.4	3
01.30	1028	55.2	2	58.4	3
02.00	934	57.2	2	60.7	2.3
02.30	912	59.9	2.7	63.2	2.5
03.00	754	62.6	2.7	66.1	2.9
03.30	668	64.7	2.1	68.4	2.3
04.00	583	66.8	2.1	70.8	2.4
04.30	416	67.2	0.4	71.5	0.7
05.00	250	67.0	0.3	70.9	0.6

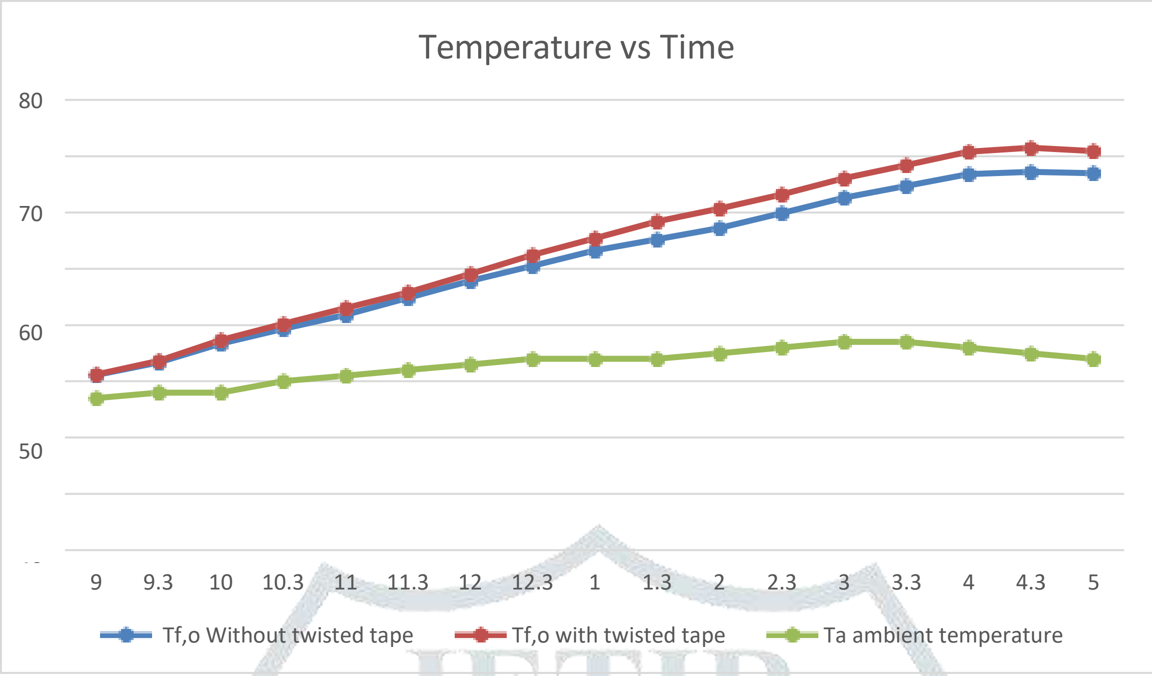

Fig: 7 Temp Vs Time

From the observation table it is clear that there is appreciable rise in the water temperature and due to presence of twisted tape inside the evacuated tube more turbulence in the flow can be achieved which enhances the rise in temperature and rate of heat transfer also. Figure 7 shows temperature variation with respect to time.

Table :3.2 Efficiency of evacuated tube solar water heater without twisted tape

TIME	I (W/m^2)	T_{fo}(^oC) (without twisted tape)	η (efficiency)
9.00	686	31.1	
9.30	795	33.3	63%
10.00	903	36.7	86%
10.30	974	39.3	61.30%
11.00	1044	41.8	55.09%
11.30	1081	44.8	63.82%
12.00	1119	47.8	61.66%
12.30	1120	50.5	55.44%
01.00	1122	53.2	55.34%
01.30	1028	55.2	44.74%
02.00	934	57.2	49.25%
02.30	912	59.9	68.9%
03.00	754	62.6	82.36%
03.30	668	64.7	72.30%
04.00	583	66.8	82.84%
04.30	416	67.2	22.11%
05.00	250	67.0	27.60%

Table 3.3 Efficiency of evacuated tube solar water heater with twisted tape

TIME	I (W/m^2)	Tf,o (ºC) (with twisted tape)	η (efficiency)
09.00	686	31.2	
09.30	795	33.6	69.43%
10.00	903	37.3	94%
10.30	974	40.2	68.48%
11.00	1044	43	61.68%
11.30	1081	45.8	59.57%
12.00	1119	49.1	67.82%
12.30	1120	52.4	67.76%
01.00	1122	65.4	61.49%
01.30	1028	58.4	67.12%
02.00	934	60.7	56.63%
02.30	912	63.2	68.9%
03.00	754	66.1	88.46%
03.30	668	68.4	79.19%
04.00	583	70.8	94.68%
04.30	416	71.5	38.70%
05.00	250	70.9	55.2%

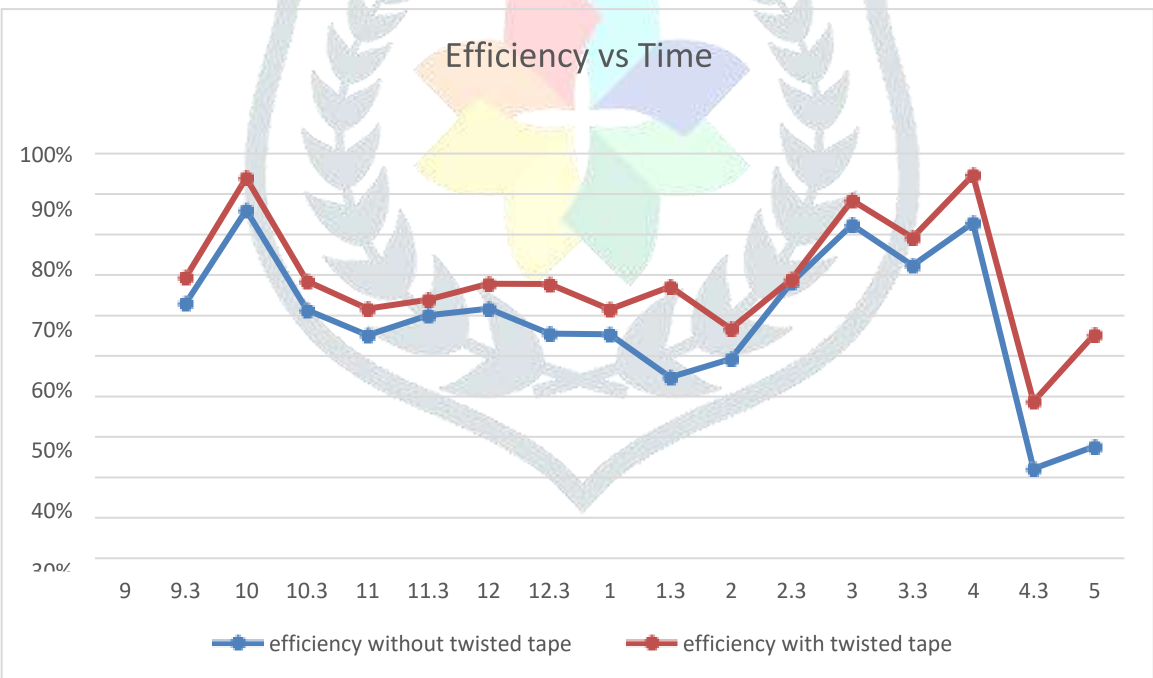

Fig: 8 Efficiency Vs Time

IV Conclusion

After performing experiment, we conclude that

- There will be more heat collected through evacuated tube and thus high temperatureis acquired(averagetemperaturethroughout thedayis 54ºC)
- Solar water heater must not loose the heat from water to air due to convection, so evacuated tube in which vacuum is created in annularspace.

- Due to introduction of twisted tape there will be more heat transfer because of water passing through swirling action and thus the efficiency obtained is greater than ETSWH without twisted tape.

- Averageefficiencyof ETSWH with twisted tape is 68.35% and that of ETSWH without twisted tape is 59%.

REFERENCES

[1] G.D. Rai, Solar energy Utilisation, Khanna Publishers, 1987

[2] Sharad B. Parekh, Performance Evaluation pf Polycarbonate Collector Based Solar Water Heating System, International Journal For Technological Research In Engineering Volume 1, Issue 5, 2014.

[3]S.SadhishkumarT.Balusamy,Performance improvement in solar water heating systems -A review Renewable and Sustainable Energy Reviews, 37,2014,191–198.

[4]Rajasekaran, S, Performance Analysis of Coated Solar Flat Plate Collector,Journal of Chemical and Pharmaceutical Sciences 974, 2015.

[5]I.Budihardjo, G.L. Morrison, Performance of water-in-glass evacuated tube solar water heaters, Solar Energy 83 (2009) 49–56.

[6]Raj ThundilKaruppa R., Pavan P. and Reddy Rajeev D. Experimental Investigation of a New Solar Flat Plate Collector, Research Journal of Engineering Sciences, 1(4), 2012,1-8.

[7] N.M. Nahar, Year round performance and potential of a natural circulation type of solar water heater in India, Energy and Buildings 35 (2003) 239–247.

[8]S.Jaisankar, T.K. Radhakrishnan, K.N. Sheeba, S. Suresh," Experimental investigation of heat transfer and friction factor characteristics of thermosyphon solar water heater system fitted with spacer at the trailing edge of Left–Right twisted tapes", Energy Conversion and Management 50 (2009)2638–2649

[9] Indra Budihardjo, Graham L. Morrison, MasudBehnia," Natural circulation flow through water-in-glass evacuated tube solar collectors", Solar Energy 81 (2007) 1460– 1472

[10] G.L. Morrison, I. Budihardjo, M. Behnia ," Measurement and simulation of flow rate in a water-in-glass evacuated tube solar water heater", Solar Energy 78 (2005)257–267

[11]Runsheng Tang, Wenfeng Gao, Yamei Yu, Hua Chen," Optimal tilt-angles of all-glass evacuated tube solar collectors", Energy 34 (2009)1387–1395

[12] A.Kumara,B.N.Prasad,"InvestigationoftwistedtapeinsertedsolarwaterheatersĐheat transfer, friction factor and thermal performance results", Renewable Energy 19 (2000) 379_398

[13]KeguangYao,TongLi,HanzhongTao,JiajieWei,KeFeng,"Performanceevaluationof all-glass evacuated tube solar water heater with twist tape inserts using CFD", Energy Procedia 70 (2015) 332–339

[14]ShyyWoei Chang, TsunLirng Yang, JinShuenLiou," Heat transfer and pressure drop in tube with broken twisted tape insert", Experimental Thermal and Fluid Science 32 (2007)489–501

[15]Dilip Mishra," Experimental Analysis of Thermal Performance of Evacuated U-Tube Solar Collector "Advance Physics Letter Vol_2, Issue_3,2015