Performance Analysis of V- Trough Solar Water Heater Fittedwith Left-Right Twisted Tape Inserts

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***Abstract*—Thermosyphon solar water is one of the most powerful Renewable Energy producer in domestic sector. V-trough water heater is upgraded design than flat plate collector. Experimentation has been carried out with Left-Right twisted tape in V-trough thermosyphon solar water heater. The average useful heat gain, Reynolds number and thermal efficiency has been calculated and compared with plain V-trough collector. Results shows that the heat gain, Reynolds number and thermal efficiency increases nearly 1.5, 3.5 and 1.6 times when compared to plain V-trough collector. Results revealed that V- trough with Left-Right twisted tape has higher Reynolds number, heat gain and thermal efficiency than plain v-troughcollector.**

Keywords—Heat transfer rate; Left-right twisted tape; Solar absorber; Solar collector; Thermal performance; V-trough solar water heater.

I.INTRODUCTION

Solar water heater is a device which converts the solar energy into useful thermal energy. Solar water heater plays a vital role in Renewable Energy Sector. Because its efficiency is more than the electric conversion. Solar water heater characterized by its thermal performance and depends on the transmittance, absorption and conduction of solar energy and the conductivity of the working fluid

The demand is increased for using hot water in domestic and industrial application due to the population explosion. In solar water heating system the direct conversion of heat energy into useful thermal energy is obtained.

In the present scenario the utilization of renewable energy sources are vital and inevitable due to the depletion of fossil fuels and also to protect the green environment. In the energy conversion cycle the conventional energy sources play an important role. The conventional energy sources mainly depend on the fossil fuels and its energy conversion process. During the process of fossil fuel energy conversion through combustion, it pollutes environment and produces undesirable effects which cause the global warming and acid rain. Hence there is an emergency crisis to alternate the fossil fuels and improve the share of non-conventional energy sources in the energy conversion system. It can be promoted through research and development, demonstration projects, dissemination projects/ programs supported by government and fiscal incentives.

Among all renewable energy technologies, solar thermal technologies have a natural advantage in India due to fact that average solar radiation available is 4.5 - 6 kW hr/m^2 per day with 280 clear sunny days over the year. The technical potential has been estimated as 140 million square meter of collector area. India was the first country in the world to set up a Ministry of non-conventional energy resources, in early 1980s.

Jawaharlal Nehru national solar mission was launched in the year of 2010 by the prime minister. The mission has set the ambitious target of deploying 20,000MW of grid connected solar power by 2022 it aimed at reducing the cost of solar power generation in the country through (i) long term policy; (ii) large scale deployment goals; (iii) aggressive research &development and (iv) domestic production of critical raw materials components and products as a result to achieve grid traffic parity by 2022. Mission will create an enabling policy framework to achieve this objective and make India a global leader in the solar energy.

Hot water plays a vital role in human society. It is used for various applications in the day-to-day human life. The utility of hot water in India covers various applications which can be categorized under three main sectors, viz., and domestic, commercial and industrial. It is used for many applications like bathing, washing and drinking in flats, bungalows and apartments under the domestic sector. Larger solar water heating systems are used in restaurants, canteens, guest houses, hotels, hospitals, hotels and dormitories under commercial sector. Similarly, water heating systems are used in process, dyeing, food industries and in thermal power plants for pre-heating the boiler feed water.

A. Naturalcirculation (Thermosyphon)

It is a physical effect and refers to a method of passive heat exchanger based on natural convection which circulates a fluid without the necessity of a mechanical pump. This type of collector works on the principle of fluid buoyancy force.Thermosyphon system operates on the temperature difference between the hot and cold water in the storage tank that accelerates the driving force. Convective movement of the liquid starts when liquid in the loop is heated in the riser tube, causing it to expand and become less dense, and thus more beyond than the cooler water in the bottom of the loop. Convective moves heated liquid upwards in the system as it is simultaneously replaced by cooler liquid returning by gravity. When the inlet and outlet temperature of the water become equilibrium them driving force will stop. Ideally, the liquid flows easily because a good thermosyphon should have very little hydraulic resistance.

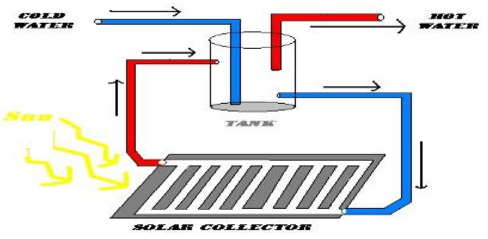

Fig.1.Natural circulation

B. Forced circulation

This type of system is mostly preferred in the industrial sectors. The fluid is circulated with the help of a hydraulic pump and there is no storage tank.

C.V-trough solar water heater

A cost effectively and easily fabricated V-trough solar water heater system by using natural circulation (Thermosyphon). The heat enhancement is higher due to additional reflection surface.

D. Helix twisted tape

Fig .2. Helix twisted tape.

II. LITERATURE REVIEW

The solar water heater and the various passive methods for enhancing the thermal performance. The different parameters in solar water heating system, the effect which would increases the thermal performance has been addressed by many researches.

Jaisankar et.al [1] studied Heat transfer and Friction factor characteristics of Forced Circulation Solar Water Heater System Fitted with Left-Right Twisted Tapes. Throughout the experimental result, Heat transfer rate is increased in solar water heater by fitted with left-right twisted tape with minimum twist ratio 3. Higher heat transfer rate reduces the heat losses and increases the thermal performance.Jaisankar et.al [2] conducted an experiment to evaluate Experimental studies on Variable Header Solar Water Heating System. The results shows that the to create Uniform velocity has been maintaining in all riser tubes by using variable header. The overall thermal performance has been increased by variable header. Nosa et.al [3] worked and Designed and a solar water heater based on the Thermosyphon Principle. The effect of water gets heated and flow into a storage tank through thermosyphon principle. It helps us save money. It does not need mechanical pump. The system designed in this work require little or no maintenance. Sanjay and Dheeraj [4] Fabricated and conducts Experimental Investigation of V-Through Flat Plate Collector in Hot Climatic Conditions of Rajasthan. The aim of this research work is to improve the thermal performance of V-through flat plate collectors using a novel cost effective enhanced heat transfer technique. This is accomplished by employing an aluminium sheet placed at the base within the system to induce a gradient of heat capacitance.Experimental Investigation of Flat Plate and V-Trough Solar Water Heater by using Thermal Analysis a cost effective cum easy fabrication V-trough solar water heater system using forced circulation system has been proposed by A.Karthikeyan et.al [5]. Reason behind the selection of v-trough is that, V-trough reflector can improve the performance of solar water heater system. Thermal performance of modified V-trough solar water heater has been designed by V. Rajive [6]. The results shown that a cost effective and easy fabricated v - trough solar water heater was modified by parallel flow thermosyphon water heater. Integrating the solar absorber with the easily fabricated v-trough reflector can improve the Performance of solar water heater system. Saravanan et.al [7] The Performance assessment in V-trough solar water heater studied fitted with square and v-cut twisted tape inserts. The experimental investigation has been carried out in V-trough solar water heater fitted with helix twisted tape, with square cut and with v-cut under two different twist ratios(y=3 and 5) in same operating condition. The minimum twist ratio 3 has higher thermal performance than twist ratio 5.

The thermal performance increases in solar water heater by using thermosyphon principle.The V-trough solar water heater can improve the thermal performance is compared with flat plate solar water heater at same operating condition. Inserting twisted tape provides higher heat transfer rate.Improving thermal performance of v-trough has been increased by some suitable design of twisted tape.

III. EXPERIIMENTAL SETUP

The experimental setup consists of five V-trough units. Each unit contains two riser tubes at the bottom side and covered by black absorber plate. Two reflector made up of float glass coated back side and fixed 120° inclination with respect to absorber plate and the top side covered by the floated glass has 3 mm thickness with 95% transmittance. Trapezium shaped floated glass was used to cover both ends of the V-trough reflector. Five V-trough units are arranged in series and called as V-trough collector and faced south direction with tilt angle of 12°.

The cold water from storage tank enters the collector from the lower header and it is evenly distributed in the riser tubes. This fluid is heated by the absorber plate by convective heat transfer. The hot water is collector in the upper header and storage tank. The density difference of water accelerated and created the driving force. When the inlet and outlet temperature of the water become equilibrium then the driving force will stop.

Table 1

Technical specification of V-trough solar water heater and Storage tank.

S.No	Description	Specification
Collector		
1	Tilt angle	12° (South facing)
2	Aperture area, A_c	$1m^2$
3	Dimension of each collector glazing	400mm(width)×1000mm(length) ×3mm(thickness)
4	Lower header	ID 25.5 mm
5	Upper header	ID 25.5 mm
6	Riser tubes	OD 12.5mm,ID 11mm,length 1000mm
7	Dimension of each absorber plate	200mm(width)×1000mm(length) ×0.3mm(thickness)
8	Absorber plate coating absorptivity	0.92
9	Transmittance of glazing	0.95
10	Number of riser tubes	10
11	Total sets of V-trough collector	5
Reflector		
12	Dimension of each mirror	200mm(width)×1000mm(length) ×5mm(thickness)
13	Total number of mirrors per V-trough reflector	2
14	Inclined angle of each mirror	60°
Storage tank and piping		
15	Tank type	Horizontal
16	Tank volume	100 litres
17	Tank wall thickness	4 mm
18	Tank insulation thickness	50 mm
19	Connecting pipe size	ID 25mm

For measuring inlet and outlet temperature of water, tapings are provided at necessary places in riser tube. A single transparent glass cover of 3 mm thickness transmits the solar energy to the absorber plate. The collector and the pipe connections are well insulated to minimize the heat losses. Absorber plate, riser tubes and header are made up of copper. The inlet and outlet temperatures of water are measured by T-type thermocouple. T-type thermocouple wires have an accuracy of ±0.5℃ are welded by thermocouple wire welding machine. The global solar radiation is measured by kipp and zonen pyranometer have an accuracy of 1 %. The inside of the riser tube is fitted with left-right twisted tape inserts.

A. Left-right twisted tape

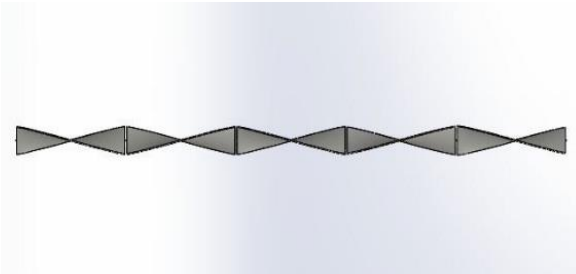

Fig.3.Left-right twisted tape

The use of left-right twisted tape provides additional disturbance in the fluid flow to enhance the heat transfer.Increase in friction factor due to flow mixing effects caused by the tangential, clockwise and counterclockwise movement of fluid and increased wetted surface area.Hence the velocity increases which affects the pressure loss of fluid flow near the tube wall.

Fig.4. Left twistFig.5.Right twist

Twist ratio Y=L/W

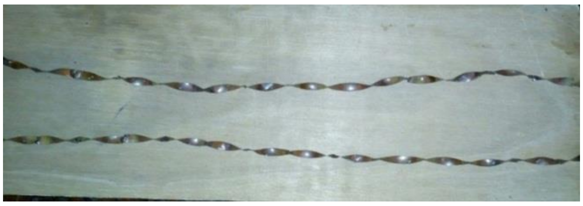

Fig.6.Left-right twisted tape

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IV. EXPERIMENTATION

Experimentation carried out from 9.30 a.m. to 4.30 p.m. Initially the cold water filled in storage tank and necessary instruments has been connected with experimentation setup. Water inlet, outlet, glass, absorber plate, riser tube temperature are recorded continuously every minute by Data logger. The recorded readings are average every 15 minutes.

Fig.7.Photographic view of thermosyphon V-trough solar water heater.

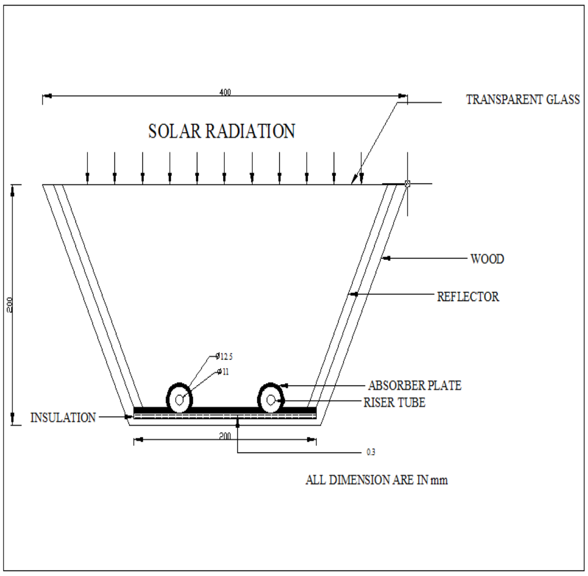

Fig.8.Cross-section of the single V-trough unit

V. DATA REDUCTION

The chapter describes used for calculating the Reynolds number,Heat transfer, and thermal performance of V-trough solar water heater plain tube collector, fitted with helix and left-right twisted tape operating under natural circulation (Thermosyphon)

A.Heat transfer

Heat transfer is defined as transmission of energy from one region to another region to temperature difference. The rate of heat transfer is the amount of heat per unit time.

The riser tubes are brazed to the bottom of a black absorber plate and the absorbed solar energy is conducted to the riser tubes. The heat is transferred by convective from the tube wall to the fluid.

The heat transfer rate (Q) is related to mass flow rate and temperature difference between the fluid outlet and inlet.

$$Q = m\,C_p\,(T_{out} - T_{in})$$

$$m = \rho\,A\,V$$

$$A = \frac{\pi}{4}(D_i)^2$$

Fluid thermo physical properties are calculated at the bulk mean temperature T_m.

$$T_f = (T_{in} + T_{out})/2$$

B. Reynolds number

It is the ratio of inertia force to viscous force. The value of the Reynolds number permits us to determine whether the flow is laminar or turbulent.

$$Re = (\rho V D)/\mu$$

C. Thermal performance

The ratio of the rate of useful thermal energy leaving the collector to the useable solar irradiance falling on the aperture area.

$$\eta = \frac{\text{Useful heat gain}}{\text{Input solar energy} \times \text{Area of the collector}}$$

$$\eta = Q_{USEFUL} / (H_t \times A_c)$$

VI. RESULTS AND DISCUSSION

Experimentation was carried out in V-trough solar water heaterwith plain tube collector, helix twisted tape and left-right twisted tape ratio and the results have been presented as follows.

A. Characteristics of thermosyphon system

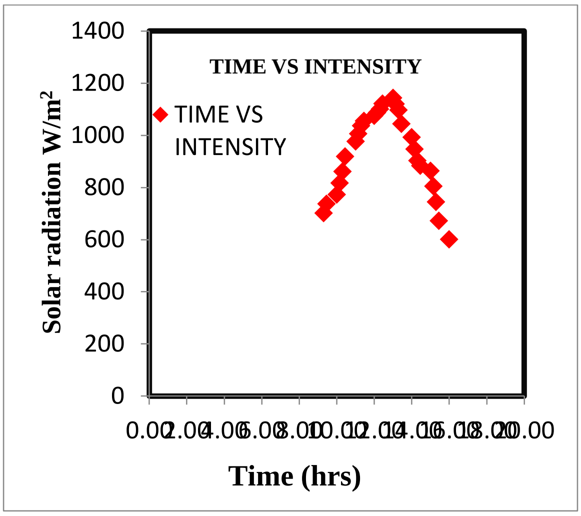

Fig.9.Characteristics of thermosyphon system

The characteristics of thermosyphon solar water heating system with v-trough collector, for typical sunny days are depicted in Figure 9. The solar radiation is found to increase gradually and reach a maximum at 1.00 p.m. and later decrease gradually till 4.00 p.m.

B. Mass flow rate

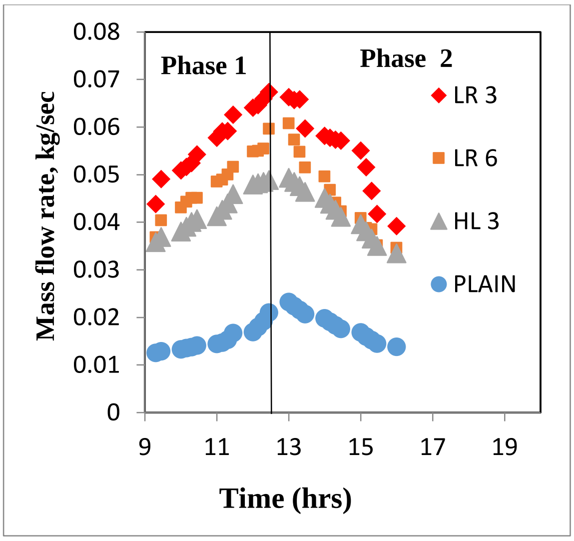

Fig.10. comparison of mass transfer between V-trough plain tube, helix and Left-right twisted tape

The variation of mass flow rate of v-trough plain tube collector, fitted with helix twisted tape and left-right twisted tape is shown in Figure 10.The use of left-right twisted tape with ratio 3 enhances the heat transfer rate which leads to increase the mass flow rate. In phase 1 due to the increasing solar intensity the mass flow rate is also increased gradually and reach maximum at 1.00 p.m. In phase 2 the mass flow rate is reduced gradually due to the reduction of solar intensity.

C.Effect of absorber plate temperature

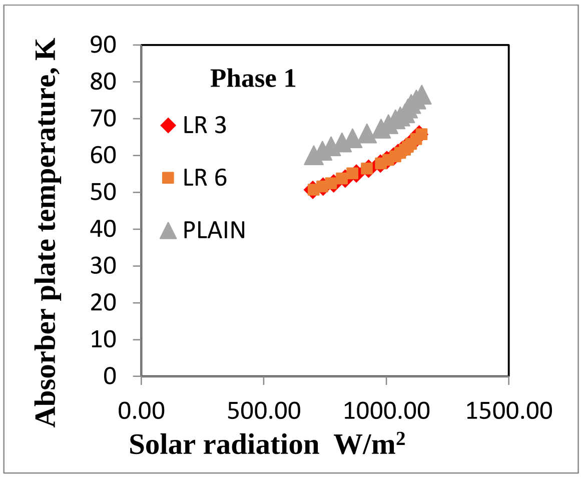

Fig.11.Effect of collector on absorber plate temperature in solar water heater

It has been found that the value of average plate temperature is higher in the case of plain tube collectors for the same value of solar radiation as shown in Fig.11.This indicates that the inefficient heat removal from the absorber plate due to lack of swirls and fin effect.

D. Discussion on thermal performance results

In plain tube v-trough collector the thermal loss is more, since there is no swirl flow and poor fluid particle mixing. This will leads to minimize the convective heat transfer and poor efficiency. The efficiency of plain tube v-trough collector is always lower than that for fitted with helix and left-right twisted tape because of the absence of swirl flow. For the same value of solar radiation the efficiency is maximum for the twist ratio3 compared with twist ratio 6. Became the swirl generation is maximum in twist ratio 3 when compared to twist ratio 6.

Compared to Left-Right and helix for twist ratio 3, the swirl flow carried out either right or left in helix twisted tape over the length of riser tube. But in Left-Right the swirl flow carried one Left and one Right and continuous same entire length of riser tube. Hence particle mixing effect more in Left-Right ratio than helix twisted tape.

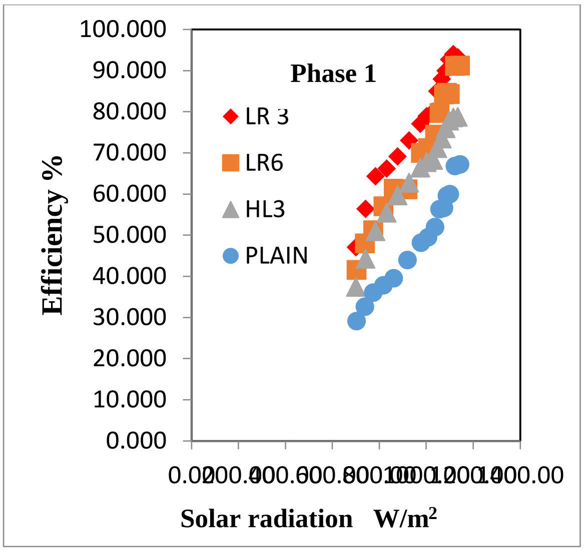

Fig 12.a. Variation of instantaneous efficiency with solar radiation for plain tube, fitted with helix and left-right twisted tape collector (PHASE 1)

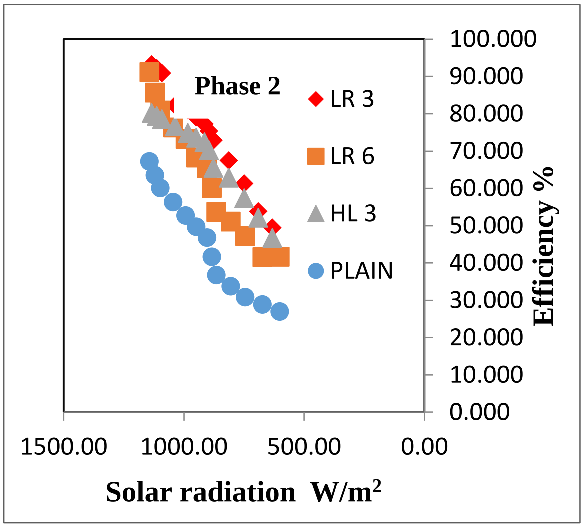

Fig 12.b Variation of instantaneous efficiency with solar radiation for plain tube, fitted with helix and left-right twisted tape collector (PHASE 2)

VII. CONCLUSION

V-trough solar water heater with Left-Right twisted tapes has been experimentally verified with plain V-trough under same operating condition. Compared to plain V-trough, Left-right twist tape collectors obtained has higher heat gain. The average heat gain for plain and Left-Right collector is respectively **453 j/s and722.74 j/s**.

Compared to twist ratio 3 and 6, the minimum twist ratio obtained higher thermal performance than twist ratio 6 and are **75%** and **66** %**.** Hence experimentation results proved that, the Left-Right V-trough collector with minimum twist ratio 3 has higher thermal performance than helix and plain v-trough collectors.

. NOMENCLATURE

Q	Heat transfer rate, W
m	mass flow rate, kg/s
C_p	Specific heat of water, kJ/kg°C
T_{in}	Average inlet temperature of water,°C
T_{out}	Average outlet temperature of water,°C
ρ	Density of water, kg/m^3
A	Riser tube area on internal diameter, m^2
V	Average riser tube velocity, m/s
T_f	Bulk mean temperature of fluid in the riser tube,°C
A_i	Inside surface area of the riser tube, m^2
D_i	Inside riser tube diameter, m
D_0	Outside riser tube diameter,
μ	Dynamic viscosity of water at bulk mean temperature, Ns/m^2
η	Collector efficiency,
T_a	Atmosphere temperature,°C
H_t	Total solar radiation, W/m^2
A_c	Aperture area,m^2
T_p	Absorber plate temperature,°C
Y	Twist ratio (length of one twist/diameter of the twist) (Dimensionless)
Re	Reynolds number based on the internal diameter of the riser tube, (dimensionless)
L	Length of one twist
W	Diameter of the twist

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