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HEAT TRANSFER AND FLOW FRICTION CHARACTERISTICS OF SOLAR WATER HEATER WITH INSERTED BAFFEL INSIDE TUBE

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ABSTRACT

Experimental investigation of friction factor and heat transfer characteristics of thermosyphone solar water heater with flat plate solar collector fitted with full length baffle of 10cm pitch have been presented. The flow regime is laminar for this study with the Reynolds number range 124 to 258. The experimental data obtained were compared with those obtained from plain tube data. The effects of full length baffle inside the tube on heat transfer and friction factor were presented. The heat transfer coefficient enhancement for baffle creates is higher than that of plain tube for a given Reynolds number. The use of baffle created improved the performance of thermosyphone solar water heater .

Keywords: Augmentation; Baffle Creates; Heat Transfer; Reynolds Number; Flat Plate Collector.

INTRODUCTION

To combat from pollution due to fossil fuel burning Solar water heating has been identified as an important means. In India water heating has large potential because of abundant sunshine availability. In the rural areas of India, the most commonly used fuel is still the biomass. In winter time in India the northern side of the country, the water chills down below 0^{oC} in the peak winter. Warm water requires in house for daily work. Almost 35-40 L of warm water is needed for a person per day in the winter season. To get higher efficiency is solar water heater many designs have been investigated. For domestic purpose most commonly used solar water heater is natural circulation type wherein the hot water is circulated between collector and storage water tank. These types referred to as thermpsyphon systems and have been extensively investigated. For better use of heat, in thermosyphone solar water heater higher thermal conductive material should be used. The techniques to enhance heat transfer are related to several engineering applications also. The cost of energy and material in recent year is high has resulted in an sincere effort aimed to produce higher efficient thermosyphone solar water heater. The rate of heat transfer can be improved by introducing a disturbance in the fluid flow to break the hydrodynamic and thermal boundary layers. Therefore, to acquire a desired heat transfer rate in an existing solar water heater at an economic pumping power, several techniques have been proposed by different researcher in recent years. **Kumar and Prasad**, presented a remarkable work on inserting twisted tapes in a serpentine solar collector. Their investigation on the effect of the twisted-tape geometry, different mass flow rates and intensity of solar radiation on thermal performance. Their observation was that heat losses were reduced for the lower value of the plate temperature and consequences was an increase on the thermal efficiency was observed**. Hobbi and Siddiqui** conducted an experiment to investigate the effect of several insert devices on the thermal performance of a flat-plate solar collector. Their studied for different passive heat enhancement devices like twisted strips, conical ridges and coil rings wires. They did not find appreciable difference in the heat transfer to the collector fluid and finally come to the conclusion that the applied passive methods based on the enhancement of viscous- produced turbulence were not effective in increasing heat transfer to the collector fluid. **Sivashanmugam**, investigated the heat transfer and friction factor characteristics of a circular tube fitted with right-left helical screw tape inserts of equal length, and unequal length of different twist ratios. The results analysed that the heat transfer augmentation for right-left helical screw tape inserts is higher than that for straight helical twist due to the effect of repeated both left and right movement of fluid during the flow through tube fitted with left-right twist tape provides better mixing in the radial direction. **Rahimi**, investigated the effect of three modified twisted tapes (notched, perforated and jagged twisted tapes) inserts in the tube on the friction factor, Nusselt number and thermal performance through experiment and computational fluid dynamics (CFD). Their results clears that the Nusselt number and thermal performance of the jagged insert were higher than those of the others inserts. **Eiamsa-ard**, gone through a comparative investigation of enhanced heat transfer and pressure loss by insertion of single twisted tape, full-length dual twisted tape and regularly-spaced dual twisted tape as swirl generators. The result reveals that all dual twisted tape with free spacing generates lower heat transfer enhancement in comparison with the full-length dual twisted tape. Work on twisted- tape started with insertion of twisted-tape in circular ducts, later it is used in non circular duct also. The width of the metal strip of twisted-tape is kept equal to or less than the internal diameter of the duct according to the loose or tight fitting inside the tube. Reduction of tape width causes a decrease in the pressure drop and heat transfer rate. The twisted-tapes may be of full length of the duct, may be of the short length or may be used for a certain length of the duct. In the present work the baffle is created inside the tube.

NOMENCLATURE

T_1 = Temperature of inlet of solar collector box

T_2 = Temperature of outlet of solar collector box (℃)

T_3 = Upper layer temperature of water tank (℃)

T_4 = Lower layer temperature of water tank (℃)

T_a = Ambient Temperature (^{0}C)

T_{fluid} = Average temperature of inlet and outlet temperatures (℃)

T_p = Collector panel temperature (℃)

A_c = Solar collector area (m^2)

F_R = collector heat removal factor

F' = collector efficiency factor

C_p = Fluid's specific heat (Kj/kg°C)

$\bar{h}_{fluid}$ = Fluid's average convective heat transfer coefficient (w/m^2°C)

I= Hourly solar radiation on the flat- panel solar collector (w/m^2)

L_c = Length of the collector panel channel (m)

L = Length of the circular tubes (mm)

Q = Rate of Heat transfer (kj)

$Q_{accumulated}$ = Accumulated heat (kj)

Q_{loss} = Heat transfer rate (kj/sec)

f= Friction factor.

Δp= Pressure drop (Pa).

U= Average Velocity of water flow (m/s).

$\dot{m}$= Mass flow rate of water (kg/s).

p_x = pitch of the baffle

EXPERIMENTAL SETUP

The schematic diagram of the natural circulation solar water heater is shown in Figure-1. The system consists of a solar flat plate collector, storage tank and connecting pipes. The absorber plate of the solar collector is of Aluminium, and six row of pipe length160cm and 2.54cm in diameter. Headers are in the two opposite sides of the box to maintain good contacts with the pipes. In the experiment 1600 mm long and diameter of 25.4 mm iron tubes are used. The pipes are placed parallel to each other and welded at both ends to the header. The front surface of the box is then covered with 4 mm thick clear plain glass and the overall dimension of flat-plate solar collector is 1380mmx750mmx250mm and the effective glazing area is $1537 inch^2$. Same dimension is selected for both the case, but in the baffled pipe 10cm of pitch is selected. The solar collector along with its water tank was installed at various angles (20.5°, 18.2°, 15.4°, 15.7°, 14.3°, 15.3°, 17.6°, 16.5°, 15.2°) on each day of observation. The whole unit was oriented in the South. The Pyranometer measuring short wave radiation was connected at same slope to as the collector to read radiation flux(W/m^2) on the inclined surface (as shown in figure). This pyranometer output reading was converted into a heat flux using the celebration relation (1mV= $129 W/m^2$) provided by the manufacturer. Readings were obtained for one inlet water temperature value (T_1) and one outlet water temperature value (T_2). In addition two readings of the temperature of water tank on top and bottom(T_3) and (T_4) of the water tank another thermocouple used to measured the absorber plate temperature (T_p). In addition, a thermocouple was also connected to measure and ambient temperature (T_{amb}). These six readings were made through the use of J-type thermocouple. The thermocouples were connected six channels of thermocouple amplifier. Once the unit was connected, it was left to run for about 2 days before the recorded measurements are taken, in order to overcome the initial transient's effect and to conform reliable operation unit. Then the experiment was run for period of 5 days on **Al- sheet**. Experimental readings were taken in plain and baffle tube. Baffling was created to break boundary layers inside the tube and proper mixing of the fluid.

Fig-1: Schematic diagram of experimental setup

DATA REDUCTION

Density difference of the fluid created by the temperature gradients causes the fluid being heated and delivered to storage tank. This type of fluid flow is usually termed as the natural or free convection. The temperature distribution, heat energy, collector efficiency and friction factor were calculated by using the equations (1) to (9) which were derived from [8], [9], [11] and [10].

The relationship between the mass flow rate (m) and the temperature, the equation for heat energy which is used for water heating (Q_a), as:

$$Q_a = A_C F_R [I\alpha\tau - U_L (T_f - T_a)] \qquad (1)$$

The heat energy is converted into thermal energy of water in the pipes, as:

$$Q_a = mC_p (T_1-T_2) \qquad (2)$$

Then

$$mCp (T_1 - T_2) = Ac F_R [I\alpha\tau - U_L (T_f- T_a)] \qquad (3)$$

Therefore

$$(T_1 - T_2) = (Ac FR / m Cp) [I\alpha\tau - U_L (T_f - T_a)] \qquad (4)$$

$$F_R = mCp/AcU_L [1- \exp (U_L F' Ac/mc_P)] \qquad (5)$$

Then the collector efficiency is obtained by using the relation,

$$\eta = Qa /AcI \qquad (6)$$

Substitution of Eqs. (2) and (4) in Eq. (5) yields,

$$\eta = F_R [\alpha\tau - U_L (T_f- T_a) / I] \qquad (7)$$

Since F_R, $\alpha\tau$ & U_L are constant, therefore,

$$\eta \;\alpha\; [(T_f - T_a) / I] \qquad (8)$$

For calculation of friction factor, The Darcy-Weisbach equation:

$$f = \frac{2dc\Delta p}{\rho U^2 \, Lc} = \frac{2dc\rho gh}{\rho(\frac{}{\rho Ac})Lc} \qquad (9)$$

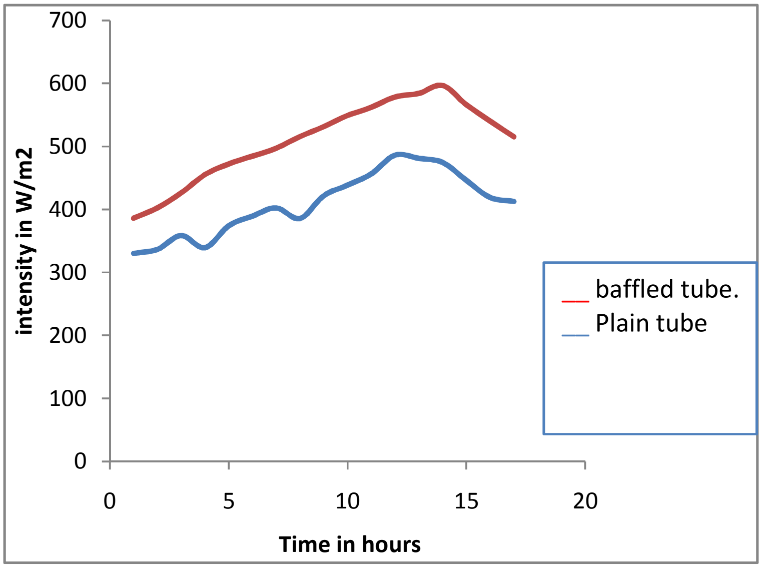

Figure No-2: Graph between Time and Intensity

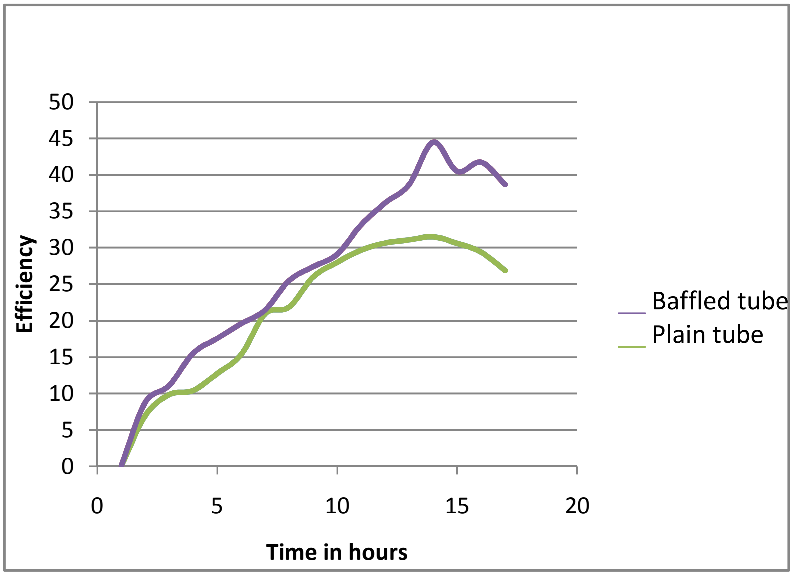

Figure No- 3: Graph between Time and Efficiency

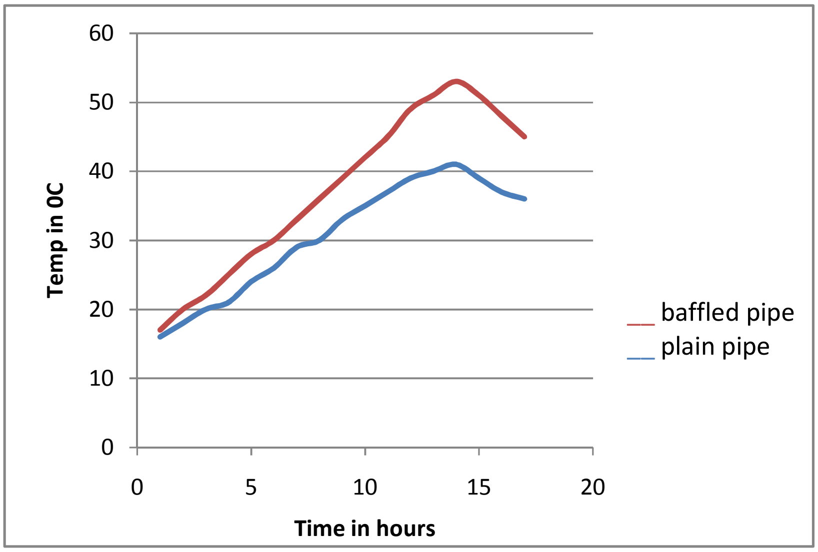

Figure No- 4: Graph between Time and Outlet temperature

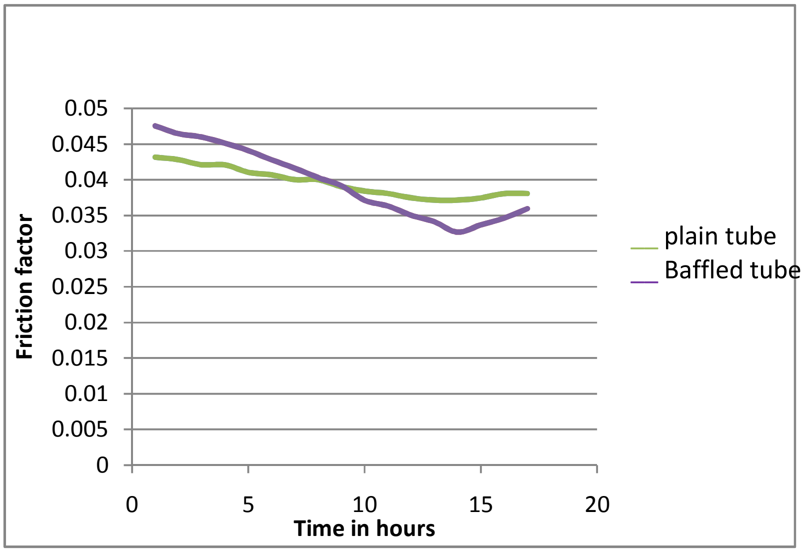

Figure No- 5: Graph between Time and Friction Factor

RESULTS AND DISCUSSIONS

The Natural circulation solar water heater was examined in the month of December-January, 2012-13 at intervals of quarter an hour between 9.30 hours and 13.30 hours. The incident solar radiation intensity was measured using pyranometer. The water inlet and outlet temperatures for the collector as well as ambient air were measured by thermocouple. The mass flow rate of the system was measured by rotometer. The collector efficiency of the system was calculated using Eq. (1) to Eq. (9). The quarterly variation of the solar intensity, collector efficiency and collector water outlet temperatures and Friction factor are shown in Figures 2, 3, 4 and 5. The solar intensity is increasing from 9.30 hours to 12.45 hours, reaching a maximum value of 596.78 W/m2 at 12.45 hour for baffled tube and for plain tube it was 486.33 W/m^2 at 12.15 hours in Figure-2. The collector efficiency is also compared with two different cases. The collector efficiency at 12.45 hour is 44.5% for baffled tubes and 31.49% for plain tubes. The maximum efficiency is observed at the time 12.45

hour in both the cases. The collector efficiency decreases after 12.45 hour till further readings were taken in the same day. The collector efficiency is shown in Figure-3. The curve shows that the maximum efficiency is at 12.45 hour in both the cases. The collector outlet temperatures are shown in Figure-4. The outlet temperatures at 9.45 hour is 18˚C for plain tube and for the baffled tube it was 21˚C. The maximum outlet temperatures were recorded at 12.45 hour for both the cases. The outlet temperature fall after 12.45 hour till further record. The Friction factor curve against time is shown in the figure- 5. According to the curve it can be say that the value is falling continuously and the friction factor value at 12.45 hours for baffled tube is 0.03265 and for the plain tube it was 0.03715.

CONCLUSION

i The collector efficiency is increases for some time and after which decreases, the maximum value is obtained at 12.45 hours in both the cases.
ii From the graph it can be say that the efficiency for baffled tube is higher in comparison to plain tube.
iii Outlet temperature of the fluid is higher for baffled tube to plain tube, and is found maximum at 12.45 hours.
iv Friction factor in the baffled tube at higher outlet temperature is lower in comparison to plain tube, it means fluid mixing is better.

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