EFFECT OF BAFFLE INSIDE THE TUBE IN SOLAR WATER HEATER ON RAYLEIGH NUMBER AND NUSSELT NUMBER

U. K. Nayak[1] ,Prof. (Dr.) S. C. Roy[2] ,Prof. (Dr.) M K Paswan[3]

[1,2]Mech .Engg. Deptt. BIT Sindri Dhanbad, Jharkhand

[3]Mech. Engg. Deptt., NIT Jamshedpur

Dhanbad Jharkhand

ABSTRACT

Experimental investigation of Nussult Number and Rayleigh number of thermosyphone solar water heater with flat plate solar collector fitted with full length baffle of 10cm, 5cm pitch and plain tube have been presented. The flow pattern was completely laminar for this study with smaller value of Reynolds number in the tubular case. The experimental data obtained were compared with plain tube data. The effects of full length baffle with 10cm and 5cm pitch inside the tube on Rayleigh number and Nussult number were presented. The Rayleigh number and Nussult number increases with lower pitch in comparison to that of plain tube and higher pitch for a given Reynolds number. The created baffle improved the performance of thermosyphone solar water heater .

Keywords: Augmentation, baffle creates, flat plate collector, Heat Transfer, Rayleigh Number.

I.INTRODUCTION

The requisite for energy increases with increasing living values each day. The key goal of the energy policy of any country should be obtaining low-priced clean, and long-lasting energy since living principles increasing, increasing world inhabitants and rapid growth in technology increases the require for energy each day, however, obtaining such energy will be tougher because of the limited energy reservoirs present around the world. The ecological pollution resulting from the unnecessary usage of energy is another very serious problem. Due to these difficulties correlated to the energy issue, the world is eyeing for substitute energy sources.There has always been a gap between supply and require of electricity especially during peak summer load and winter seasons. The situation further worsen all through early hours of the peak winter season when extreme heating load is switched 'ON'. This has been a consistent problem. If the heating load is switched over to renewable sources of energy from conventional energy sources; the gap can be bridged considerably. Therefore, there is a requirement to take up measures to initiate steps for adoption of 'Solar Energy'. 'Solar Energy' is an infinite source of non conventional energy. Solar Energy, if utilized, shall not only bridge the space between demand and supply of electricity, but will also put aside money since running cost of apparatus working on solar energy is minimum or it could be say that

very insignificant. Its use will also help in dropping pollution and maintenance of eco-balance. The amount of solar energy received by the earth is considerable, but is dilute and its accessibility varies with time. The variation in availability occurs daily as a result of the day –night cycle and also seasonally because of the earth's orbit around the sun. In addition, variation occur at a specific place because the local weather conditions. Consequently, the energy accumulated when the sun is shining must be stored for use during periods when it is not obtainable. The need for storage also adds significantly to the cost of the system. Thus, economics is an important consideration in utilizing solar energy as an energy alternative. In 2006 Eiamsa-ard et al, cold and hot water are used as working fluids in a double pipe heat exchanger fitted with regularly spaced twisted tape elements. Results show that the heat transfer coefficient and friction factor increase with the free space ratio .In 2007Eiamsa et al, The value of heat transfer is about 15% lower with regular spacing twisted tape than the full length twisted tape inserts with 90% decreased in pressure drop is investigated by the researcher. In 2007Sivashanmugam and Nagarjan, The heat transfer coefficient can be enhanced higher, by using a circular tube fitted with right and left helical screw inserts is than that for straight helical twist inserts of equal and unequal length for a given twist ratio.In 2007 Hong et al. Experimental study on Pressure drop and compound heat transfer characteristics of a converging-diverging tube with evenly spaced twisted-tapes have been investigated . Swirl was generated through evenly spaced twisted-tape elements which vary in twist ratio and rotation angle. Space ratio considered an important effect on the characteristics. Experiments in a smooth circular tube and in a converging diverging tube without twisted-tapes were carried out for Comparison. The results with twisted tape with twist ratio y=4.72 and rotation angle 8= 1800 has the best performance among the four types of twisted-tapes presented in this paper. In 2008 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. In 2009 Jaisankar et al, Achieved that the minimum twist ratio provides higher percentage of enhancement performance of twisted tape solar water heater collector compared to the plain one. In 2009 Rahimi et al, Experimentally and theoretically proved that the Nusselt number and performance of the jagged inserts are higher than other modified twisted tape inserts. In 2009 Eiamsa-ard et al. By using water as working fluid heat transfer, flow friction and thermal performance factor characteristics in a tube applied with delta-winglet twisted tape, are investigated experimentally. Effects of the oblique delta-winglet twisted tape (0-OWT) and straight delta-winglet twisted tape (S-OWT) arrangements are also described. The experiments are performed using the tapes with three twist ratios (ylw = 3, 4 and 5) and three depth of wing cut ratios (DR = dlw = 0.11, 0.21 and 0.32) over a Reynolds number range of 3000-27,000 in a uniform wall heat flux tube. The experimental results show that mean Nusselt

number and mean friction factor in the tube with the delta-winglet twisted tape increase with decreasing twisted ratio (y/w) and increasing depth of wing cut ratio (DR).

II.NOMENECLATURE

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)
R_a	Rayleigh Number
F'	collector efficiency factor
C_p	Fluid's specific heat (KJ/kg℃)
$\overline{h}_{fluid}$	Fluid's average convective heat transfer coefficient (w/m^2℃)
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)
p_x	pitch of the baffle
$\overline{Nu}$	Average Nussult number.
k_{fluid}	Conductivity of the fluid.

III.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 1537inch^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 angle of 15° 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= 129W/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 2days 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

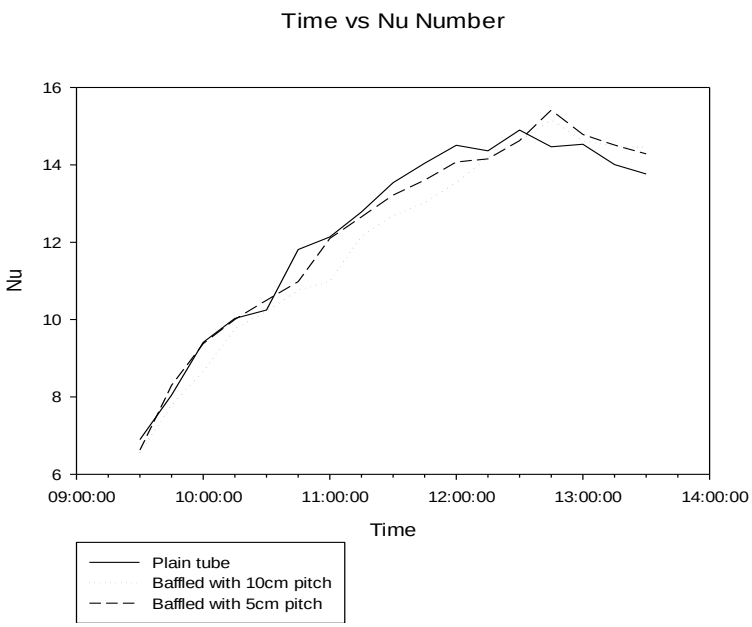
IV.DATA REDUCTION

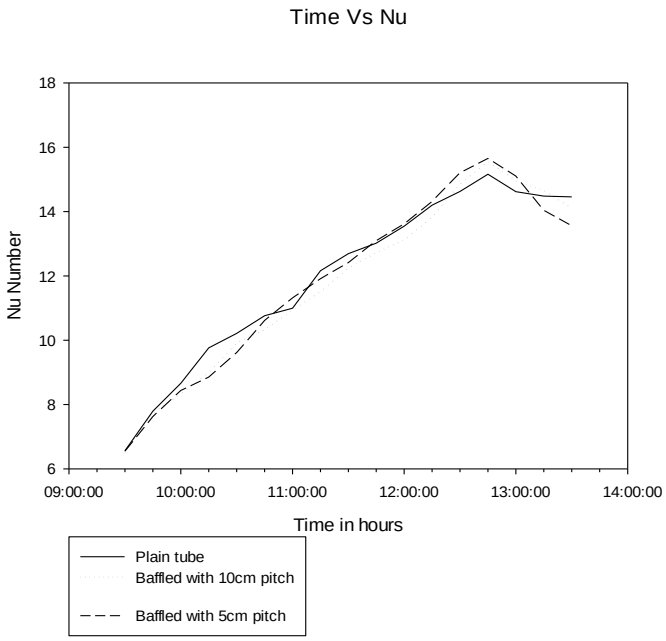
Density difference of the fluid created by the temperature gradients causes the fluid being heated and delivered to storage tank. This type of fluid flow is usually termed as the natural or free convection. The temperature distribution, heat energy , collector efficiency and friction factor were calculated by using the equations. But in this paper our primary consideration is heat transfer coefficient and Nusselt number through which the performance of solar water heater is calculated.

Calculation to find out Average Nusselt number and Convective heat transfer coefficient

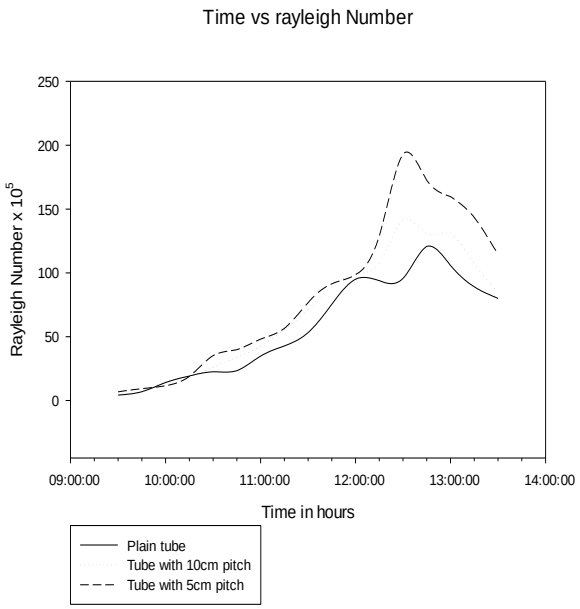
$$Ra = g\,\beta\,(T_p - T_{fluid})\frac{S^3}{\alpha\nu} \quad \text{.....} \quad ...(1)$$

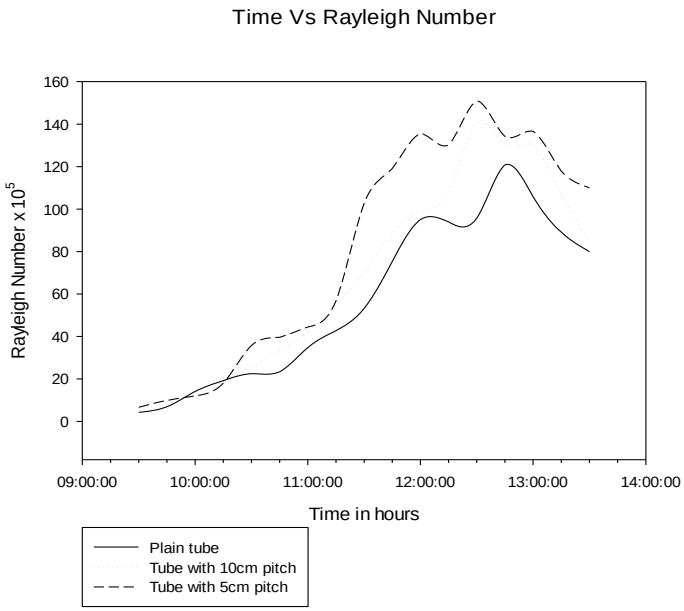
$$\overline{Nu} = 0.645[Ra\,(\frac{S}{Lc})\,]^{0.25} \quad \text{.....} \quad (2)$$





Graph No-1(Day 1)Graph No - 2 (Average)





Graph No - 4(Average)

Graph No- 3(Day 1)

V.RESULTS AND DISCUSSIONS

The Natural circulation solar water heater was examined in the month of December-January, at intervals of quarter an hour between 9.30 hours and 13.30 hours. The incident solar radiation intensity was measured by 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 rota meter. The performance of solar water heater is measured through Nu number and Rayleigh number. The quarterly variation of the Nu number and Ra are shown in Graphs 1, 2, 3 and 4. The solar intensity was measured quarterly from 9.30am to 1.30pm, and observed that the intensity was increasing from 9.30 hours to 12.45 hours, reaching a maximum value at 12.45 hour and after that it was declining in all the three cases. In the first graph the value of Nu number for plain tube is 14.47, 15.416 for 5cm pitch tube and 15.164 for 10cm pitch tube. In the average value it is also shown that the value of Nusselt number is higher for 5cm pitch tube in comparison to two other tube. The Ra number Value for plain tube was found $120x10^5$, for 10cm pitch tube $130x10^5$ and for 5cm pitch tube it was $134x10^5$. But in the average case it was found that the value of Ra number is higher for 5cm pitch tube in comparison to the other two.

VI.CONCLUSION

I. The Nu number value and Rayleigh number was increasing for some time and after which decreases, the maximum value is obtained at 12.45hours in all the three cases.

II. from the graph it could be say that the Nusselt number and Rayleigh number for baffled tube with 5cm pitch tube is higher in comparison to other tubes.

III. With increasing temperature the turbulence of the fluid increases that's why natural convection also increases.

REFERANCES

[1] A. Kumar, B. N. Prasad. Investigation of twisted tape inserted solar water heaters—heat transfer, friction factor and thermal performance results. Renewable Energy, 19 (3), 2000, pp. 379-398.

[2] A. Hobbi, K. Siddiqui. Experimental study on the effect of heat transfer enhancement devices in flat-plate solar collectors. Int. J. of Heat and Mass Transfer 52, 2009, pp. 4650–4658.

[3] S. Eiamsa-ard, Chinaruk Thianpong , Petpices Eiamsa- ard and Pongjet Promvonge, Thermal characteristics in a heat exchanger tube fitted with dual twisted tape elements in tandem, International Communications in Heat and Mass Transfer Vol. 37 (2010), PP.39–46.

[4] C.Nithiyesh Kumar, P.Murugesan, Review on Twisted Tapes Heat Transfer Enhancement, International Journal Of Scientific & Engineering Research, Volume 3, Issue 4, April-2012 .

[5] P. Sivakumar, W. Christraj, M. Sridharan1 and N. Jayamalathi, PERFORMANCE IMPROVEMENT STUDY OF SOLAR WATER HEATING SYSTEM, ARPN Journal of Engineering and Applied Sciences , VOL. 7, NO. 1, JANUARY 2012

[6] Gupta H.P. and Garg H.P. 1968. System designs in solar water heaters with natural circulation. Solar Energy. pp. 12-163.

[7] Rai. G.D. 2005. Solar Energy Utilization. Khanna Publishers. pp. 102-104 and 135-145.

[8] Sukhatme S.P. and Nayak J.K. 2008. Solar Energy, Principles of Thermal Collection and Storage. TMH

[9] Soteris A. Kalogirou. 2004. Solar thermal collectors and applications Progress. Energy and Combustion Sciences. 30: 231-295.

[10] Smith Eiamsa-ard, Chinaruk Thianpong and Pongjet Promvonge, Experimental investigation of heat transfer and flow friction in a circular tube fitted with regularly spaced twisted tape elements, International Communications in Heat and Mass Transfer Vol. 33 ,2006, pp. 1225–1233.

[11] Sivashanmugam, P., Suresh, S., Experimental Studies on Heat Transfer and Friction Factor Characteristics of Turbulent Flow Through a Circular Tube Fitted with Regularly Spaced Helical Screw-Tape Inserts, Applied Thermal Engineering, Vol.27, 2007, pp. 1311–1319.

[12] P. Promvonge and S. Eiamsa-ard, Heat transfer behaviors in a tube with combined conical ring and twisted-tape inserts, International Communications in Heat and Mass Transfer Vol. 34 ,2007, pp. 849–859.

[13] S. Jaisankar, T.K. Radhakrishnan and K.N. Sheeba, Experimental studies on heat transfer and friction factor characteristics of thermosyphon solar water heater system fitted with spacer at the trailing edge of twisted tapes, Applied Thermal Engineering Vol. 29 ,2009, pp. 1224–1231.

[14] S. Eiamsa-ard, Chinaruk Thianpong, Petpices Eiamsa-ard and Pongjet Promvonge, Convctive heat transfer in a circular tube with short-length twisted tape insert, International communication in Heat and Mass Transfer, Vol. 36, 2009, pp. 365-371.

[15] Rahimi, M., Shabanian, S.R., Alsairafi, A.A., Experimental and CFD studies on heat transfer and friction factor characteristics of a tube equipped with modified twisted tape inserts, Chem. Eng. Process, Vol.48, 2009, pp. 762– 770.

[16] P. Murugesan, K. Mayilsamy, S. Suresh and P.S.S. Srinivasan, Heat Transfer And Pressure Drop Characteristics of Turbulent Flow in a Tube Fitted With Trapezoidal-Cut Twisted Tape Insert, International Journal Of Academic Research, Vol. 1. No. 1 ,2009, PP. 123-128