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To Investigate the Performance of a Flat Plate Solar Water Heater with Twisted Tape Insert and Without Insert

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Abstract—*This work presents an experimental study on the use of Twisted Tape inserts to enhance heat transfer in a typical flat-plate solar water heater. Energy crisis is becoming a major problem which is faced by all over the world. In order to control this energy crisis problem many research are performed using renewable energy sources like using solar energy instead of electrical and fuel energy, because solar energy is free of cost and environmentally friendly. There have been many studies to improve the performance of the solar water heater. Heating water for domestic purpose is a simple and effective way of utilizing solar energy. Initial cost of solar water heating system is high but we get zero green energy cost.*

The specific objective of this study is to find or develop new models and models that can improve the efficiency of the solar water heater. This investigation discusses improving the performance of a flat plate solar water heater by inserting the various type of insert in the riser tubes. They promote higher heat transfer coefficient by disturbing or altering the existing flow behaviour (except for extended surfaces) which also leads to increase in the pressure drop.

Keywords:—*Twisted Tape, Raynolds Number, Heat transfer enhancement, passive method.*

1. INTRODUCTION

Heat transfer enhancement or augmentation technique refers to the improvement of thermo hydraulic performance of heat exchangers. Existing enhancement technique can be broadly classified into three different categories 1) Passive Technique 2) Active Technique 3) Compound Technique. Passive Technique generally uses surface or geometrical modification to the flow channel by incorporating insert or additional devices. They promote higher heat transfer coefficient by disturbing or altering the existing flow behavior (except for extended surfaces) which also leads to increase in the pressure drop. Passive solar water heater system contain no electrical components, are generally more reliable, easier to maintain and possibly have a longer work life than active solar heater system. Solar water heaters help to avoid carbon dioxide, Nitrogen, Sulphur dioxide and the other air pollution. Insert refer to the additional arrangements made as an obstacle to fluid flow so as to augment heat transfer. Different types of insert are Porous Baffles, Mesh Insert, Helical screw inserts of increasing twist ratio, Incline angle of the springs, Tape with attached baffle. There have been many studies to improve the performance of the solar water heater. The long term goal of research is to obtain scientific information, teaching materials and as the foundation of scientific development of energy conversion. The specific objective of this study is to find or develop new models and models that can improve the efficiency of the solar water heater. Research method conducted using the experimental method, and heating of working fluid that can improve the efficiency of flat plate solar water heater.

2. EXPERIMENTAL PROCEDURE

2.1 The set-up

The schematic diagram of the solar flat collector along with the tank under consideration is shown in Figure 3.1, along with thermocouple locations. The flat plate collector is mounted inclined 45^0 and facing north south near to 100 liters tank. The experiment part consists of a 2.0 m^2 of flat plate collector which is having the six numbers of riser tubes of outer diameter 1.27 cm made up from the copper with a length of 6 feet and a wall thickness of 1.2 cm. These riser tubes are consists of a copper heat collecting surfaces of thickness 0.20 mm. The wall temperature distribution of the riser pipe of collector plate measured using K-type thermocouples with an uncertainty of $\pm 0.1^o$C.In addition the temperature of water flowing inside the tubes are also measured with the help of digital thermo meter. The riser pipe is connected with the copper tubes of outer diameter 5mm (drawn outside from the collector panel). This outside drawn copper tubes are attached with the valve by means of flaring nut for measuring the pressure inside each riser tubes. The pressure gauge used for measure the pressure inside the tubes is attached to the valve through charging cable. The flow of water from tank is controlled with help of ball valve cock which is having certain opening for maintain the flow of water entering into the collector plate. This ball valve cock having the marking for different flow rate.

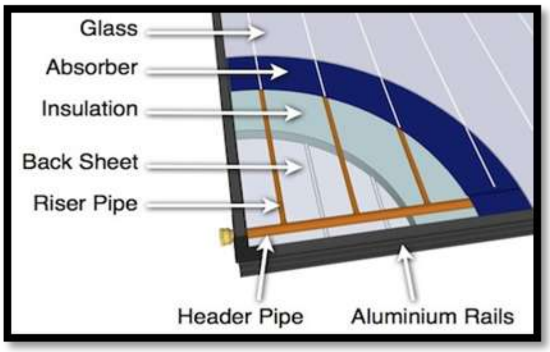

Figure 1: Cut-way View of Flat Plate Solar Water Heater

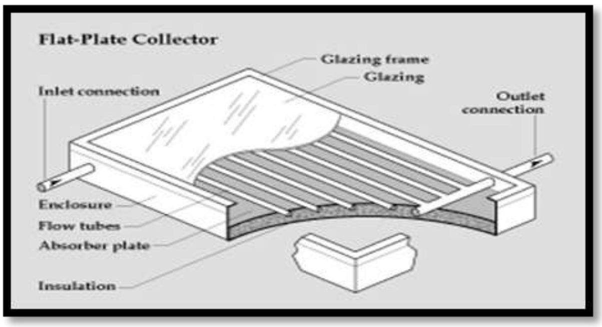

Figure 2: Cut-way view of Flat plate solar water heater

Figure 3: Flat Plate Solar Water Heater with insertion of twisted tape

2.2 Experimental Procedure

The experiments are conducted using riser tube of solar flat plate collector. The solar flat plate collector is initially, started with water flow rate of 2 liter per minute and which is gradually increasing step wise for conducting the experiment. When water from the tank comes into the solar flat collector the inlet temperature of water is recorded with help of thermocouple.

The water from the tank first comes into the footer pipe and then gradually lifted up as heating due to sun, and decreasing in the densities of water. The temperature of water within each tubes are recorded by the digital thermometer and also the pressure inside the tubes were recorded with help of pressure guage. This process is continued for all six riser which are alternately fitted with helical insertion inside. Similarly same reading is noted down for different flow rate water entering and the leaving the collector and different time duration. Finally the results which are obtained from experiments are analyzed for conclusion.

2.3 The specification of a typical 100 litres capacity thermosyphon system is given below:

Flat Plate Collector

Gross Area :	2 m^2
Cover :	Toughened glass, single, 4 mm thick
Absorber Plate :	Copper sheet (0.20mm thick) with selective coating
Riser for water flow :	Copper tubes (1.27cm) 6 numbers
Tube centre to centre distance:	120mm
Casing :	extruded aluminium section with aluminium sheet on back side.
Side insulation :	25mm thick glass wool
Bottom insulation :	50mm thick glass wool

2.4 Storage Tank

Shape : Cylindrical shape with axis horizontal made from SS 304 (1.2mm thick)

Capacity : 100 liters

Insulation : 100mm thick glass wool on all side

2.5. Constructional Features

The material selected for the tubes is copper as it easily available and ease in manufacturing. Twisted tape insert is also manufactured from aluminium. A twisted tape is inserted in tube at different arrangements. As the main objectives of the project is to compare the performance of plain tubes and inserted tubes.

2.6. Specifications of inserts:

Material: Aluminium

Width of twisted tape = 05mm

Twist ratio = 2.5:1

Length of insert = 100cm

Thickness of inserts = 3mm

Figure 4. Aluminium Twisted Tape (Enlarged view)

3. RESULT

The experiments were carried out on the test rig initially smooth tube without using any inserts and the different heat transfer characteristics were calculated and then the same is done using twisted tape inserts. The experimentation is divided in following cases.

Case I: Experimentation on test tube without using any inserts.

Case II: Experimentation on test tube using twisted tape inserts.

(Number of inserts use=6)

Based on the observations recorded while experimentation, following parameters are calculated.

1. Mass flow rate for all two cases.

2. Heat transfer coefficient for all two cases.
3. Nusselt number for all two cases.
4. Reynolds Number for all two cases.
5. Pressure drop for all two cases.
6. Frictional factor for all two cases.

3.1 Graphs

Based on the above calculations following graphs are plotted for interpretation of performance

1. Heat transfer coefficient Vs Reynolds No.
2. Nusselt No. Vs Reynolds No.
3. Frication factor Vs Reynolds No.
4. Heat transfer coefficient Vs Pressure Drop

3.2 Effect of Reynolds Number on Heat Transfer Coefficient

The experimentation was carried out with the smooth tube without using any insert and with using twisted tape in Passive heat transfer enhancement methods. Following graphs are plotted to compare the performance of inserts used in tube

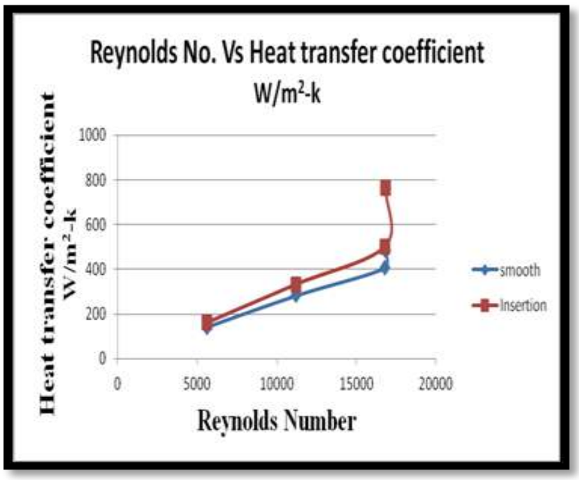

Figure: 5 Heat transfer coefficient Vs Reynolds Number

From the Figure 5, it is observed that the heat transfer coefficient increases with increase in Reynolds number. As Reynolds number increases, the water flow will cause more turbulence, so due to which the heat transfer rate will increase. From the Figure 5 it is observed that the tube without using any insert gives less heat transfer coefficient than with the use twisted tape inserts. Twisted tape insert create more turbulence in tube which increases the heat transfer coefficient. Twisted tape insert gives maximum value of heat transfer coefficient as compared to the smooth tube respectively.

3.3 Effect of Reynolds Number on Nusselt Number

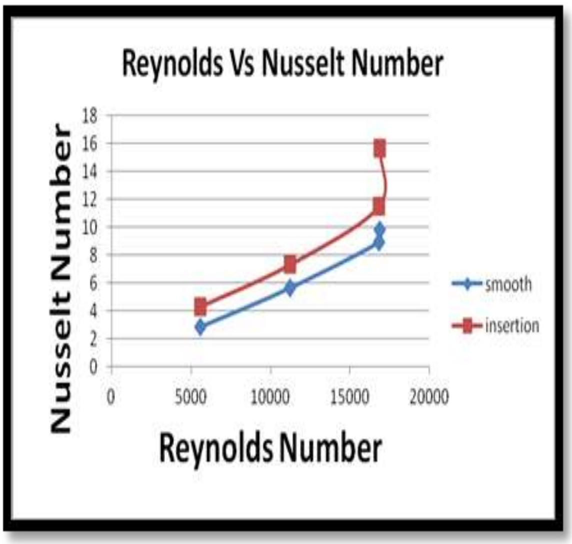

Figure 6: Reynolds Number V/s Nusselt Number

From the Figure 6, it is observed that there is increase in Nusselt number with Reynolds number. As Reynolds number increases the water flow will cause more turbulence due to which heat transfer rate will increase. As heat transfer coefficient is directly proportional to Nusselt number, Nu=hD/K i.e. increase in heat transfer coefficient increases the Nusselt number. From Figure 6 it is observed that maximum Nusselt number is obtained for twisted tape insert as compared to smooth tube. Minimum Nusselt number is obtained for smooth tube without using any inserts.

3.4 Effect of Reynolds Number on Friction Factor

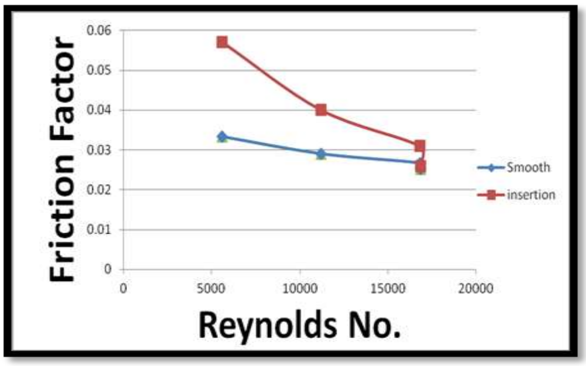

Figure 7: Friction factor Vs Reynolds Number

From the Figure 7 it is observed that as Reynolds increases there is decrease in friction factor is observed. This is because friction factor is inversely proportional to the velocity. So as velocity increases (i.e. Reynolds number increases) friction factor will decrease. From Figure 7 , it is observed that least friction factor is obtained in smooth tube without using any inserts.

3.5 Effect of Heat Transfer Coefficient on Pressure drop

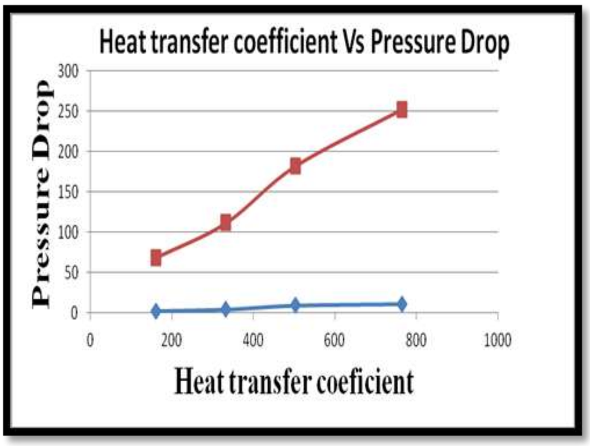

Figure 8: Heat transfer coefficient Vs Pressure Drop

From the Figure 8 it is observed that as Heat transfer coefficient increases there is increase in pressure drop is observed. This is because as Reynolds number increases, the water flow will cause more turbulence, so due to which the heat transfer rate will increase with increase in the pressure drop. Twisted tape insert create more turbulence in tube which increases the heat transfer coefficient due to this increase in the pressure drop.

4. CONCLUSION

Experimental investigations have been carried out in the circular tube to study the effect of twisted tape inserts on heat transfer enhancement, pressure Drop and friction factor. From the experimentation, following conclusions are made.

The heat transfer in tube with twisted tape inserts is consequently increased (1312.24 W/m^2 K to 1659.27 W/m^2 K) with increase in Reynolds number (35674.78 to 52367.97). The percentage increment in heat transfer coefficient is 29.14 %. This is due to the fact that the rise of Reynolds number leads to increase in degree of turbulence intensity and the improvement of convective heat transfer by using twisted tape shaped of inserts as compared to smooth tube. This means that twisted tape provide superior chaotic mixing and more efficient interruption of thermal boundary layer. Hence Nusselt number or heat transfer coefficient becomes higher with higher Reynolds number.

Due to inserts in tube there is increase in pressure drop is observed. The increase in Average pressure drop of water from 29.1851 N/m^2k to 592.88 N/m^2 This is because as Reynolds number increases, the water flow will cause more turbulence, due to which the heat transfer rate will increase with increase in the pressure drop.

Friction factor reduces (0.1142 to 0.1447) as the Reynolds number increases. This is because with increase in Reynolds number, velocity increases and as friction factor is inversely proportional to velocity. This friction factor found maximum in twisted tape inserts and minimum friction factor is obtained in smooth tube.

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