EXPERIMENTAL INVESTIGATION OF A SOLAR FLAT PLATE COLLECTOR

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ABSTRACT :

In growing energy consumption scenario, to reduce the burden on conventional energy sources, non conventional energy sources like solar energy wind energy is getting importance. In this project we deals with solar energy. The development of sustainable energy services like the supply of heating water may face a trade-off with a comfortable quality of life, especially in the winter season where suitable strategies to deliver an effective service are required. Solar energy is becoming an alternative for the limited fossil fuel resources. One of the simplest and most direct applications of this energy is the conversion of solar radiation into heat, which can be used in water heating systems. A commonly used solar collector is the flat-plate. A lot of research has been conducted in order to analyze the flat-plate operation and improve its efficiency.

This study investigates the heat transfer process as well as the thermal behaviour of a flat plate collector evaluating different configurations of Tubes. This study investigates the heat transfer process as well as the thermal behaviour of a flat plate collector evaluating different configurations of Tubes. The main objective of this research is to evaluate the performance of solar flat plate collector with tube arrangement, through experimentation, theoretical formulation and its computational analysis of heat transfer.

Index Terms : Solar flat plate collector, Heat Transfer, Riser tube, Water heating.

1. INTRODUCTION

Using the sun's energy to heat water is not a new idea. More than one hundred years ago, black painted water tanks were used as simple solar water heaters in a number of countries. Solar water heating technology has greatly improved during the past century. Today there are more than 30 million m2 of solar collectors installed around the globe. Hundreds of thousands of modern solar water heaters, are in use in countries such as China, India, Germany, Japan, Australia and Greece. In fact, in some countries the law actually requires that solar water heaters be installed with any new residential construction project (Israel for example).

Harnessing the sun radiant energy as a clean and renewable source of energy has proven to be a challenge over the centuries and in modern times has fallen off in favours of other technologies which are easier to commercialize and capitalize on. The last few decades have shown exponential increases in the energy demands and consumption patterns of many countries, which have opted to meet this challenge with more conventional means such as fossil fuel.

In addition to the energy cost savings on water heating, there are several other benefits derived from using the sun's energy to heat water. Most solar water heaters come with an additional water tank, which feeds the conventional hot water tank. Users benefit from the larger hot water storage capacity and the reduced likelihood of running out of hot water. Hot water is essential both in industries and homes. It is required for taking baths, washing clothes and utensils, and other domestic purposes in both the urban and rural areas. Hot water is also required in large quantities in hotels, hospitals, hostels, and industries such as textile, paper, and food processing of dairy and edible oil. Solar water heating systems can heat water from ambient temperature to temperatures over 90 °C depending on the collector type employed in a given locality. Using solar collector to heat the water can easily attain required temperatures.

As a consequence of the increase in the world's population, human development, the increase in individual income and the aspiration for more comfortable life styles, power consumption has increased significantly over the last three decades and this can be reduced by increasing the percentage of energy generated from clean resource like solar energy. Research involving clean sources of energy such as solar energy, has increased significantly over the last four decades, particularly after the World Oil Crisis in 1973 .Solar energy can be used in the industrial, commercial and domestic sectors. In the domestic applications like water heating, lighting and other applications. An economic and efficient system is required to encourage households to use solar water heating. The solar collectors are devices which capture the solar energy and transfer it into thermal energy that increases the internal energy in the fluids, and hence increases their temperature. There are several types of solar collectors, including the flat plate collector, evacuated tube, parabolic trough, central receiver and dish concentrator. In this project study is focused on solar flat plate collector.

The focus of the present work is on investigates the heat transfer process as well as the thermal behavior of a flat plate collector evaluating different configurations of Tubes. The main objective of this research is to evaluate the performance of solar flat plate collector with zigzag tube arrangement, through the construction, experimentation, theoretical formulation and its computational analysis of heat transfer.

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 Fig 2.1, along with thermocouple locations. The flat plate collector is mounted inclined 450 and facing north south near to 100 litters tank. The experiment part consists of a 2.0 m2 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 ±0.1oC.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.

Fig.2.1 Solar Flat Plate collector water Heater with straight riser tube

The difference between the earlier straight riser tube collector and new zigzag riser tube collector is the riser tube configuration shown in fig.2.2.Although it serves the same functions the physics is different from the conventional one. In this collector the heat transfer heat is conducted from the fins to the zigzag riser tube first and then convection to the fluid from to the zigzag riser tube. Whereas in the conventional collector the heat is conducted from the fins to the straight riser tube first and then convection to the fluid from the tube takes place. This work is primarily concerned with the possibility of replacing the conventional straight riser tube with zigzag riser tube. So, only the important practical parameters like the steady state outlet temperatures and the pressure drop can be compared.

Fig.2.2 Solar Flat Plate collector with zigzag riser tube

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 1 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 gauge. This process is continued for all four riser with straight riser tube and zigzag riser tubes. 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 analysed for conclusion.

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

FLAT PLATE COLLECTOR

Gross Area : 2 m2

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) 4 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 litters

Insulation : 100mm thick glass wool on all side

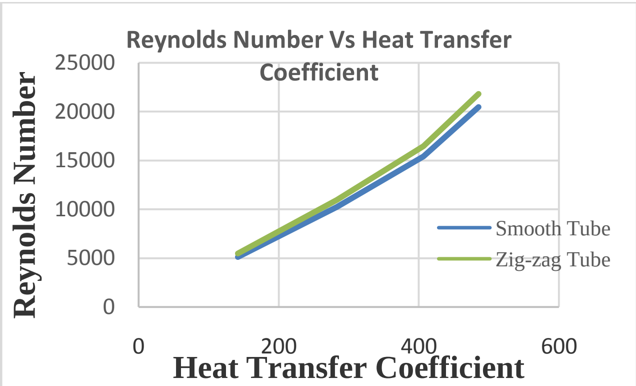
.3. Result

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.

3.1 Graphs

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

- Heat transfer coefficient Vs Reynolds No.
- Nusselt No. Vs Reynolds No.
- Frication factor Vs Reynolds No.



3.2 Effect of Reynolds Number on Heat Transfer Coefficient

The experimentation was carried out with the straight tube and zigzag riser tube in Passive heat transfer enhancement methods. Heat transfer coefficient and friction factors are calculated for all cases. Parameters were plotted for Reynolds no. and mass flow rate..

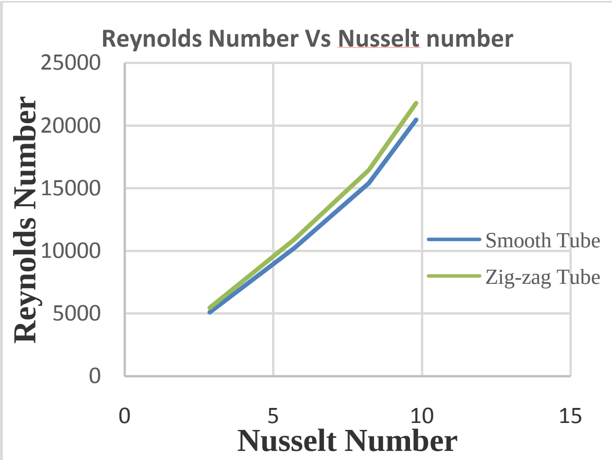


Fig: 3.2 Heat transfer coefficient Vs Reynolds Number

From the Fig. 3.2, 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..It is observed that the tube with straight riser gives less heat transfer coefficient than with the zigzag riser tubes. zigzag riser tubes create more turbulence in tube which increases the heat transfer coefficient as compared to straight riser tube.

3.3 Effect of Reynolds Number on Nusselt Number

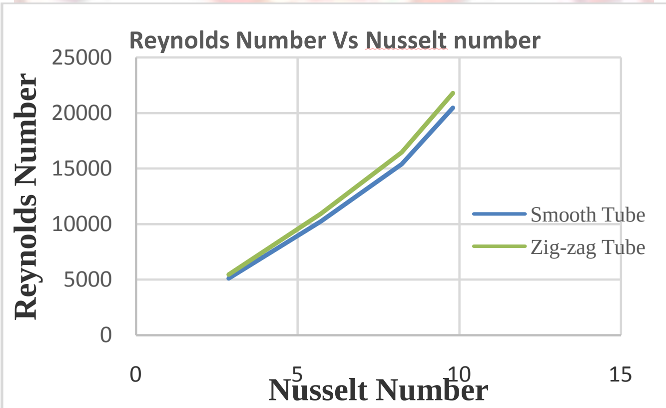


Fig. 3.3 Reynolds Number V/s Nusselt Number

From the Fig. 3.3, 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=hDh/K i.e increase in heat transfer coefficient increases the Nusselt number. From graph it is observed that maximum Nusselt number is obtained for zigzag riser tube as compared to straight riser tube. Minimum Nusselt number is obtained for straight riser tube without any modification.

3.4 Effect of Reynolds Number on Friction Factor

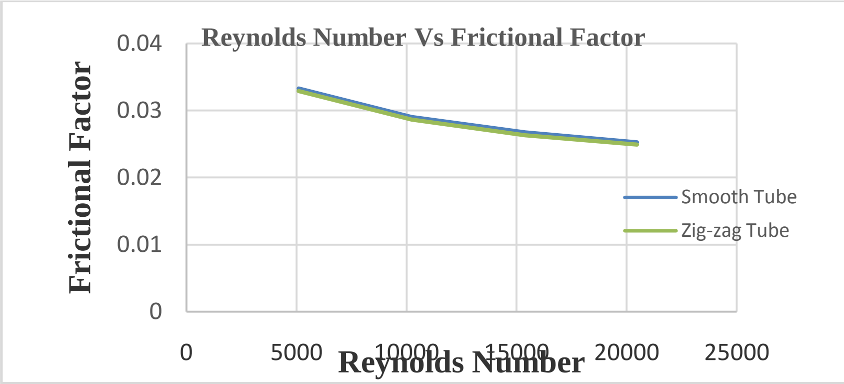


Fig.3.4 Friction factor Vs Reynolds Number

From the Fig.3.4 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.

3.5. Computational Analysis By Ansys

Heat Flux=Heat Transfer Rate Per Unit Area for straight riser tube at 2 LPM =Q /As = 110.28/0.36=306.33 W/m2

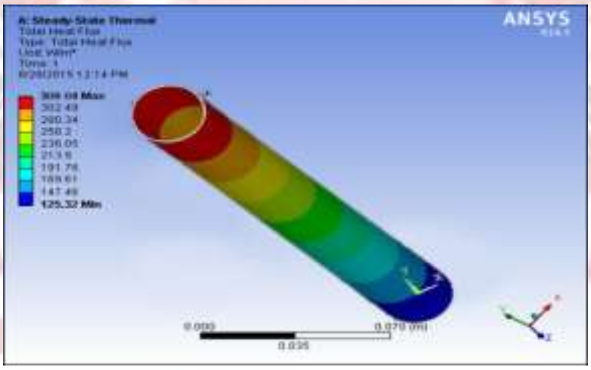


Fig. 3.5 Heat Flux For A straight riser Tube.

Heat Flux=Heat Transfer Rate Per Unit Area for zigzag riser tube at 2 LPM =Q /As = 121.33/0.36=337.33 W/m2

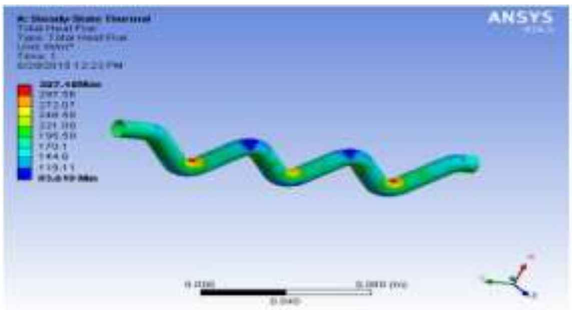


Fig. 3.6 Heat Flux For Zigzag Tube With 30 Degree Angle

E-ISSN No:2349-0721

Volume 2 Issue 5

Heat Flux=Heat Transfer Rate Per Unit Area for zigzag riser tube at 2 LPM =Q /As = 121.33/0.36=337.33 W/m2

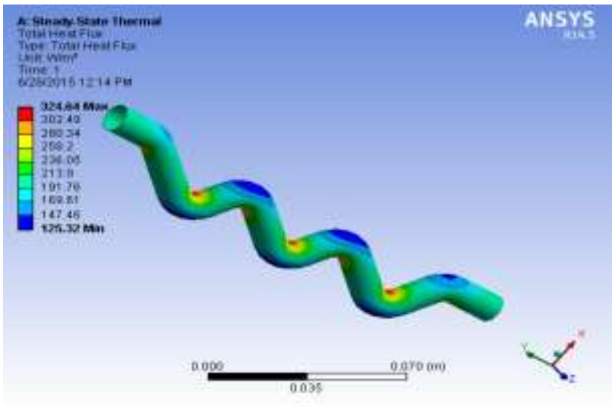


Fig. 3.7 Heat Flux For Zigzag Tube With 35 Degree Angle

Heat Flux=Heat Transfer Rate Per Unit Area for zigzag riser tube at 2 LPM =Q /As = 121.33/0.36=337.33 W/m2

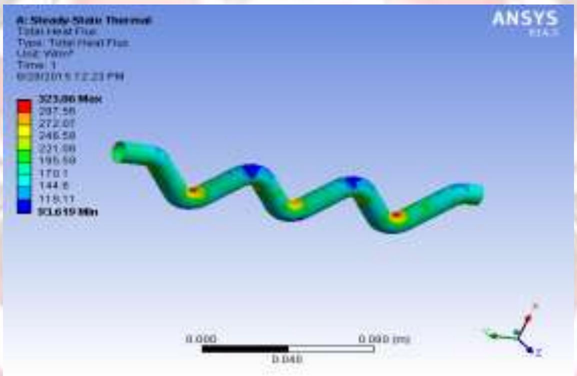


Fig. 3.8 Heat Flux For Zigzag Tube With 40 Degree Angle

Heat Flux=Heat Transfer Rate Per Unit Area for zigzag riser tube at 2 LPM =Q /As = 121.33/0.36=337.33 W/m2

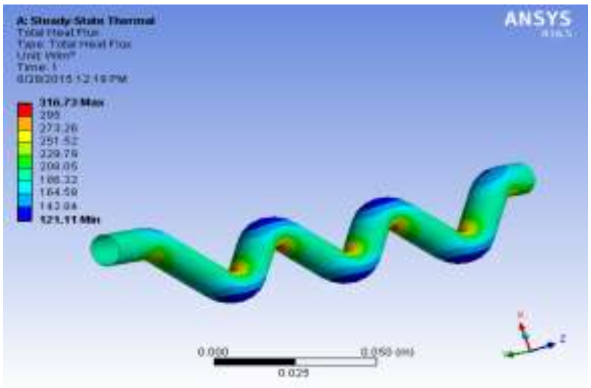


Fig. 3.7 Heat Flux For Zigzag Tube With 45 Degree Angle

4. Conclusion

Experimental investigations have been carried out on straight riser tube and zigzag riser tube on heat transfer enhancement, friction factor. From the graphs plotted, following conclusions are made.

- The heat transfer in tube with zigzag riser tube is found to be more as compared to straight riser tube. The increase in relative heat transfer coefficient of water for zigzag riser tube is 19.60 % higher than straight riser tube.

- The relative decrese in friction factor for zigzag riser tube is 1.39 % than straight riser tube.

- The relative increase in Reynolds number for zigzag Riser tube is 6.31% higher than straight riser tubes.

- The relative increase in Nusselte number for zigzag riser tubes is 18.91% higher than straight riser tubes.

- From the Ansys image of thermal analysis for straight riser tube it is found that the maximum design heat flux is found to be 306.33 W/m2 for straight riser tube and 327.15 W/m2 for zigzag riser tube with 30 degree angle respectively. So the maximum value of heat flux will be obtain in zigzag riser tube case.

- The Heat Flux experimental value are found to be 306.33 W/m2 for straight riser tube.

By Computation Analysis it is found to be as follows.

- At 30 Degree Zigzag riser tube 327.15 W/m2
- At 35 Degree Zigzag riser tube 324.64 W/m2
- At 40 Degree Zigzag riser tube 323.06 W/m2
- At 45 Degree Zigzag riser tube 316.73 W/m2

- From the manufacturing point of view 35 degree angle is safe and leakages problem is not induce and easy for welding and gives optimum heat flux value.

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