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Performance Analysis of Square and Circular Type Solar Water Heater

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Abstract

Solar water heater plays a vital role in energy conversion. Because its efficiency is more than the electric conversion. It is a well proven technology and established in various sectors such as domestic, industry and commercial. Continuous research in solar water heater will improve overall thermal efficiency of the system. Therefore any improvement in the construction and operation of solar water heating system would definitely result in saving conventional fuel and cost. Header is one of the major parts in the solar water heater system, because it divided the flow equally to the nine riser tubes. Circular and square shape header has been experimented under same operating conditions. The result reports that the overall efficiency of the circular shape header is 80.18% instead of square shape header and is 77.58%.

Keywords: Header, Square Type, Circular, Heat Transfer, Heat gain.

Introduction

Solar collector is the central component of solar water heating systems. Solar water heater plays a role in energy conversion. Solar water heaters are characterized by its thermal performance that depends on the transmittance, absorption and conduction of solar energy and the conductivity of the working fluid.Hence improvement in collector will increase the efficiency of the system. It has been characterized by thermal performance that depends on the transmittance, absorption and conduction of solar energy and the conductivity of the working fluid. The absorber plate in a solar water heater plays a major role in the performance of solar water heaters. Plate efficiency factor (F') and heat removal factor (F_R) are the important design parameters in the fabrication of solar collector systems. It has been analyzed by Hottle and Woertz [1] and later redefined by Whiller [2] and then by Hottle and Whiller [3] which significantly reduced the empiricism associated in the design of solar collectors.

A good contact between the riser tube and absorber plate is found to increase the thermal performance which has been analysed experimentally by Whiller and Saluja [4] and their findings prove that the efficiency factor (F') of collector increases from 0.77 to 0.89 for soldered bond instead of unsoldered bond. Yet another breakthrough is the use of Vee- shaped absorber plate to improve the convective heat transfer and this has been analyzed experimentally and numerically in both natural and forced circulation mode [5-6]. Besides this, the performance of solar collector also depends on the geographical conditions, collector orientation, tilt angle and material of fabrication. Robel [7] and Andersen [8] studied these aspects and illustrated the effect of these parameters on the thermal performance of the system. Thermal performance of solar collector with storage tank has been analysed numerically and models developed by Brinkworth [9] and Andres [10].

Zerrouki, Duffie and Beckman [11, 12] made several assumptions regarding mass flow rate of collector like neglecting the headers area, uniform distance between riser tubes, laminar flow and uniform distribution of flow in the tubes that proved to be useful for the design of thermosyphon system. Hence header plays a vital role in fluid distribution. In general circular shape header used in conventional solar water heater. This research mainly focus to analyze the shape of the header and study the performance for the above.

Experimental Setup and Experimentation

The experimental setup consists of a flat plate collector of 1 m^2 aperture area show in Fig.1. A digital flow meter connected outlet of the collector measures the flow rate. 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 headers are made up of copper. Differential pressure transducers having an accuracy of ± 0.1% are used to measure differential pressure of water in each riser tube .The global solar radiation is measured by Kipp and Zonen pyranometer.

The work is carried out at Star Lion College of Engineering & Technology, Thanjavur, Tamilnadu, India. Data is continuously recorded for sunny days. The solar collectors (Circular and square shape headers) are kept in outdoor condition facing south direction with a tilt angle of 10^0. The experiment is carried out for the entire day. Solar radiation, ambient, absorber, riser tube, inlet and outlet temperatures are recorded continuously for every flow rate.

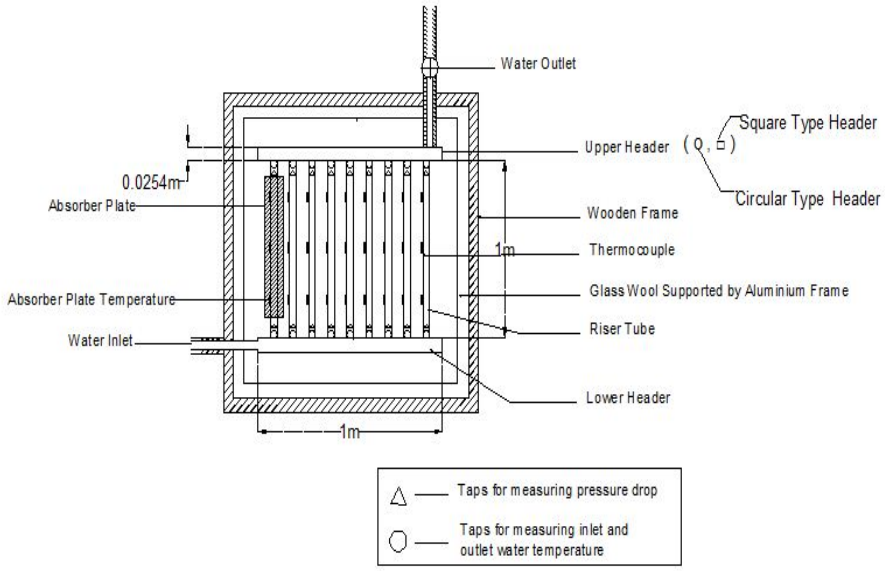

Figure 1: Schematic Layout of solar water heater

Data Reduction

The total heat gain Q, is related to overall heat transfer coefficient by the following equations from which the internal convective heat transfer coefficient (h_i) has been calculated.

$$Q = mc_p(T_{out} - T_{in}) = U_0 A_0 (T_{w0} - T_m) \tag{1}$$

$$\frac{1}{(U_0 A_0)} = \frac{1}{(h_i A_i)} + \frac{\ln(D_0/D_i)}{(2\pi k_w L)} \tag{2}$$

The internal convective heat transfer coefficient, h_i is calculated

$$Nu = \frac{h_i D}{k} \tag{3}$$

The thermal performance of a solar water heater is calculated as follows

$$\eta = F_R(\tau\alpha) - F_R U_l \frac{T_{in} - T_a}{H_t} \tag{4}$$

Result and Discussion

The internal connective heat transfer (hi) can be calculated from Equation 1 and 2. The Nusselt number, fluid velocity and over all thermal efficiency for circular and square has been discussed as follows.

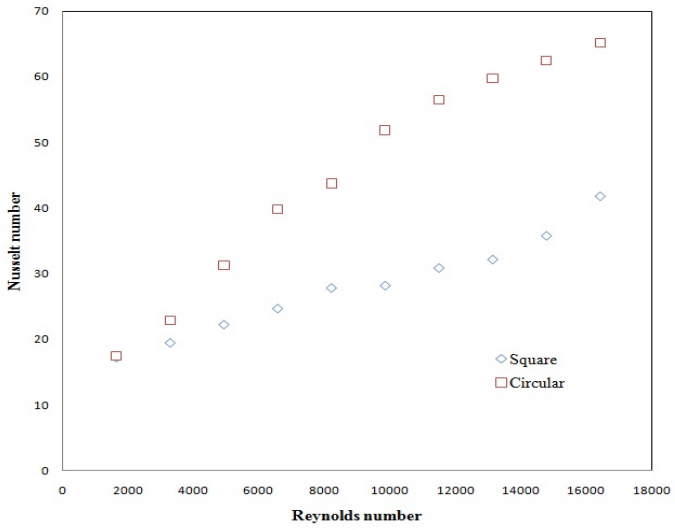

Figure 2: Reynolds Number Vs Nusselt Number

The variation between Nusselt number and Reynolds number for square and circular header has been explained in Fig.2. It is clear from that the increasing Reynolds Number increases the Nusselt number. Compared to square and circular, circular has been obtained high heat transfer than square. Because circular shape has smoothed flow and distributed the fluid evenly in nine riser tube. But in square shape the fluid gets disturbed and has not been uniform in the four corners. Hence the uneven fluid velocity in riser tubes has been disturbed the heat transfer mechanism. Due to the above, the overall heat transfer rate is high in circular than square shape.

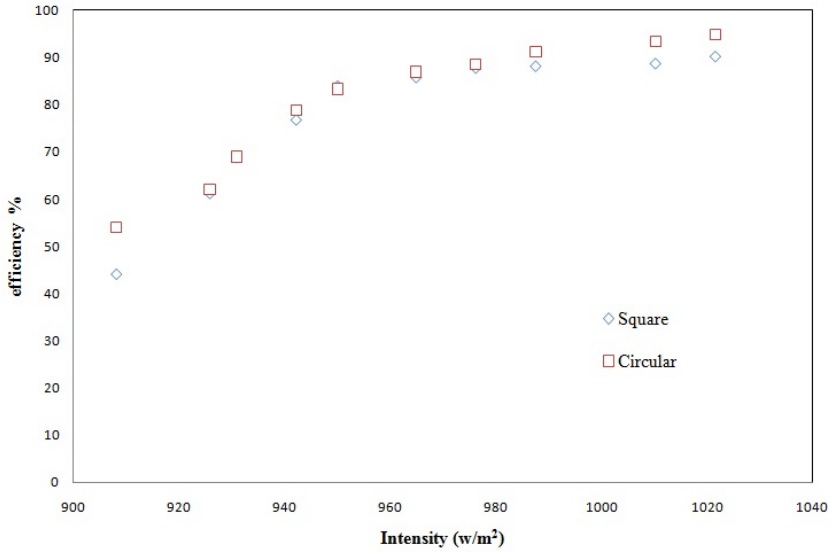

Figure 3: Intensity Vs efficiency

The variation between solar intensity and over all thermal efficiency for square and circular header has been explained in Fig.3. It is clear from that the increasing solar radiation increases the efficiency. Compared to square and circular, circular has been obtained higher efiicency than square. Because, the uniform flow in circular shape has been increases the heat transfer rate. The uneven flow in square shape reduces the heat enhancement. Hence the overall efficiency of the system has been reduced.

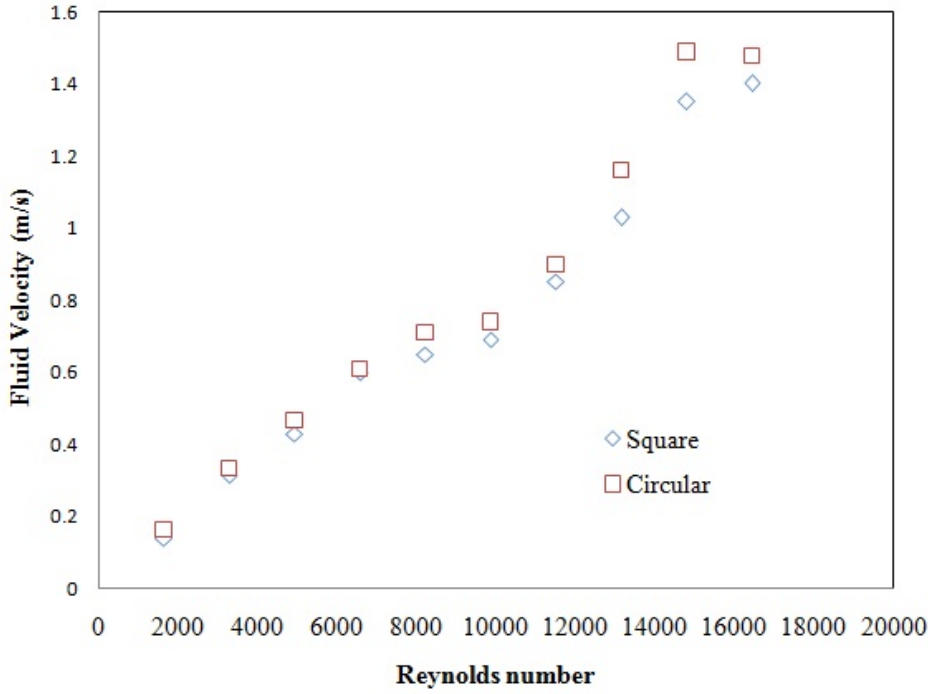

Figure 4: Reynolds Number Vs Fluid Velocity

The variation between fluid velocity and Reynolds number for square and circular header has been explained in Fig.4. It is clear from that the increasing Reynolds Number increases the fluid velocity. Compared to square and circular, circular has been obtained higher velocity than square. Because circular shape has smoothed flow and distributed the fluid evenly in nine riser tubes. But in square shape the fluid gets disturbed and has not been uniform in the four corners. Hence the overall fluid velocity high in circular shape.

Conclusion

The results show that the uniform circular header distributed the fluid flow evenly in nine riser tubes. Hence the fluid velocity increases in circular, which would increase the internal convective heat transfer. Due to this, the overall efficiency of circular header solar water heaters is 80.18 % instead of square shape and is 77.58 %. It is conclude that circular header is best for solar water heater than the square header.

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