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Title: Analyze the Effect of Various Shapes of Riser Tubes on Flat Plate Solar Water Heater Efficiency

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Abstract - *A flat plate collector solar water heater is a simple and effective way to gather solar energy. Any enhancement in its heat transfer performance will undoubtedly result in cost savings from conventional fuel. Although it has been recognized that the riser tube plays an important role in the performance of flat plate solar collectors, little research has been done on it. The goal of this research is to examine the effects of various riser tube shape configurations, and modelling will be done using the ANSYS CFD tool. Different heat fluxes were compared in terms of entrance and exit temperature.In comparison to circular riser tubes, CFD studies demonstrate that square and triangular riser tubes have the highest water exit temperature for the same heat flux and inlet temperature. This is due to the fact that square and triangular riser tubes have a larger surface area of contact between the tube and the plate, allowing for higher heat absorption and thus improved collector performance.*

Key Words: Solar energy, Flat Plate Solar Water Heater, CFD simulation, geometry of Riser Tubes, optimization.

1. INTRODUCTION:

Solar energy collectors are a type of heat exchanger that converts solar radiation energy into the transport medium's internal energy. The solar collector is the most important part of any solar system. Although flat plate collectors yield lower temperatures than other solar thermal collectors, they have the advantage of being easier to build, maintain, and invest in. The low energy density w/m2 of solar energy poses a barrier in harnessing it. One possible solution to this problem is continuing increases in solar application working efficiency. The collection plates absorb as much solar energy as possible and send it to the working fluid flowing through the absorber tube. The heat transfer fluid is usually passed through a metallic tube that is attached to the absorber plate. The absorber is typically made of metallic materials like copper, steel, or aluminum, with a black surface. To avoid heat loss, the collection box can be constructed of plastic, metal, or wood, and the transparent front cover must be sealed so that heat does not escape, as well as the collector itself being protected from dirt and humidity. Water or water with antifreeze liquid can be used as the heat transfer fluid. Convection and radiation losses come from heat losses caused by the temperature difference between the absorber and the surrounding air. Flat plate collectors have the advantage of utilising both the beam and diffuse components of solar energy. Flat plate collector efficiency is affected by plate temperature, ambient temperature, solar insolation, top loss coefficient, plate emissivity, cover sheet transmittance, and number of glass covers [4].

1.1 Problem Statement:

The objective of this study is to analysis the effect of various geometry configurations of riser tubes and modeling is to be carried out with ANSYS CFD tool. The overall aim of this work is to understand the temperature distribution of water inside the solar collector and compare the outlet temperature of water with numerical results for various geometry configurations of riser tubes Here the flow domain consists of a three flat plate absorber plates having circular, square and triangular riser tubes shapes as shown in Figure 1 for comparing their thermal efficiency for optimization of design.

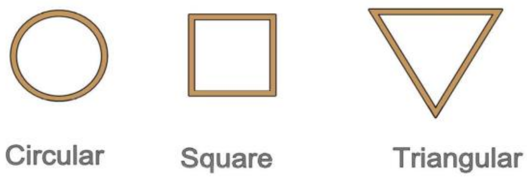

Fig.1:Schematic drawing showing *various geometry* configurations of riser tubes

1.2 Circular Tube Configuration

The Figure shows the absorber plate and the Circular tubes attached below the absorber plate. The heat energy from the sun is absorbed by the absorber plate

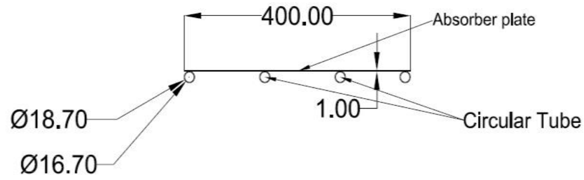

Fig. 2: Circular Tube Configuration

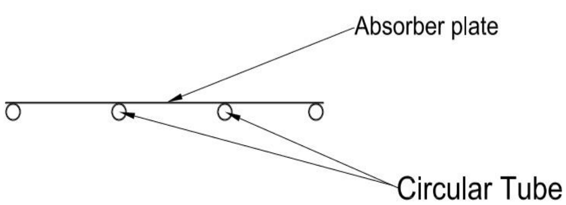

Fig. 3: Circular Tubes Configuration

And conducted to the tubes having surface contact with the absorber and heat is absorbed by the working flowing through the circular tubes. The collector absorber plate length and width for all the design is taken as 0.7 m and 0.4 m respectively

The Dimension of simple circular tube as follow

Length = 0.720 m, Diameter = 0.0167 m ,

Thickness = 0.001m

Effective surface area of circular riser tubes = $(\pi/4)$ X d^2

= $(\pi/4)$ X $(0.0167)^2$

= 0.0002190 m^2

Effective Volume of circular riser tubes = $(\pi/4)$ X d^2 X L

= $(\pi/4)$ X $(0.0167)^2$ X 0.720

= 0.000157708 m^3

1.2 Square Tube Configuration

The Figure shows the absorber plate and the square tubes attached below the absorber plate. The heat energy from the sun is absorbed by the absorber plate and conducted to the tubes having surface contact with the absorber and heat is absorbed by the working flowing through the square tubes. By this arrangement the surface area of contact between the tube and the plate will increase, resulting in more heat absorption and hence enhanced performance of the collector. But only drawback of this arrangement is scale formation and sludge formation in the inside corners of square tube

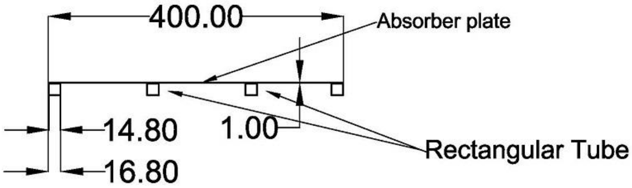

Fig. 4: Square Tube Configuration

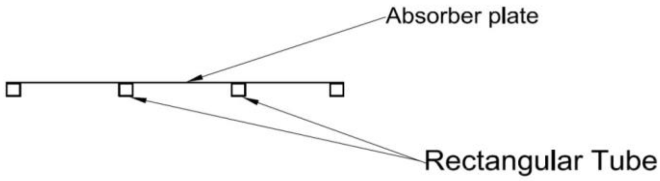

Fig. 5: Square Tubes Configuration

The Dimension of simple Square tube as follow

Length =0.720m, side=0.0148m, Thickness = 0.001m

Effective surface area of square riser tubes = $(side)^2$

= $(0.0148)^2$

= 0.000219 m^2

Effective Volume of square riser tubes = $(side)^2$ X Length

= $(0.0148)^2$ X 0.720

=0.000157708 m^3

1.3 Triangular Tube Configuration

The Figure shows the absorber plate and the Triangular tubes attached below the absorber plate. The heat energy from the sun is absorbed by the absorber plate and conducted to the tubes having surface contact with the absorber and heat is absorbed by the working flowing through the Triangular tubes. By this arrangement the surface area of contact between the tube and the plate will increase, resulting in more heat absorption and hence enhanced performance of the collector. But only drawback of this arrangement is manufacturing process is complicated

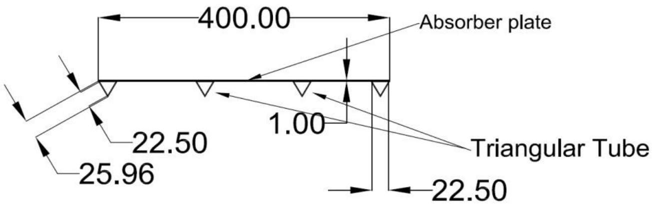

Fig. 6: Triangular Tubes Configuration

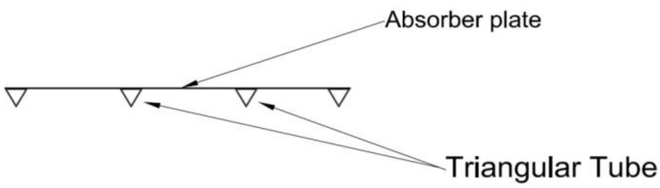

Fig. 7: Triangular Tube Configuration

The Dimension of Triangular tube as follow

Length = 0.720 m
Side = 0.0225m
Thickness = 0.001 m

Effective surface area of Triangular riser tubes= $\frac{\sqrt{3}}{4}$ x a2

= $\frac{\sqrt{3}}{4}$ x 0.0225 x 0.0225

= 0.000219 m^2

Effective Volume of Triangular riser tubes= 0.000157708 m^3

2: METHOD OF SOLUTION

In this paper, CFD Simulation are done for three shapes,

1. Circular tube 2. Square tube 3. Triangular tube

Computational Fluid Dynamics (CFD) analysis:

1. First carried out analytical design of absorber plate, riser and header tube, Inlet Temperature & solar radiation of solar thermal flat plate collector
2. Modelling of flat plate collector for different riser tubes configuration (circular, square, and triangular using modeling software CATIA V5 R20,
3. Comparison of the performance of different riser tubes configurations of flat plate collector in terms of outlet temperature, useful heat gain and collector efficiency using CFD analysis (Ansys R 19)

2.1: Boundary conditions:

In this analysis mass flow rate of 0.0038 kg/s with constant inlet temperature is introduced. The Inlet temperature is measured at different time during day at 10 am, 12 noon & 2 pm. For solar energy data, refer following site https://apps.solargis.com/prospect/map c=21.3496,74.8797,10&s=21.3496,74.8797(shirpur location) The material used for both absorber plate and the tube is copper. The input parameters used in the analysis are as shown follows.

Density (Copper) 8978 kg/m3

Specific Heat (Copper) 381 J/kg-K

Thermal Conductivity (Copper) 386 W/m-K

Density (Water) 998.2 kg/m3

Viscosity (Water) 0.001003 kg/ (m.s)

Specific Heat (Water) 4182 J/kg-K

Thermal Conductivity (Water) 0.6 W

2.2: Assumptions:

Following assumptions are made in the analysis

- Water is circulated through the absorber tube. Following assumptions are made in the analysis.
- Water is a continuous medium and incompressible.
- The flow is steady and possesses laminar flow characteristics.

The thermal-physical properties of the absorber plate, water and the absorber tube are independent of temperature [4]. CFD analysis is carried out as follows:

Meshing of circular tubes configuration:

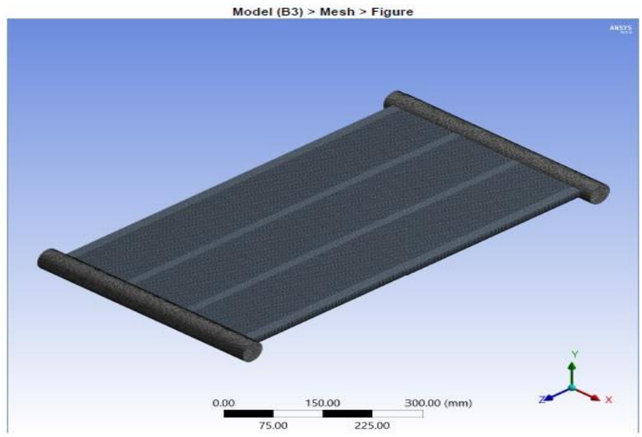

Fig. 8: Mesh model of circular riser tubes

Temp. Distribution for 706 W/m2 Radiation at 12 pm (Circular riser tube):

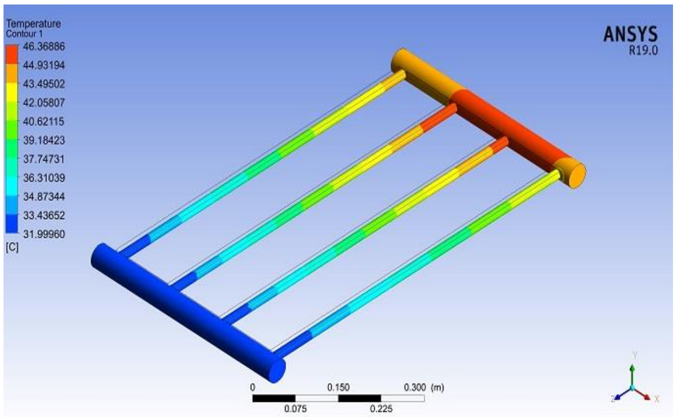

Fig. 9: Temp. distribution in circular riser tubes

Meshing of Square tube configuration:

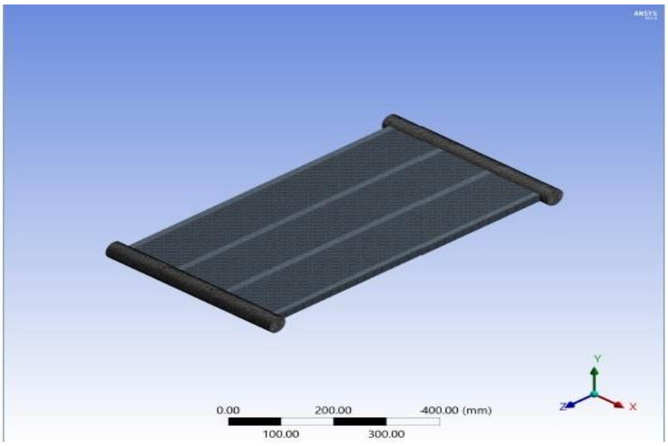

Fig. 10: Mesh model of Square riser tubes

Temp. Distribution for 706 W/m2 Radiation at 12 pm (square riser tube):

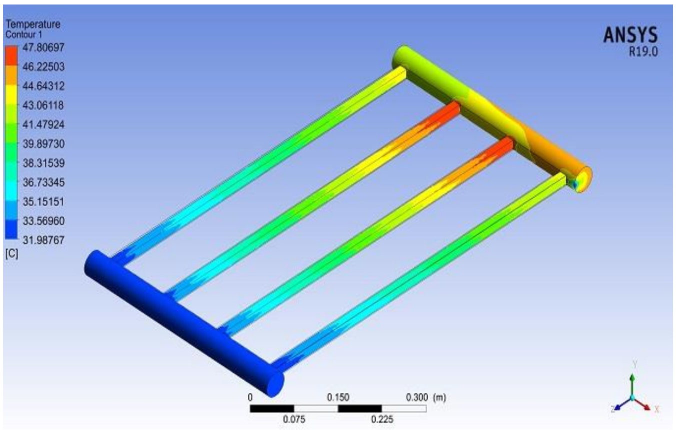

Fig. 11: Temp. distribution in sqaure riser tubes

Meshing of Triangular tube configuration:

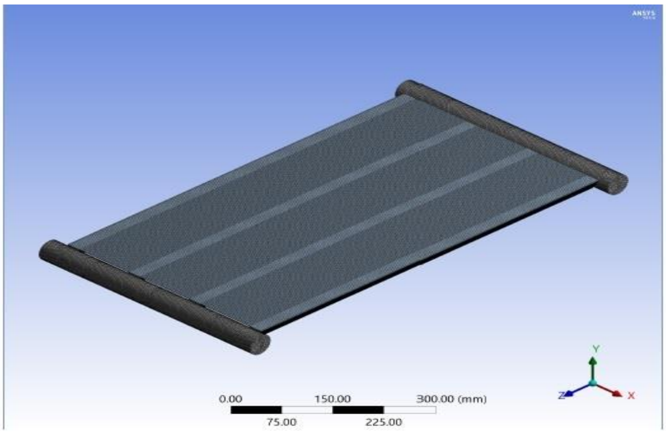

Fig. 12: Mesh model of Triangular riser tubes

Temp. Distribution for 706 W/m2 Radiation at 12 pm in Triangular riser tube:

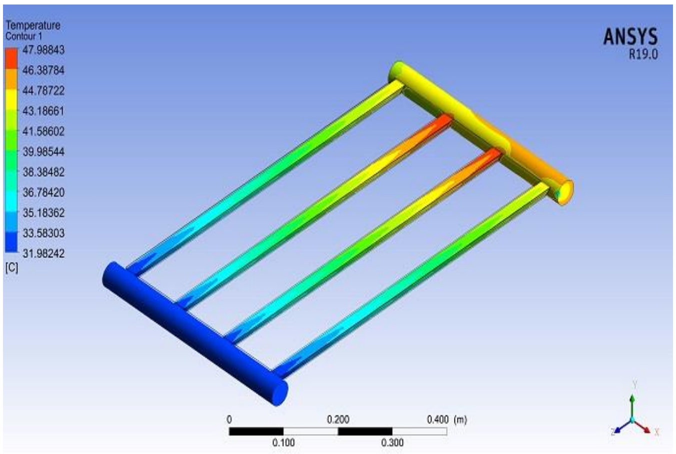

Fig. 13: Temp. distribution in Triangular riser tubes

2.3: Efficiency of flat plate collector:

The efficiency of flat plate collector can be evaluated by

$\eta = (Qu) \div (IT \times Ac)$

Where,

Qu = Useful heat gain (W).

IT = Total solar radiation incident on top cover of the collector (W/m2)

Ac = Collector gross area (m2)

For flat late collector, the useful heat gain (Qu) can be calculated by the formula below.

Qu = m Cp (Tout - Tin)

Where,

m = Mass flow rate (kg/s)

Cp = specific heat of water (kJ/kg k)

T_{out} = Fluid outlet temperature (0^{C})

T_{in} = Fluid inlet temperature (0^{C})

3: RESULTS AND DISCUSSION

Table 1: Useful Heat Gain in Circular, Square & Triangular riser tubes

Time	Qu of Circular (W)	Qu of square (W)	Qu of Triangular (W)
10 am	183.92	203.33	205.40
12 pm	228.63	251.70	254.56
2 pm	179.78	197.76	200.47

Variation of Useful Heat Gain in Circular, Square & Triangular riser tubes:

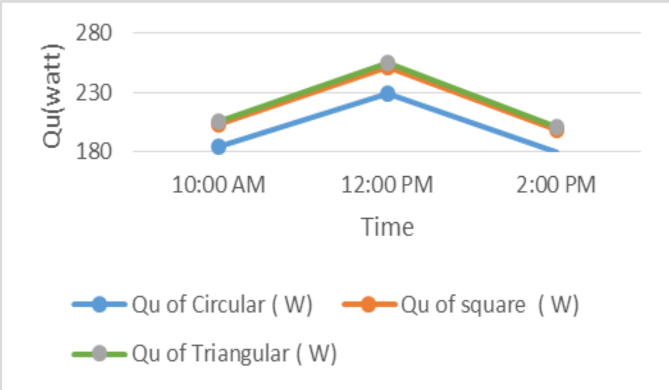

Fig 14: Useful Heat Gain in Circular, Square and Triangular riser tubes

From the above graph, it is seen that maximum heat gain is obtained in Square & triangular riser tubes configurations as compared to circular tubes

Table 2: Outlet temperature of water for circular, square & Triangular riser tubes:

TIME	TEMP (Circular 0c)	TEMP (Square 0c)	TEMP (Triangular 0c)
10 AM	37.55	38.77	38.89
12 PM	46.36	47.80	47.98
2 PM	41.29	42.42	42.58

Variation of Outlet temperature of water in circular, square & Triangular riser tubes:

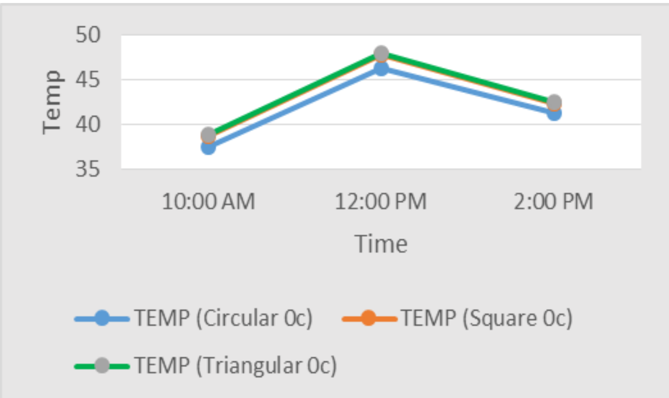

Fig 15: Outlet temperature of water in circular, square & Triangular riser tubes

Table 3: Collector efficiency (η) of circular, square & Triangular riser tubes:

Time (hr)	η Circular (%)	η Square (%)	η Triangular (%)
10 am	75.48	83.45	84.30
12 pm	75.76	83.40	84.35
2 pm	75.78	83.36	84.50

Variation of collector efficiency for Circular, Square and Triangular riser tubes:

Fig 16: collector efficiency for Circular, Square and Triangular riser tubes

From the graph, outlet temperature difference between square/triangular and circular riser tubes is almost 2^{0C}.& rising efficiency 8 to 10%

Table 4: Comparison of flow velocity for different riser tube configuration:

S. N.	Riser tube	Time	Radiation (w/m²)	Maximum flow velocity obtained(m/s)	Mass flow rate (M) kg/s	Discharge (lit/sec)
1	Circular	10 AM	570	0.00598	0.001309	0.001309
2		12 PM	706	0.00603	0.001320	0.001320
3		2 PM	555	0.00603	0.001320	0.001320
4	Square	10 AM	570	0.00752	0.001646	0.001646
5		12 PM	706	0.00752	0.001646	0.001646
6		2 PM	555	0.00752	0.001646	0.001646
7	Triangular	10 AM	570	0.00735	0.001609	0.001609
8		12 PM	706	0.00735	0.001609	0.001609
9		2 PM	555	0.00735	0.001609	0.001609

From the above result it seen that Discharge is more for Square/ Triangular riser tubes as compared to Circular riser tubes

CONCLUSION:

From the above study it is concluded that, square and triangular riser tubes configurations gives the maximum outlet temperature of water for the same heat flux and inlet temperature in comparison with circular geometry. A triangular/square tubes configuration raises the outlet temperature due to better contact between tubes and absorber plate in comparison with circular one. Result also shows the peak outlet temperature difference between square/triangular and circular riser tubes is almost 20C. The efficiency for different shapes of riser tubes was calculated and the comparison shows that there is an increase of about 8-10 % efficiency in case of square/triangular riser tubes in comparison with circular one.

REFERENCES:

[1] S.P. Sukhatme, J.K.Nayak, "Solar Energy Principles of Thermal Collection and Storage", 3rd edition, 8th reprint, Tata McGraw Hill, New Delhi,(2011)

[2] B. H. Khan, "Non-Conventional Energy Resources", 2nd edition; 7th reprint, Tata Mc-Graw Hill, New Delhi, (2011)

[3] KE Amori. and NS Jabouri ,"Thermal Performance of Solar Hot Water Systems using a Flat Plate Collector of Accelerated Risers", TJER Vol. 9, No. 1, (2012),

[4] Vishal G. Shelke, Prof. Chinmay V. Patil Analyze the Effect of Variations in Shape of Tubes for Flat Plate Solar Water Heater IJSER Volume 3 Issue 4, April 2015

[5] Basavanna S. and K. S. Shashishekar , "CFD Analysis of Triangular Absorber Tube of a solar flat plate collector", International Journal of Mechnical Engineering and Robotic Research, Vol 2, No. 1,(2013), pp 19 - 24.

[6] Manjunath M.S., K. Vasudeva Karanth, and N. Yagnesh Sharma, "A Comparative CFD Study on Solar Dimple Plate Collector with Flat Plate Collector to Augment the Thermal Performance", World Academy of Science, Engineering and Technology 70 (2012), pp 969 - 975.

[7] P. Sivakumar , W. Christraj, M. Sridharan and N. Jayamalathi,"Performance Improvement Study of Solar Water Heating System" ARPN Journal of Engineering and Applied Sciences VOL. 7, NO. 1, JANUARY 2012 pp 45-49

[8].Rhushi Prasad, H.V. Byregowda, P.B.Gangavati, Experiment Analysis of Flat Plate Collector and Comparison of Performance with Tracking Collector Euro- pean Journal of Scientific Research, ISSN 1450- 216X Vol.40 No.1 (2010), pp.144 -155, EuroJournals Publishing, Inc. 2010

[9] Balaram Kundu, "Performance analysis and optimization of absorber plates of different geometry for a flat-plate solar collector: a comparative study", Applied Thermal Engineering 22 (2002), pp 999-1012.

[10]https://apps.solargis.com/prospect/map c=21.3496,74.8797,10&s=21.3496,74.8797(Shirpur location)