Design and Optimization of Inner Grooves in Solar Water Heater

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Abstract

This study shows the design and optimization analysis of effect of inner groves with semi circular, square, triangular, and trapezoidal geometry profile inside the water collecting system in solar water heater. The water heater was designed using solid works software and numerical analysis was done by ANSYS14.0.The results shows that the system performance depends upon the geometry profile of the inner groves which is placed inside the water collecting system. A typical optimization analysis of the system shows that the total relative temperature of the system is high especially in triangular groove geometry. During the analysis the results showed that the system exhibited maximum relative temperature of 367.20 K in triangular geometry profile among the other three profiles.

Key words-

Solar water heater; inner groves; geometry profiles; optimization; ANSYS

1. Introduction

Solar water heater plays a vital role in energy conservation. Because of its efficiency is more than the electric conversion. It has become the well proven and established appliance for providing hot water requirements in thousands of families in India. Solar water heating is a very simple and efficient way to grab energy from the sun and use it. In spite of its low efficiency it occupies a respectful place among the energy users. Therefore any improvement in the construction and operation of solar water heating system would definitely result in saving conventional fuel and cost [1].Solar water heater (SWH) is an environmentally friendly device which absorbs free and renewable solar energy to reduce hot water, economically, reducing the use of conventional energy such as electricity by up to 80%. The solar hot water system produces hot water of 50°C to 70°C depending upon the season, location, solar intensity and number of solar collector panels [2].

2. Methodology

Methodology of this analysis is shown the fig.1. Based on the different review of literatures this analysis is carried out to improve the performance of the solar water heater. Identification of different problems encountered with solar water heater is the second step of this analysis. A different type of problems which is the barrier of solar water heater is summarized and the existing solar water model dimensions are taken into account to design the new model. Solid works software is used to design the new model of solar water heater based on the existing design parameters. Meshing of the above said four geometric models were done by using ANSYS software. Flow analysis inside the solar water heater collector ANSYS software with a constant mass flow rate of 0.6 m/s at an operating temperature of 323 K. Results are obtained from ANSYS//FLUENT software after the successful completion of iterations. Optimized inner groove profile is selected based on the highest total relative temperature values.

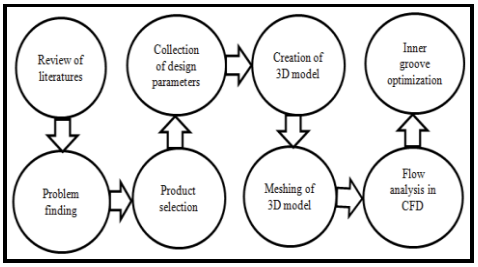

Figure 1Methodology

3. Modelling

The schematic diagram of the natural circulation solar water heater is shown in Fig.1.the system consists of a flat-plate solar collector (Fig.2), storage tank (Fig.3) and connecting pipes. The absorber steel plate of the solar collector was formed, like a corrugated sheet to accommodate the water pipes and headers in the grooves to maintain good contacts with the pipes (Fig.2). Each pipe is 1 m long and has an inner diameter of 17 mm and outer diameter of 20 mm. the pipes are placed close together horizontally with

a space of 83 mm in between and welded at both ends to the header pipes of 22 mm internal diameter, 25 mm outside diameter and 700 mm long each. The absorber-water pipe assembly formed an inner box, which in turns is mounted in an outer box, the space between the absorber-water pipe assembly and outer box is filled with wood shaven as insulating material. The front surface of the box is then covered with 4 mm thick clear plain glass and air gap between the plate and the glass cover is 76 mm. the overall dimension of flat-plate solar collector is 1130x830x190 mm and the effective glazing area is 0.7 m^2.The following parameters are taken into account to design the semi circular inner groove geometry profile.

Table 1 Design and operating parameters

Sl.No.	Inner grove profile	Material	Mass flow rate (m/s)	Cross sectional dimensions (mm)	Atmospheric temperature (K)
1.	Semi Circular	Copper	0.6	42	323
2.	Square				
3.	Triangular				
4.	trapezoidal				

Configuration of solar water heater flat plate type is given in fig.2 which is obtained from the existing journal for design purpose only.

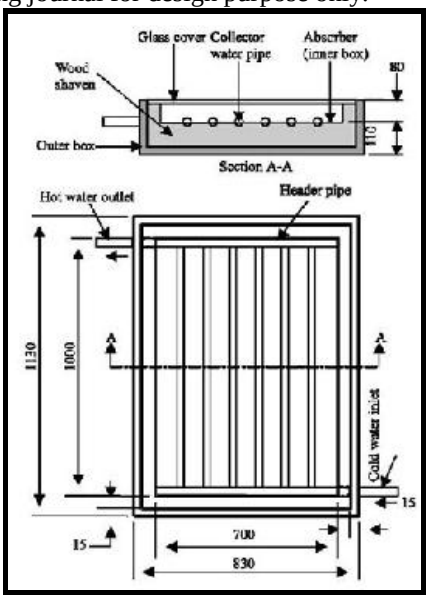

Figure 2 Configuration of flat plate solar collector[3]

Configuration of solar water heater storage tank is given in fig.3 which is obtained from the existing journal for design purpose only.

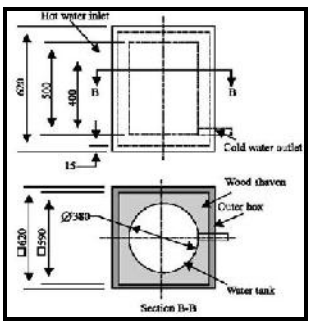

Figure 3 Storage tank[3]

Three dimensional geometric model of the semi circular, Square, Triangular and trapezoidal inner grooves are shown in fig.4, 5, 6 & 7 respectively. All these models were created by using solid works software.

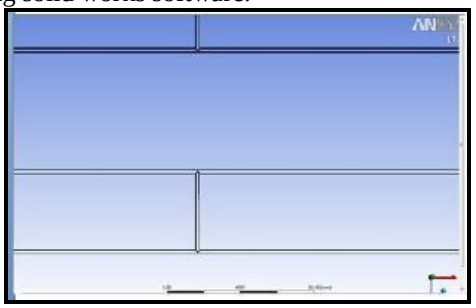

Figure 4 Geometric model of semi circular inner groove profile

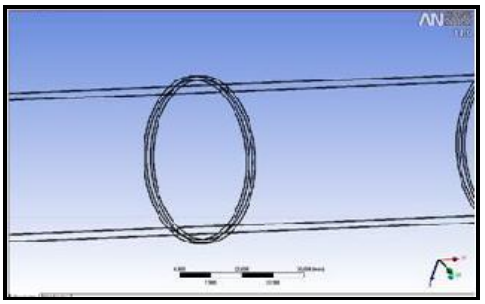

Figure 5 Geometric model of square inner groove profile

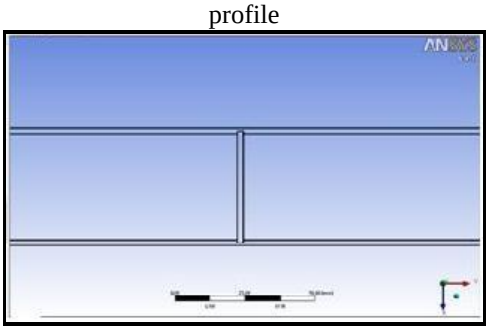

Figure 6 Geometric model of triangular inner groove profile

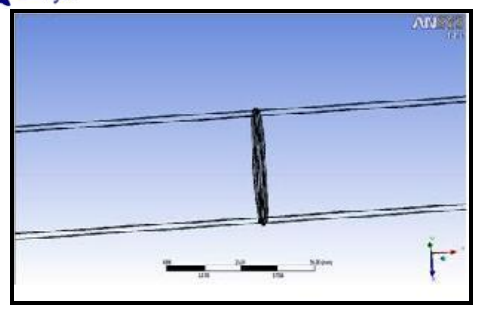

Figure 7 Geometric model of trapezoidal inner groove profile

4. Analysis

Analysis of the four different inner groove profiles like semi circular, square, triangular and trapezoidal geometries are done by using ANSYS 14.0 software. Fig.8 shows the complete mesh model of the semi circular inner groove profile. Fig.9 shows the complete mesh model of the square inner groove profile. Fig.10 shows the complete mesh model of the triangular inner groove profile. Fig.11 shows the complete mesh model of the trapezoidal inner groove profile. Analyses of four different inner groove profiles are carried out under a mass flow rate of 0.6 m/s at an operating temperature of 323 K.

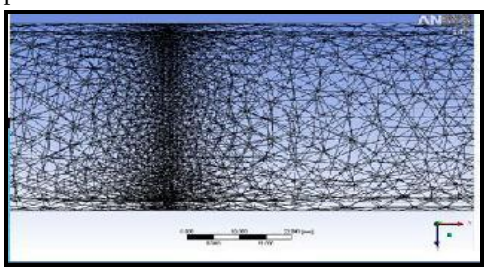

Figure 8 Mesh model of semi circle inner groove profile

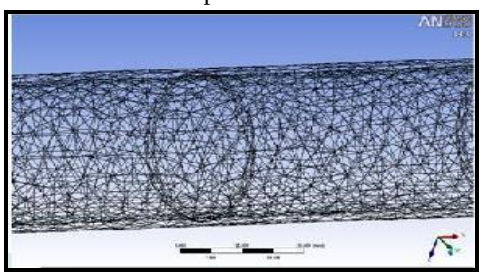

Figure 9 Mesh model square inner groove profile

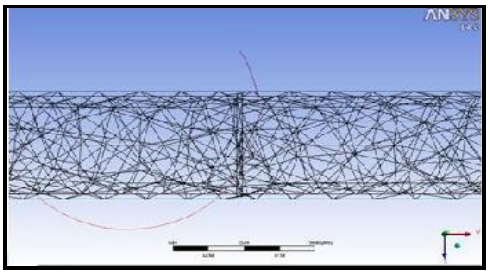

Figure 10 Mesh model triangular inner groove profile

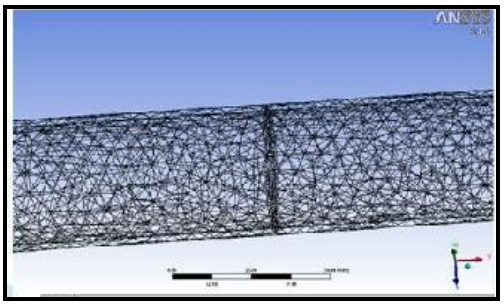

Figure 11 Mesh model trapezoidal inner groove profile

5. Results & discussions

Following total relative temperature analysis with respects to mass flow rate of 0.6 m/s for different inner groove geometry profiles (semi circular, square, triangular, and trapezoidal) are carried out by using ANSYS/FLUENT software. Contour plots of the results taken from the Fluent software are given in the below figures.

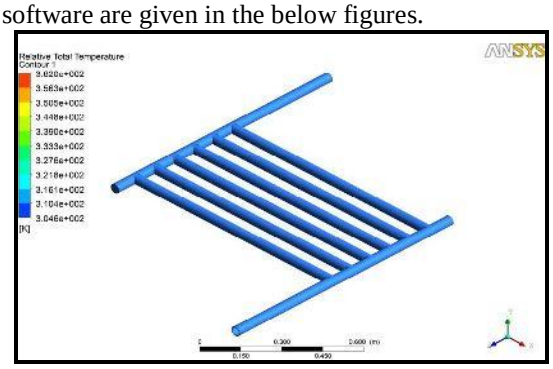

Figure 12 Total relative temperature for Semi circular inner groove profile

Fig.12 shows the effect of total relative temperature with respect to the Semi circular inner groove profile of water collecting system. By using this profile minimum and maximum temperature obtained is 304.6 K & 362 K.

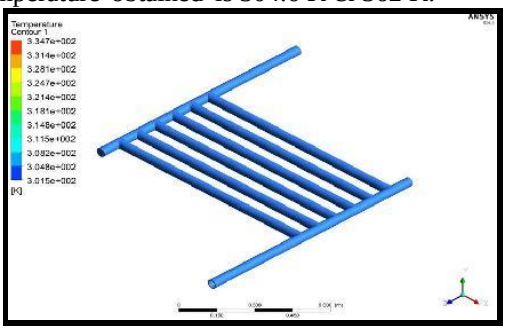

Figure 13 Total relative temperature for square inner groove profile

Fig.13 shows the effect of total relative temperature with respect to the square inner groove profile of water collecting system. By using this profile minimum and maximum temperature obtained is 301.5 K & 334.7 K.

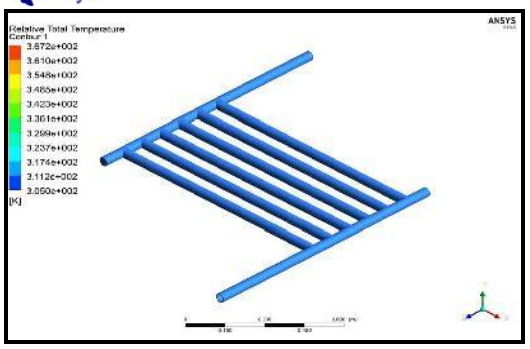

Figure 14 Total relative temperature for triangular inner groove profile

Fig.14 shows the effect of total relative temperature with respect to the triangular inner groove profile of water collecting system. By using this profile minimum and maximum temperature obtained is 305 K & 367.2K.

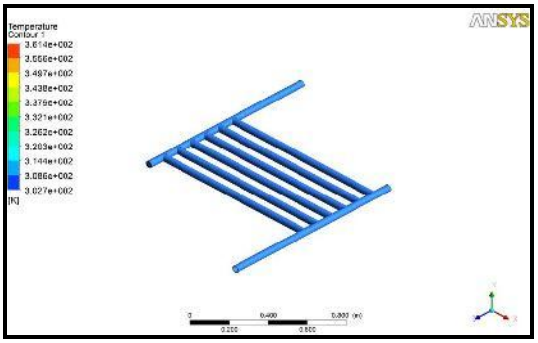

Figure 15 Total relative temperature for trapezoidal inner groove profile

Fig.15 shows the effect of total relative temperature with respect to the trapezoidal inner groove profile of water collecting system. By using this profile minimum and maximum temperature obtained is 302.7 K & 361.4 K.

Table 2 Total relative temperature for different inner groove profiles

Sl.No.	Inner groove profile	Total relative temperature (K)
1.	Semi circular	362.0
2.	Square	334.7
3.	Triangle	367.2
4.	Trapezoidal	361.4

Total relative temperatures for four different geometric profiles are tabulated in table.2. It shows clearly solar water heater collecting tube with triangle cross section has the maximum total relative temperature value of 367.2 K.

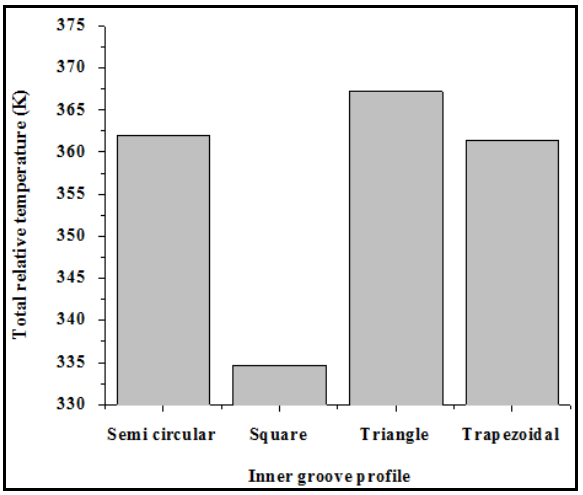

Figure 16 Total relative temperature for different inner groove profile

Fig.16 shows the effect of total relative temperature with respect to changes in the inner groove profile of water collecting system.

6. Summary

From the above discussions we have concluded that the inner groove with triangle cross section posses the maximum total relative temperature of 367.2 K which is higher than the other inner groove profiles.

References

[1] Jaisankar Subramanian, Senthilkumar Tamilkozhndu, and Thulasi Selvam, Experimental Studies on Variable Header Solar Water Heating System, 2nd International Conference on Mechanical, Production and Automobile Engineering (ICMPAE'2012) Singapore April 28-29, 2012.

[2] G.N. Okonkwo and A.O.C. Nwokoye, Experimental Investigation and Performance Analysis of Thermosyphon Solar Water, Advances in Natural and Applied Sciences, 6 (2), 2012, 128- 137.

[3] Bucola.O.Bolaji, Flow design & collector performance of natural circulation solar water heater, Journal of Engineering & applied Sciences 1(1), 2006, 7-13.