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Transient Thermal Analysis of Solar Air Heater Using Different Shape Roughened Plates to Improve Air Outlet Temperature

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A B S T R A C T

The sun is the very important source of energy in the world. The sun radiates a large amount of energy to the surface of earth. The application of solar energy includes photosynthesis, vaporization in oceans, heating the water, cooking the food, power generation etc. Now a days, most of the industries are trying the application of solar energy to transportation, space conditioning, some smaller industrial appliances, etc. The main objective of this paper is to improve the air quality and temperature flowing through Solar Air Heater (SAH) with the help of Transient Thermal Analysis of Solar Air Heater using various shape roughened plates and compared with conventional Solar Air Heater. The results will shows that the study and analysis of Solar Air Heater has been successfully understood and the Shape Roughened Plates are useful in improving the performance of Solar Air Heater by increasing the Air Outlet Temperature.

Keywords:Solar Air Heater, Solar Energy, Solar Radiation, Transient Thermal Analysis.

1. Introduction

The Sun is a very large source of energy on the earth. Solar oriented technology can be divided into two categories: Active and Passive Solar systems. Passive solar oriented technology includes natural circulation in designing spaces for cooling or heating, locating buildings with respect to sun. While active solar oriented technology includes use of fans, pumps to convert this energy into required output. Solar Air Heaters are the devices which utilizes solar energy for various technical applications. They are used in industries because of simplicity and inexpensiveness. Commonly, Solar Air Heater consist of a top transparent cover plate, a good absorber plate and insulation. The air enters in the passage between top cover and absorber plate. The absorber plate absorbs the heat form sun radiation and delivered to air flowing over it. This process increases the temperature of air. The heated air can be used for variety of industrial applications. The main advantages of Solar Air Heater are easy to design, repair and maintain. Also, no leakage and corrosion problems. Since no any combustion method so, they are ecofriendly with no hazardous gases emission. The primary disadvantage of Solar Air Heater is low heat transfer coefficient between absorber plate and working fluid specially, when water is used. In this paper, different shape roughened plates are used in a solar air heater and the effect of this technique on the air temperature had been evaluated by means of Transient Thermal Analysis which is a tool of Finite Element Analysis.

Nomenclature

ANSYS	Analysis
NTD	Net Temperature Difference
SAH	Solar Air Heater

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1.1. Proposed Methodology

The present work includes methodology adopted for case study is shown in Fig.1. Firstly, introduction has been defined based on theoretical work presented. The concept of Solar Air Heater is explained in introduction. The various types of solar air heaters and their designs are studied in the solar air heaters section. The literature have been discussed for performance of solar air heater. The purpose of this study is to check the performance of solar air heater under different shape roughened plates of the solar air heater. Thus, for this purpose, the three roughened shape plates were selected as Parallel fin assisted shape, Zig-zag fin assisted shape and combined Parallel and Zig-zag fin assisted shape (See Fig. 2). The assumptions had made for thermal analysis of solar air heater design. The model is developed in solid modelling software PRO-E (Cryo) version and analyze in Compressed Fluid Dynamics analysis which is the type of thermal analysis in ANSYS 15.0 analysis software. After the successful completion of thermal analysis of all the developed models, the results and comparison has made based on theoretical data and ANSYS data obtained. The conclusion has been made based on results obtained from thermal analysis of solar air heater and literature review.

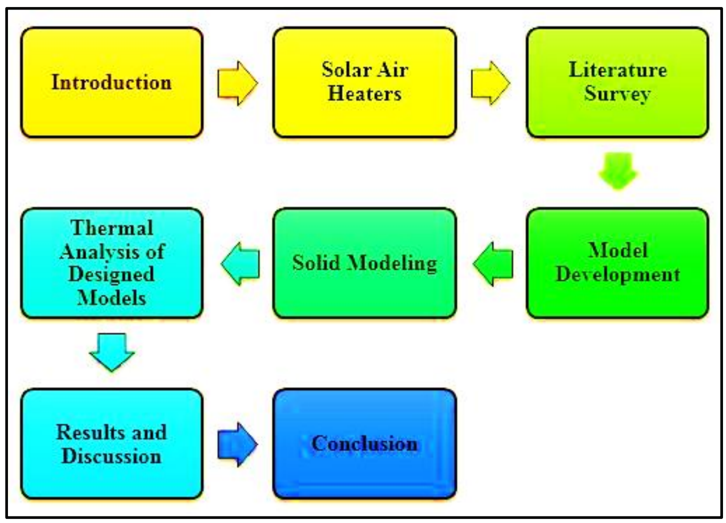

Fig.1 – Proposed Methodology

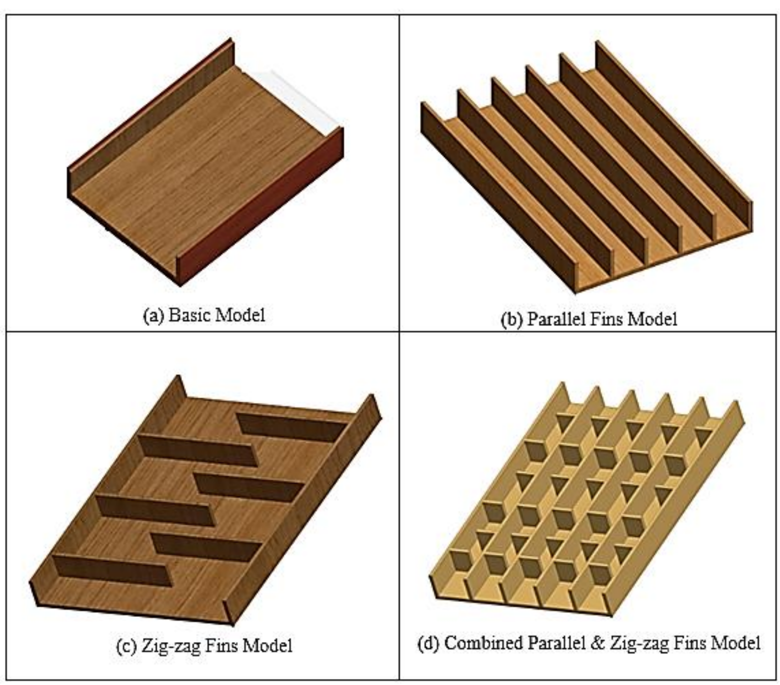

Fig. 2- Sample of Various Shape Roughened Plates

2. Transient Thermal Analysis

Heat transfer analysis has been performed in ANSYS Fluent 19.0 software. Initially, a geometry had modelled in geometry modeler (Pro-E). The dimensions taken for designing the SAH models are 610 mm width and 915 mm length having thickness as 12 mm. The material used for designing the SAH models are plywood for outbox and holding devices and cover plate has made of glass material having thickness 3 mm. A fluid domain has been added in geometry by considering volume enclosed by air. The inlets and outlets are specified and boundary conditions are specified. After that meshing has been done. The default mesh size is selected and mesh sizing is performed with face meshing to obtain accurate results. The size and properties are specified as given in Table 1. After doing all necessary conditions, the solution has started and results are shown by temperature counters and volume rendering. The steps required to obtain the results are summarized as below:

[1] Start ANSYS Fluent in Workbench.
[2] Import the Assembly from ProE Solid Model software.
[3] Create the solid domain and fluid domain.
[4] Name the inlet, outlet and wall as per the considerations.
[5] Go to setup
[6] Mesh the generated geometry. (Use default meshing and mesh sizing with face meshing)
[7] Define the materials and fluids. (Plywood for outer box, glass for cover plate and air as fluid domain)
[8] Specify the boundary conditions. (Air inlets and outlets, intensity of radiation on cover plate by inserting location coordinates of GPS)
[9] Solve the model with default setting parameters and up to 50 iterations.
[10] Observe the results by adding temperature counters at inlet and outlet.
[11] Observe the volume rendering along length of SAH for temperature variation.
[12] Perform above steps for all types of Solar Air Heaters.

The Table 2 shows the specifications of various shape roughened plate models and Table 3 represents the analysis settings carried for performing the ANSYS.

Table 1- Size and Properties for ANSYS Fluent

Sr. No.	Component/ Parts	Specifications
1	Outer Box	Width 610 mm, Length 915 mm, Thickness 12 mm, Rectangular Shape Made of Plywood Material with default ANSYS Properties.
2	Inner Absorbing Area	Width 586 mm, Length 915 mm, Thickness 12 mm, Rectangular Shape Made of Plywood Material with default ANSYS Properties.
3	Cover Plate	Width 586 mm, Length 915 mm, Thickness 6 mm, Rectangular Shape Made of Glass Material with default ANSYS Properties.

Table 2- Specifications of Shape Roughened Plate Models

Model No.	Model Name	Specifications
1	Basic Model	The Model having simple rectangular shape with no fins attached having inner box size of 586 mm width and 610 mm length. The wall thickness is 12 mm.
2	Parallel Fins Model	The model having four parallel fins are provided at a distance of 105 mm with each other and width 76.2 mm over a full length. The inner box size is same for this model as in case 1.
3	Zig-Zag Fins model	The model having six fins of size 350 mm length, 76.2 mm width and 12 mm thick are arranged in zig-zag model. The inner box size is also same as model 1.
4	Combined Parallel & Zig-Zag model	The model having fins parallel as well as zig-zag. The four parallel fins are placed equidistance from walls and the zig zag arrangement has been placed in that area. The large fin size is same as in case of model 2 and small fin size is same as in model 3.

Table 3- ANSYS Setting to Perform Analysis of SAH

ANSYS Parameters	Settings Required for ANSYS
ANSYS Type	Pressure Based, Transient and Gravity at Y-axis
Radiation Model	Rosseland Radiation Model with Solar Tracking by Location- Jalgaon 20.99790N, 75.56670E Date: 22/12/2020 Time-01:00 PM The Radiation Intensity = 996.18 W/m2
Materials	Fluid = Air with properties at NTP conditions Solid = Wood & Glass with properties at Room Temperature
Boundary Conditions	Inlet & Outlet Mass Flow Rate = 0.1 Kg/s. Inlet & Outlet Pressure of Air = 101.325 KPa Inlet Temperature of Air = 298 K Absorber Wall Radiation Constant = 0.85 Glass Wall Radiation Constant = 0.1 Wooden Box Wall Convective Heat Transfer Coefficient = 3 W/m2K.

3. Results and Discussion

The Fig.3 shows the comparison of average inlet temperatures of various solar air heater models. The average inlet temperature of model 1 (Basic Model) is observed to be 298.14 K. The average inlet temperature of model 2 (Parallel Fins Model) is observed to be 298.16 K. The average inlet temperature of model 3 (Zig-zag Fins Model) is observed to be 298.17 K. The average inlet temperature of model 4 (Combine Parallel and Zigzag Fin Model) is observed to be 298.21 K. So, as compared to model 1 the remaining models have high inlet temperature.The Fig.4 shows the comparison of average outlet temperatures of various solar air heater models. The average outlet temperature of model 1 (Basic Model) is observed to be 298.71 K. The average outlet temperature of model 2 (Parallel Fins Model) is observed to be 298.84 K. The average outlet temperature of model 3 (Zig-zag Fins Model) is observed to be 301.29 K. The average outlet temperature of model 4 (Combine Parallel and Zigzag Fin Model) is observed to be 301.01 K. So, as compared to model 4 the remaining models have low outlet temperature.The fig.5 shows the Net Temperature Difference (NTD) between outlet temperature and inlet temperature. The NTD for models observed are 0.57, 0.68, 3.12 and 2.80 for model 1, 2, 3 and 4 respectively. The maximum temperature difference (NTD) is observed to be 3.12 showing that the model 3 is most optimum model design out of the four models design. The model 4 has NTD of 2.8 which also reliable but the design of model is more complex as compare to model 3.

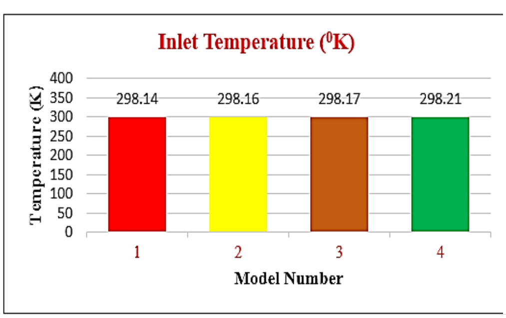

Fig. 3- Comparison of Inlet Temperature

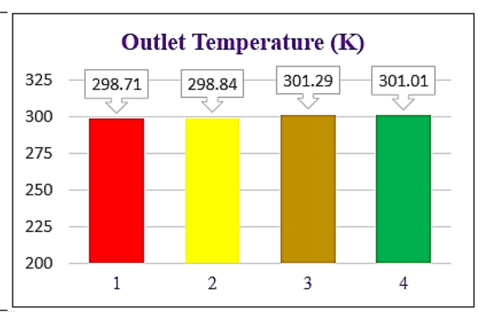

Fig. 4 -Comparison of Outlet Temperature

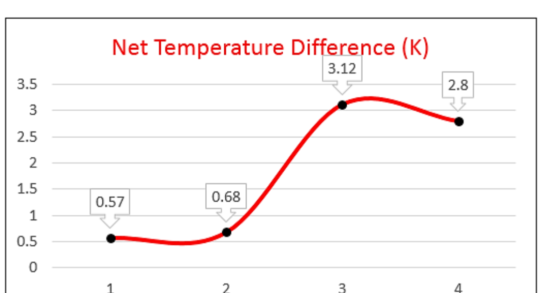

Fig.5- Comparison of Net Temperature Difference

4. Conclusion

The present study includes the thermal analysis of Solar Air Heater using different shape roughened plate. For that purpose four models are selected basic model, parallel fins model, zigzag fin models and combined fins model. The size of all solar air heaters is 610 mm in width and 915 mm in length made by plywood having thickness 12 mm. The ANSYS Fluent had been used to find the heating of air due to sun radiations. It can be concluded from the study that the solar air heater performance depends on various parameters including inlet and outlet temperatures, mass flow rates and properties of air. The variation in any of the parameter results in change of performance. It is concluded that the ANSYS Fluent method is well suitable for obtaining the performance of such solar air heaters. The ANSYS method gives the results but it is complex and time consuming. However, experimental work could be validated with ANSYS work. It is concluded that the model design changes the performance of solar air heater. The maximum net temperature difference obtained in model 3 having Zigzag Fins and is 3.12 which is increased by 10% compared with model 4. Thus, the study concluded that, the model 3 is optimum as compared to other models.

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