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CFD Analysis of Solar Air Heater

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ABSTRACT

An attempt has been made to carry out CFD based analysis using FLUENT to fluid flow and heat transfer characteristics of solar air heater. 3D model of the Solar Air heater involving air inlet, absorber plate, glass, modelled by ANSYS Workbench and the unstructured grid was created in ANSYS. The results were obtained by using ANSYS FLUENT software. This work is done by using computational fluid dynamics (CFD) tool with respect to flow and temperature distribution inside the solar air heater.

Keywords-Solar Energy, Solar Air Heater, Heat transfer, CFD.

I. INTRODUCTION

Solar energy is the most considerable energy source in the world. Sun, which is 1.495x1011 (m) far from the earth and has a diameter of 1.39x109 (m), would emit approximately 1353 (W/m2) on to a surface perpendicular to rays, if there was no atmospheric layer. The world receives 170 trillion (KW) solar energy and 30% of this energy is reflected back to the space, 47% is transformed to low temperature heat energy, 23% is used for evaporation/rainfall cycle in the Biosphere and less than 0.5% is used in the kinetic energy of the wind, waves and photosynthesis of plants.

Solar energy systems consist of many parts. The most important part of these systems is the solar air heaters where the heat transfer from sun to absorber and absorber to fluid occurs. In order to affect the performance of these systems, generally modifications on solar air heaters are performed. With the rapid development in civilization, man has increasingly become dependent on natural resources to satisfy his needs. Drying fruits and vegetables such as grapes, pepper, pawpaw, etc. is one of those indispensable processes that require natural resources in the form of fuels. Solar energy air heaters are special kind of heat exchangers that transform solar radiation energy to internal energy of the transport medium. The major component of any solar system is the solar air heater. Of all the solar thermal air heaters, the solar air heaters though produce lower temperatures, have the advantage of being simpler in design, having lower maintenance and lower cost. To obtain maximum amount of solar energy of minimum cost the solar air heaters with thermal storage have been developed. Solar air heater is type of solar air heater which is extensively used in many applications such as residential, industrial and agricultural fields.

Solar air heaters, because of their simplicity are cheap and most widely used collection devices of solar energy, has great potential for low temperature applications, particularly for drying of agricultural products. The thermal efficiency of a solar air heater is significantly low because of the low value of the convective heat transfer coefficient between the absorber plate and the air, leading to high absorber plate temperature and high heat losses to the surroundings. It has been found that the main thermal resistance to the heat transfer is due to the formation of a laminar sub-layer on the absorber plate heat-transferring surface.

A solar air heater absorbs incident solar radiations and transforms them into useful heat for heating the collector fluid such as water and air. Solar air heaters, being inherently simple and cheap, are most widely used collection devices. Solar air heaters find several applications in space heating, seasoning of timber and crop drying.

II. PROBLEM STATEMENT

The objective of present study is to perform CFD simulation for solar air heater. The results obtained by CFD simulation are been validated with experimental results. The experimental conditions taken for solar air heater, the same has been used for CFD simulation. The overall aim of this work is to understand the flow behaviour and temperature distribution of air inside the solar air heater and compare the outlet temperature of air with experimental results and also will see results with different parameters of solar air heater.

III. CFD ANALYSIS AND COMPARISON OF CFD AND EXPERIMENTAL RESULTS

The 3D model consisting of the solar air collector involving air inlet, wavy structured absorber plate, and glass cover plate is modeled by ANSYS Workbench and the unstructured grid was created in ANSYS ICEM. The results were obtained by using ANSYS FLUENT software

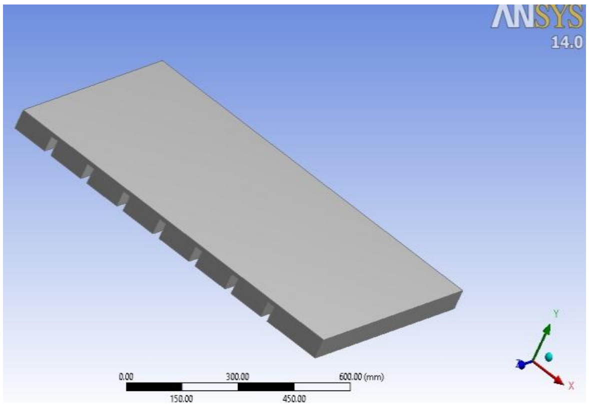


Fig.1: 3D modeling

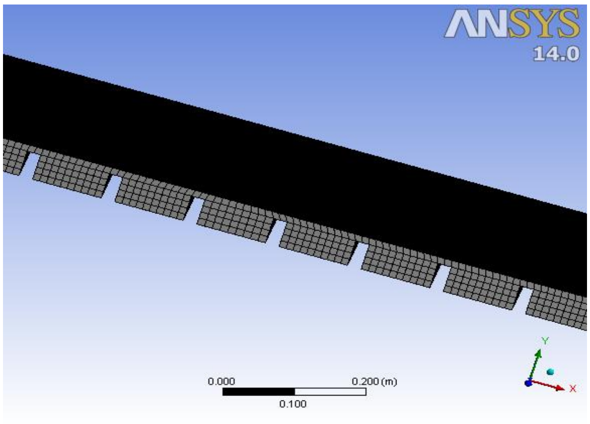


Fig. 2: 3D mesh

The overall dimension for solar air heater is 1000X1000X137 mm^3 with 3 mm thick glass plate. A sheet of copper with thickness 0.001 m and 1x1 m^2 area with longitudinal fins attached to its upper and lower surfaces was used as the absorber plate. The distance between two adjacent fins and fins height are 0.1 and 0.04 m, respectively. Two sheets of ordinary glass (0.003 m thick) were used to cover the heater in order to minimize the heat losses from the top of the air heater. The gap between the two glass covers equals 0.03 m. Another sheet of galvanized iron, with thickness 0.001 m, was used as a back plate. The heater was insulated from the back and sides using foam as an insulating material with thickness 0.04 m. The absorber plate divides the gap between the lower glass cover and the back plate into two channels of 0.05 m depth. [6]

Table-1: Properties of air

Property	Value
Mass flow rate of air	0.0203 kg/sec
Density	1.1925 kg/m3
Thermal Conductivity	0.0259 W/m K
Specific Heat	1006.2 J/kg K

Table-2: Properties of aluminium

Property	Value
Density	2719 kg/m3
Thermal Conductivity	202.4 W/m K
Specific Heat	871 J/kg K

Table-3: Properties of glass

Property	Value
Density	2500 kg/m3
Thermal Conductivity	744.3 W/m K
Specific Heat	670 J/kg K

The simulation is carried out for different times of the day 14 to 10 hrs. Then the results obtained by this simulation compared with the experimental results as shown in table 4. From table 4 and fig. 3 it can be seen that the difference between experimental and simulated outlet temperature is much similar.

Table-4: Comparison of experimental and simulated results

Sr. No	Time Hrs.	Solar Intensity (W/m^2)	Inlet Temperature (k)	Experiment results Temperature (k)	Simulation results Temperature (k)
1.	14	1000	304	330	347
2.	13	980	306	328	346
3.	12	950	303	330	348
4.	11	900	305	332	351
5.	10	800	304	325	343

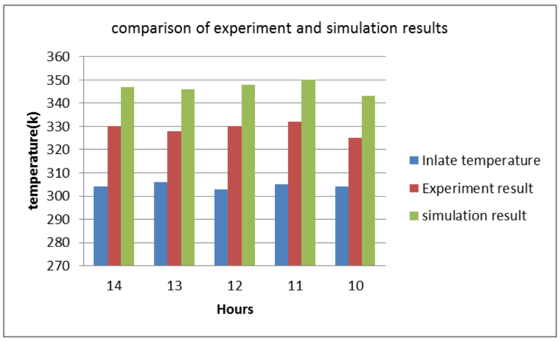


Fig.3:-comparison of experiment and simulation results

Also the temperature distribution and flow distribution are obtained by CFD simulation. The mesh file of geometry in fluent software shown in fig 4. The contours obtained for temperature distribution, velocity distribution and pressure distribution are shown in fig 5,6,7 respectively.

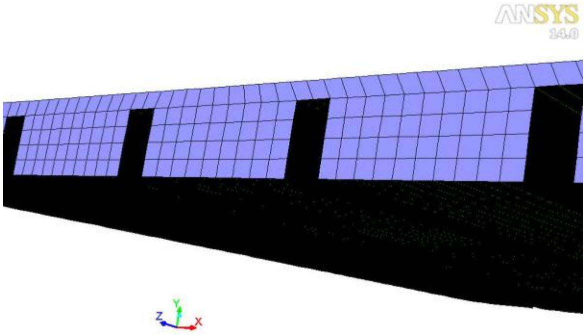


Fig .4: Meshing file in fluent software

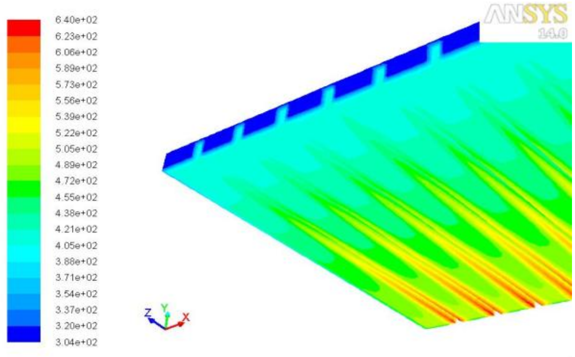


Fig .5: contours of temperature distribution

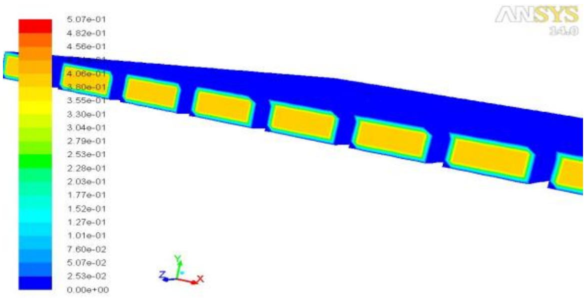


Fig .6: Contours of velocity magnitude(m/s)

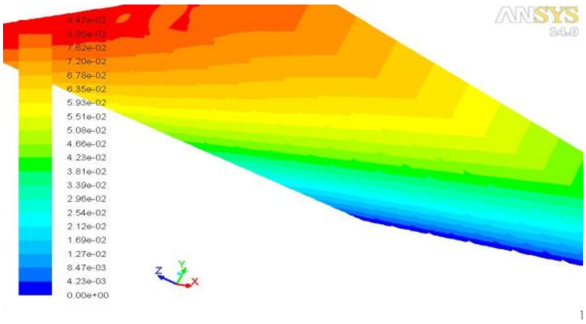
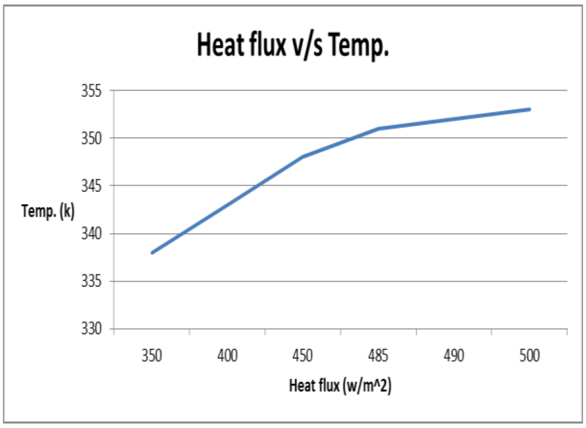


Fig .7:contours of static pressure(pascal)

Constant mass flow rate 0.0203kg/s and inlet temperature 305K is taken and the heat flux is varied By the CFD simulation results are obtained. Results of performance of solar air heater with different heat flux are seen in table- 5.

Table 5: Simulation Results

Sr. no.	Heat flux	Simulation results Outlet Temperature(k)
1.	500	353
2.	490	352
3.	485	351
4.	450	348
5.	400	343
6.	350	338



Graph 2:-Heat flux v/s temperature

Outlet temperature is decrease as heat flux is decrease. The behavior can be seen in fig.

IV. CONCLUSION

In this present investigation, a numerical prediction has been conducted to study heat transfer and flow friction behaviors of a solar air heater having fin on the absorber plate surface. The following conclusions have been drawn from the present work:

1. There is a good agreement results reference for outlet air temperatures. Although there are some small discrepancies due to some experimental imperfectness matters, we still have a good confidence in the CFD simulation program that can be used in the future for more solar air heater problem.
2. Effect of different heat flux value on solar air heater shown that increase the value of heat flux increase the thermal efficiency of solar air heater.
3. In recent years CFD has been applied in the design of solar air heater. The studies reported that the quality of the solutions obtained from CFD simulations are largely within the

acceptable range proving that CFD is an effective tool for predicting the behavior and performance of a solar air heater.

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