CFD Analysis Of Solar Air Heater With Different absorber Material And Extended Glass Fins

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Abstract- *Solar energy constitutes one of the main alternatives for facing the energy crisis of the future, taking this into account a lot of research is been carried out to improve the performance of the solar devices. In this paper, Computational Fluid Dynamics (CFD) analysis is carried to enhance the heat transfer rate of the solar air heater (SAH) with extended glass fins and different absorber material namely polyester, tedlar black and paladin black. The 3D model of SAH is modeled using SOLIDWORK CAD tool and simulations were carried out using ANSYS FLUENT.*

Standard k-ε turbulence model with standard wall function and Discrete ordinates (DO) solar load model were used and the simulation results have been validated with the results of experimental study. From the analysis its found that putting extended fins below the glass increases the heat transfer rate.

Keywords*-* Solar air heater, absorber, polyester, tedlar black, paladin black, ANSYS.

I. INTRODUCTION

For development of nation per capita energy consumption shall be higher. Increase in the demand of energy requirement the fuel prices are sharply raising and also degrading the environment by emission of green house gases. To avoid the consequences, one has to lean towards alternative energy sources. Among many renewable sources the solar energy is most prominent. This renewable energy is free from pollutions. The solar energy can be collected, stored and used for heating purposes and direct energy conversion. Solar air-heater is a device which absorbs solar radiation from sun and heats the fluid i.e. water or air.

A basic solar air heater consists of absorber plate which is black in nature enclosed in a box with glass cover at the top and insulation on the periphery. Solar insolation falling on the glass is transmitted to absorber plate where these radiations absorbed by black absorber plate, eventually increases the temperature of the plate, the fluid passing over the absorber plate absorbs the heat and temperature of the fluid increases[1]. The augmentation of heat transfer may be achieved by creating the turbulence in the fluid. The simulation of such augmentation can be studied by CFD tools available such as ANSYS FLUENT [2]

II. LITRATURE REVIEW

Varshney et al. [3] conducted an experiment on simple solar heater to study the effect wire mesh comb on heat transfer characteristics and found that there is an increase in heat transfer rate. Pakadman et.al [4] increased the thermal efficiency of SAH considerably by placing metal ribs on absorber plate at an angle of 60^0 to flow directions.

Yeh et.al [5] and Chii Dong Ho et.al [6] independently conducted by placing fins over the absorber plate and observed improvement in heat transfer rate.

Similar work is carried by Foued C et.al [7] and Irfan Kurtbas et.al[8] and observed improvement in thermal performance for solar air heater.

An alternative method to simulation and analysis of SAH is carried out by many researchers [9-16]. Ekramian et.al carried out CFD analysis by considering parameters such as absorber thickness, absorber material, mass flow rate, glass transmittivity etc. Its found that thermal efficiency will increase absorber thickness and glass transmittivity.

Manish Kumar et.al, Sukrut et.al, Kumar Mukesh et.al, Anuj Mathur et.al were carried CFD analysis placing a different fin like obstacle or turbulence generator to increase thermal efficiency of SAH.

In this paper an attempt to evaluate the thermal performance of SAH by embedding glass fins under the glass transmitter instead of placing on absorber plate directly further the analysis is carried out for different absorber material.

III. METHODOLOGY

Geometric modelling

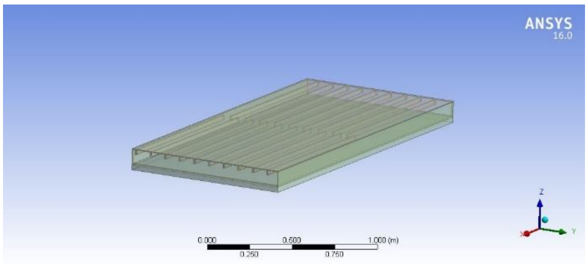

Fig. 1 3D model of the solar air heater

The computer aided design (CAD) geometry for all models is modelled in SOLID WORKS. dimensions for the current study were taken from the work done by Sanjeev et al [18].

Model consist transparent glass cover, insulation of wood at bottom and sides of SAH. Polyester black, paladin black and tedlar black are used as absorber material. The dimensions for SAH is 2 m x 1m and depth of air flow channel is 0.055 m and 19 rectangular glass fins are attached below the glass in staggered configuration as shown in Fig.1.Volume is generated using Ansys Fluent.

CFD model

Meshing is defined as the process of dividing the whole component into number of elements. The geometry of the model is meshed in ANSYS WORKBENCH mesh generator. Unstructured quadrilateral elements are used for meshing as in Fig. 2. The mesh is refined near the walls particularly for the reacting flow channel with fins. The mesh refinement near the wall helped in calculating the fluid flow and heat transfer properties accurately. Unstructured quadrilateral mesh is created with 60738 nodes and 171770 elements.

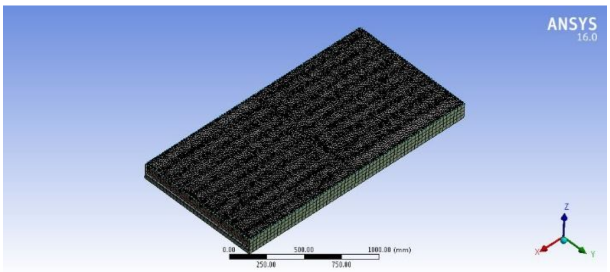

Fig.2Mesh generation with quadrilateral elements

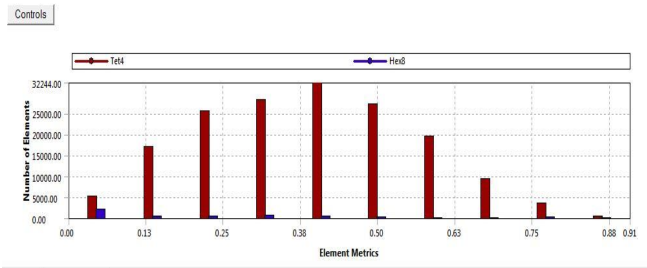

Fig 3 Skewness of the mesh

Fig. 3 represents theskewness factor of the mesh matrices for the proposed model. These represent quality of the mesh,these are determined from the range 0 to 1, where elements closer to 0 is a high-quality mesh and values closed to 1 is a bad quality mesh.

Analysis is carried out using steady state pressure-based solver in Ansys Fluent v16.0. To predict turbulence inside the model flow domain, standard k-ε turbulence model with standard wall function is used.

Energy equation is selected, since model includes heat transfer. Discrete ordinates (DO) is used for simulating radiation heat transfer and solar load is given it through solar calculator. Sunshine factor is considered as unity with fair weather conditions.

Appropriate boundary conditionsare used for the model as per flow problem. For the air inlet 'mass flow rate' boundary condition specified and which remains constant (0.01 kg/s). For outlet 'pressure outlet' condition is specified which is 0-gauge pressure. Glazing i.e. glass considered as semi-transparent. All other boundaries are considered as opaque and side walls considered as opaque adiabatic wall. Appropriate values of materials are taken as in Table 1.

Table 1. Fluid and material properties

Material	Density (kg m^{-3})	Specific heat ($Jkg^{-1} K^{-1}$)	Thermal conductivity (w $m^{-1} K^{1}$)
Air	1.225	1006.24	0.0242
Glass (gazing)	2400	1.6	0.16
Wood (Insulation)	700	2310	0.03
Polyester (Absorber)	1400	1300	0.3
Tedlar black (Absorber)	1720	1760	0.3
Paladin black(Absorber)	1410	1520	0.9

IV. RESULTS

Validation of the outlet air temperature is carried using Ansys Fluent for 1300,1400,1500,1600 and 1700 hours on 16th February 2017 are presented in the Fig.4 on the same Fig experimental data obtained Sanjeev et.al [18] were plotted to compare the results obtained from CFD results are well comparable with experimental data.

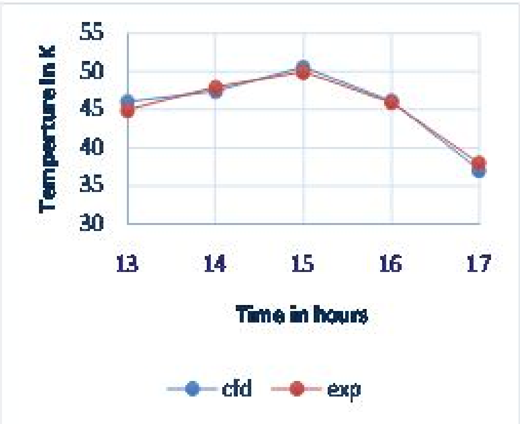

Fig. 4Comparison of CFD with experimental results

The analysis was carried out for different absorber material namely paladin black, polyester black and tedlar black from 1300 hrs to 1700 hrs. Obtained outlet temperature are tabulated in Table 2.

Table 2. Average outlet temperatureof fluid for different absorber material

Time in hours	Average temperature in(K)		
	Paladin black	Polyester	Tedlar black
1300	331.5	335.61	339.08
1400	342.8	346.63	349.93
1500	349.04	352.64	355.82
1600	349.19	352.77	360.18
1700	341.6	345.42	348.70

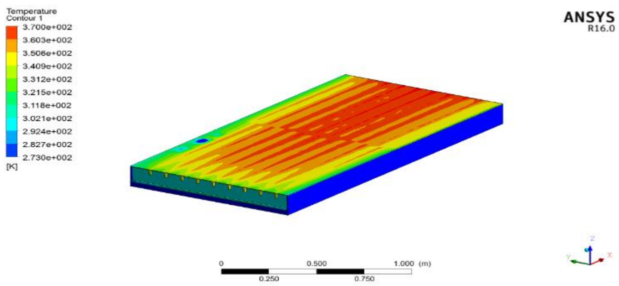

Fig.5 Temperature contour of solar air heater with paladin black absorber

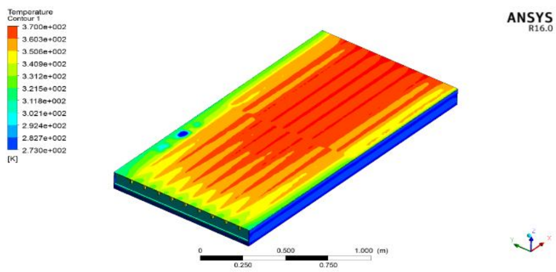

Fig. 6Temperature contour of solar air heater with polyester absorber

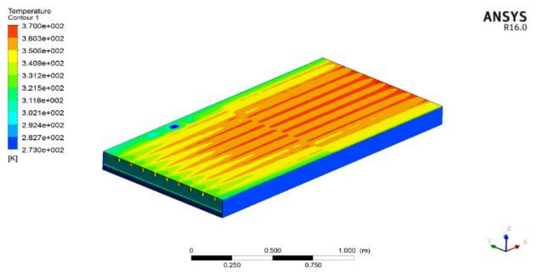

Fig. 7 Temperature contour of solar air heater with tedlar black absorber

Fig.5, 6 and 7 represents the temperature contour of the solar air heater (SAH) with paladin black, polyester black and tedlar black absorber material respectively at 1600 hrs. The inlet temperature is 300 K and it increases along the flow from inlet to outlet, the maximum temperature 349.19 K, 352.7 K and 360.18 K. Left and right side of SAH is provided with perfect insulation of wood and temperature of 273 K is maintained since boundary temperature is low, it's evident that temperatures of fluid will be maximum at center and decreases to the left and right as shown.

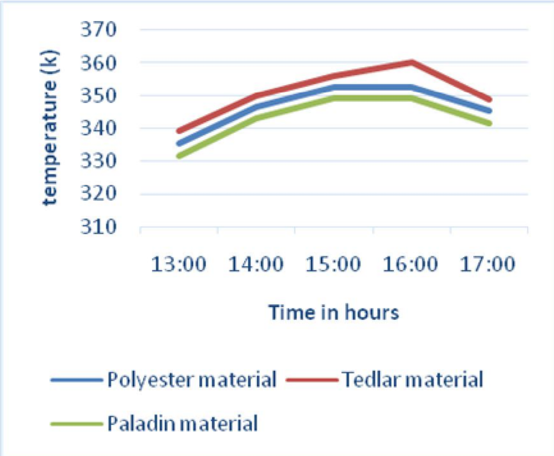

Fig. 8 Outlet temperature of fluid for different absorber material Vstime in hours

Fig.8 represents the outlet temperature of fluid for different absorber material from 1300 hrs to 1500 hrs. It can be observed from the figure that the temperature is higher for the tedlar black absorber material followed by polyester black and paladin black absorber. The maximum temperature obtained using tedlar material is 360.17 K at 1600 hrs. The maximum temperature for polyester and paladin black material are 352.778 K and 349.12 K respectively. The performance of the tedlar absorber material is better due to higher emissivity of 0.90 compare to that 0.80 and 0.75 of polyester black and paladin black absorber respectively.

Rate of heat transfer and pressure drop:

Maximum heat transfer rate is calculated for maximum temperature raise for air at different absorber material and pressure drop from respective graphs. The calculated heat transfer rate and pressure drop are tabulated in Table 3.Pressure drop with fin drastically increase compared to that of without fin.

Referring to the Table 3. the pressure drops with the fin of the order 0.9062 bar compared to that of without fin 0.3015 bar. Due to turbulence rate of heat transfer increases.

Table 3 Heat transfer rate and pressure drop for differentabsorber material..

S.No.	Absorber material	$(dT)_{max}$ (K)	Max (kW)	Pressure drops (bar)
1	Polyester without fin	14.59	0.146	0.3015
2	Polyester Withfin	52.77	0.530	0.9062
3	Tedlar blackck v fin	60.18	0.604	0.9061
4	Paladin black with fin	49.19	0.494	0.9062

V. CONCLUSION

In this project CFD analysis of heat transfer rate of solar air heater with and without extended glass fins is carried out. Solar air heater is designed using SOLID WORKS CAD software and the simulation is carried out using ANSYS FLUENT. The thermal performance of SAH without fin having polyester absorber material is taken as baseline data. Raise in temperature and rate of heat transfer for different absorber material namely polyester, paladin black and tedlar black with fin were evaluated and compared with baseline data. Conclusion drawn from the work are as follows.

- By installing fins under glass increases the temperature raise and eventually rate of heat transfer. Due to increase in turbulence. By installing fins rate of heat transfer in this case increases by 263%.
- Performance of SAH with paladin absorber plate is lower than that of polyester absorber material, since having lower emissivity (0.75).
- The tedlar black have higher emissivity that is 0.90 compared with that of polyester material 0.8. There is increase heat transfer rate by 313.7%.
- Pressure drop with fin drastically increase compared to that of without fin.

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