A Review of Solar Air Heaters using wire Mesh Absorber

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Abstract- Solar air heater is one of the valuable heat sources with variety of applications such as space heating and cooling, industrial process heating and drying of fruits and vegetables etc. The major heat losses from a normal solar air collector are through the top cover which reduce the thermal efficiency also, the low heat transfer coefficient between the air stream and the absorber plate is another reason of low thermal efficiency in solar air heaters. Thermal efficiency of double pass solar air heater with porous media is higher than single pass and double pass solar air heater without porous media. Many experiments have been carried out on the performance analysis of double pass solar air heater with porous media and solar air heater with extended surfaces. Effect of various parameters of porous media like pitch, number of layers , bed depth, porosity, thermal conductivity, pitch to wire diameter ratio have been studied. Also these studies includes the design of double pass solar air heater, heat transfer enhancement, pressure drop, type of flow. It is found that more increase in thermal efficiency in comparison with conventional solar air heater. Based on literature review, it is concluded that most of the studies carried out on solar air heater with porous media and extended surfaces. Few studies are carried out on corrugated absorber plate. Improvement of thermal efficiency of solar air heater is to be obtained by enhancing the rate of heat transfer.

Keywords: solar air heater, porous media, absorber plate;

Nomenclature

I	Intensity of solar radiation, W/m^2
α_c	Absorptivity of glass cover
h	W/m^2K
T_c	Glass cover temperature,℃
T_a	Atmospheric temperature, ℃
a	Area,
T_{f1}	fluid temperature in the top channel
$h_{r,cp}$	Radiative heat transfer coefficients between the glass cover and the absorber plate, W/m^2K
T_p	Absorber plate temperature, ℃
$h_{r,ac}$	Radiative heat transfer coefficients between the glass cover and ambient, W/m^2K
h_{f1c}	Heat transfer coefficient between the glass cover and working fluid, W/m^2K
б	Stephen Boltzmann constant
ε_c	Emissivity of glass cover
ε_p	Emissivity of absorber plate
ṁ	Mass flow rate, Kg/s
c_p	Specific heat of air, J/kg K
h_{f1p}	Heat transfer coefficient between the absorber plate and working fluid., W/m^2K
h_{f2p}	Heat transfer coefficient between the absorber plate and working fluid in lower channel, W/m^2K
$h_{r,pb}$	Radiative heat transfer coefficients between the absorber plate and bottom plate, W/m^2K
k_p	Thermal conductivity of the porous media, W/mK
h_{f2b}	Heat transfer coefficient between the bottom plate and working fluid, W/m^2K
U_a	overall heat transfer coefficient, W/m^2K
Nu	Nusselt number
V	Velocity, m/s
De	Equivalent diameter of duct, m
τ_c	Transmitivity

I. INTRODUCTION

Energy is available in many forms and plays an important role in worldwide economic growth and industrialization. The growth of world population and rising industrialization need large amount of energy. Environment degradation with use of fossil fuels is a danger to life in this earth. In view of world's depleting fossil fuel reserves and environmental threats, development of renewable energy sources is important. Among many renewable energy sources, solar energy is huge energy source for meeting the demand. The freely available solar radiation provides an infinite and non-polluting reservoir of fuel. The easiest way to utilize solar energy for heating applications is to convert it into thermal energy by using solar collectors.

Flat-plate solar collectors are extensively used in low temperature energy technology and have attracted the attention of a large number of investigators. Several designs of solar air heaters have been developed over the years in order to improve their performance. Basically, there are two types of flat-plate solar heating collectors; water heating collectors and air heating collectors. The pace of development of air heating collector is slow compared to water heating collector mainly due to lower thermal efficiency. Conventional solar air collectors have poor thermal efficiency due to high heat losses and low convective heat transfer coefficient between the absorber plate and flowing air stream. Attempts have been made to improve the thermal performance of conventional solar air collectors by employing various design and flow arrangements.

Use of porous packing material in the duct of double flow solar air heater is one of the preferred methods to improve the thermal performance. The double-duct flow mode of solar air heater has the advantage of decreasing the heat losses and provides improvement in thermal efficiency with marginally increasing the heater size or cost. A number of analytical and experimental studies have been carried out with packed bed, fins integrated double pass solar air heater which shows significant increase of the performance compared to the conventional system. Few studies have been reported with corrugated absorber surface.

II. MATHEMATICAL MODELING:

The basic physical equations used to describe the heat transfer characteristics are developed from the conservation equations of energy.

Following are the assumptions:

– Flow of air is steady.

– Outside convective heat transfer coefficient is constant along the length of solar air heater.

– Inside convective heat transfer coefficient is constant along the length of solar air heater.

– Thermal conductivity of the porous media is constant along the length of solar air heater.

A. Double pass solar air heater without porous media

For top glass cover

$$I\alpha_c = ha(T_c - T_a) + h_{f1c}(T_c - T_{f1}) + h_{r,cp}(T_c - T_p) + h_{r,ac}(T_c - T_a) \quad (1)$$

Where,

$$h_{r,cp} = \frac{\sigma(T_c^2 + T_p^2)(T_c + T_p)}{\frac{1}{\varepsilon_c} + \frac{1}{\varepsilon_p} - 1} \quad (2)$$

$$h_{r,ac} = \frac{\sigma(T_c^2 + T_a^2)(T_c + T_a)}{\frac{1}{\varepsilon_c} - 1} \quad (3)$$

For first air-pass air stream

$$\dot{m}c_p \frac{dT_{f1}}{d_x} = (T_c - T_{f1}) + h_{f1p}(T_p - T_{f1}) \quad (4)$$

For absorber plate

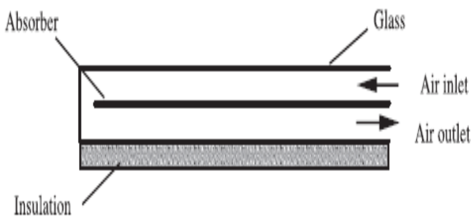

Fig. 1.Double pass solar air heater without porous media. [2]

$$I\alpha_p \tau_c = h_{f1p}(T_p - T_{f1}) + h_{f2p}(T_p - T_{f2}) + h_{r,cp}(T_p - T_c) + h_{r,pb}(T_p - T_b) \quad (5)$$

For second pass air stream without porous media.

$$\dot{m}c_p \frac{dT_{f2}}{d_x} = h_{f2p}(T_p - T_{f2}) + h_{f2b}(T_b - T_{f2}) \quad (6)$$

B. Double pass solar air heater with porous media

For second pass air stream with porous media.

$$I\alpha_c = ha(T_c - T_a) + h_{f1c}(T_c - T_{f1}) + h_{r,cp}(T_c - T_p) + h_{r,ac}(T_c - T_a) \quad (1)$$

Where,

$$h_{r,cp} = \frac{\sigma(T_c^2 + T_p^2)(T_c + T_p)}{\frac{1}{\varepsilon_c} + \frac{1}{\varepsilon_p} - 1} \quad (2)$$

$$h_{r,ac} = \frac{\sigma(T_c^2 + T_a^2)(T_c + T_a)}{\frac{1}{\varepsilon_c} - 1} \quad (3)$$

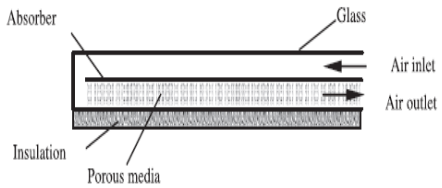

Fig. 2.Double pass solar air heater with porous media. [2]

$$\dot{m}c_p \frac{dT_{f2}}{d_x} = k_p \frac{d^2T_{f2}}{dx^2} + h_{f2p}(T_p - T_{f2}) + h_{f2b}(T_b - T_{f2}) \quad (7)$$

For absorber plate.

$$0 = h_{f2b}(T_b - T_{f2}) + h_{r,pb}(T_b - T_p) + U_a(T_b - T_a) \quad (8)$$

The heat transfer characteristics of solar air heaters for the model are described by Eqs. (1)– (8).The solar air heater can be divided into numerous sections as shown in fig. 3. The calculation is performed section by section along the solar air heater length.

The heat transfer coefficient is given by equation

$$h_a = 5.7 + 3.8V \quad (9)$$

$$De = \frac{4WH}{2W + 2H} \quad (10)$$

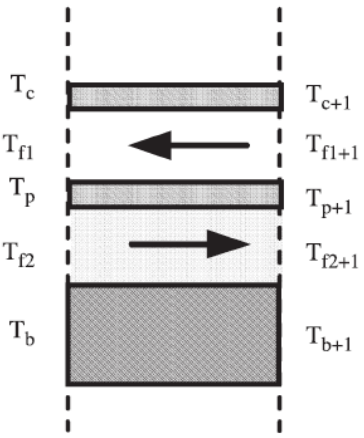

Fig. 3. Schematic diagram of simulation aproch [2]

III. DOUBLE PASS SOLAR AIR HEATER USING POROUS MEDIA

Double pass solar air with porous media has been used for enhancement of thermal efficiency. There are two problems associated with the thermal performance of solar air heater. One is the heat transfer from the metallicplate to the flowing air is very less as low thermal conductivity of air. The second associated with the low heat transfer due to small thickness of absorber plate. This is increased by using a porous bed absorber. As the voids exits in the porous bed, solar radiation impinges to a greater depth and thus relatively absorbs there. The packing provides an increase in the turbulence which results a high rate of heat transfer. The packing material also acts as a heat storing media. Mohamad[1] numerically studied the performance of a double-pass solar air heater with and without porous matrix and compared with the performance of single and double glazing conventional solar air heaters. For a given flow rate, increasing the spacing between the absorber and the glass cover reduces the average flow velocity and decreases the heat transfer coefficient. Hence, the distance between the absorber plate and the glass cover has a significant effect on the performance of the collector. The thermal efficiency of a counter flow air heater without a porous matrix is between 10 and 18% higher than that for a double glazing conventional air heater. Naphon [2] studied theoretically the performance of counter flow solar air heater without and with porous media in the lower channel. The effect of the thermal conductivity of the porous media on the heat transfer characteristics and performance is considered. The solar air heater with the porous media gives 25.9% higher thermal efficiency than the without porous media.

Sopian et al. [3] evaluated the thermal performance of the counter flow collector with porous and nonporous media theoretically and validated experimentally .The porous media has been arranged in different porosities varying no of layers, pitch, diameter of wire to increase heat transfer, area density and the total heat transfer rate. The effect of changes in upper and lower channel depth on the thermal efficiency with and without porous media has been studied. Moreover, the effects of mass flow rate, solar radiation, and temperature rises on the thermal efficiency of the double-pass solar collector have been studied. Typical thermal efficiency of the double pass solar collector with porous media is about 60–70%.

The similar study is conducted by Ramani et al. [5] on the design of counter flow packed bed solar air heater as proposed in previous study[1,4]. It is noted that the thermal efficiency of packed collector increases as porosity decreases. This is due to the fact of decrease in porosity increases the effective heat transfer area per unit volume of packed duct. A mathematical model has been developed based on volumetric heat transfer coefficient. The major reason of interest in porous material includes high effective heat transfer area per unit volume resulting in high heat transfer capability. Also solar radiations are absorbed gradually by layers of porous matrix. Comparison of results reveals that the thermal efficiency of double pass solar air collector with porous absorbing material is 20–25% and 30–35% higher than that of double pass solar air collector without porous absorbing material and single pass collector respectively. Mittal et al. [6] has been carried out thermo hydraulic investigations on a packed bed solar air heater having its duct packed with blackened wire screen matrices of different geometrical parameters (wire diameter and pitch). It has been observed that merely the porosity of the bed does not govern the performance. The performance of a packed bed air heater is also a strong function of the geometrical parameters of the matrix.

Thakur et al. [8] has been investigated low porosity packed bed solar air heater .This investigation covers a wide range of geometrical parameters of wire screen matrix, i.e. wire diameter 0.795 to 1.40 mm, pitch 2.50 to 3.19 mm and number of layers from 5 to 12. The packed bed solar air heater absorbs the solar radiation 'in depth' and has a higher ratio of heat transfer area to volume and a high heat transfer coefficient. The maximum deviations between the experimental results and those predicted by the correlations for the jhfactor and the friction factor were 10.5 and 7%, respectively.

Lalji et al. [9] found that performance of flat plate collector improves appreciably by packing its duct with blackened wire screen matrices and this improvement is a strong function of bed and operating parameters. The heat transfer enhancement is a function of Porosity and operating parameters. The Reynolds number has been found to be a strong parameters affecting heat transfer and friction factor for packed bed solar heater. The maximal outlet temperature reached was 73°C for the collector without porous media at 70 l/h flow rate and 60 °C for the collector backed with porous medium at 50 l/h flow rate.

Elardi et al. [10] has been developed Correlations of transient heat transfer and pressure drop for air flowing through the porous media, which packed a double-pass solar air heater. Porous media are arranged in different porosities to increase heat transfer, area density and the total heat transfer rate. Transient heat transfer experiments indicate that both the heat transfer coefficient and the friction factor are strong functions of porosity. The experimental values of thermal efficiency differed from theoretical ones by 6 to 15%.Dhiman et al. [11] has been studied the counter and parallel flow packed bed solar air heaters theoretically and experimentally. The effect of air mass flow rates and bed porosity on the thermal and thermohydraulic efficiencies of the counter and parallel flow packed bed solar air heaters are investigated. The results showed that the thermal efficiency of the counter flow packed bed solar air heater is 11-17%

more compared to the parallel flow packed bed solar air heater whereas, parallel flow system achieved a 10% higher thermohydraulic efficiency. Alejandro et al. [12] has been developed two analytical models that describe the thermal behavior of solar air heaters of double-parallel flow and double-pass counter flow.

Tiwari et al. [18] studied a porous packed bed solar air heater using iron chips as packing material.It is found that the collector efficiency increases with a decrease in the porosity of the bed. A maximum efficiency of 70.3% has been found with a bed having a porosity of 0.652 for a maximum mass flow rate of 0.0364 kg/s-m2. Karmare and Tikekar[19] performed an experimental and CFD investigation on metal grit ribs and showed that the effective efficiency is maximum for particular Reynolds number in given operating condition. The kε model is selected as turbulent model for further analysis in FLUENT. Amongst the different shape and orientations analyzed, the absorber plate of square cross-section rib with 58^0anangle of attack gave the best possible results. Kumar and Saini [20] worked on performance analysis of solar air heater using CFD as a tool. A solar air heater having artificial roughness in the form of thin circular wire in arc shaped geometry was observed and the results obtained by the Renormalization-group (RNG) kε model were in good agreement with Dittus-bolter empirical results.

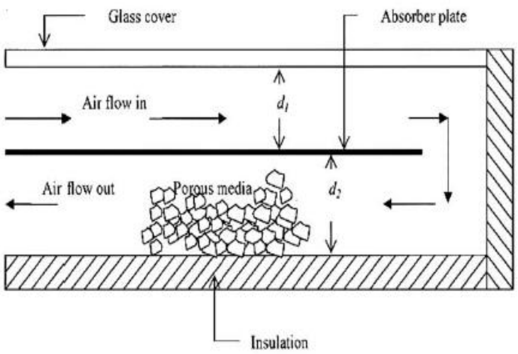

Fig. 2.Schematic diagram of solar air heater using porous media. [3]

The above review shows that there is substantial rise in the heat transfer coefficient with a decrease in porosity. Hence lower porosity system would be a better choice when one is looking for the enhancement of the thermal performance of solar air heater using porous media. Therefore it was decided to investigate the effect of porosity on heat transfer and friction factor for lower range of porosity. This paper presents the details of an experimental investigation and CFD analysis of the heat and fluid characteristics of solar air heater having different porosity ranging from 0.72 to 0.86. Tests were conducted in actual outdoor conditions for both with and without porous media to compare their thermal performance with CFD analysis.

IV. DOUBLE PASS SOLAR AIR WITH FINS ATTACHED

Double pass solar air heater using porous media with transverse fins and longitudinal fins has been studied. Aldabbagh et al. [4] has been studied the performance of single and double-pass solar air heater with fins and steel wire mesh as absorber is investigated experimentally. The effects of mass flow rate of air on the outlet temperature and thermal efficiency were studied. The thermal efficiency in both collectors was improved with increasing air mass flow. Moreover, the maximum efficiencies obtained for the single and the double pass air collectors are 45.93 and 83.65% respectively for the mass flow rate of 0.038 kg/s.

Omojaro et al. [7] investigated the thermal performance of single and double pass solar air heaters with fins attached (Figure 3). The lower channel of the double pass solar air heater filled with porous media acted as the absorber plate. The porous media was created by seven black painted steel wire mesh layers, each placed at 1 cm distance from the bottom to the top. The frame of the collector was made from 2 mm thick black painted plywood with dimensions of 1500 x 1000 mm. Double glass was used to cover the collector. The distance between the lower and upper glass was 30 mm. The distance between the lower glass and the bottom of the collector was 70 mm. By removing the upper glass cover, the system tested as a single pass solar air heater. Black painted metallic fins were used to increase the heat transfer area and were installed longitudinally along the lower and upper channels. The fins were 1500 mm in length for both channels with heights of 70 and 30 mm for lower and upper channels, respectively. In this arrangement, both channels were divided into five equal sections for air passage. The mass flow rate varied between 0.012 and 0.038 kg/s. It was concluded that the flow rate of air affects the efficiency significantly. The efficiency of the system was enhanced with the increased flow rate of air. For the same flow rate, the efficiency of the double pass was found to be higher than the single pass. When the flow rate was 0.038kg/s, the efficiency of a single and double pass solar air heater was 59.62 and 63.74%, respectively. As a result, fin consolidated single or double pass air heater using steel wire mesh layers as absorber was found to be much more efficient when compared with conventional type heaters. It was found that a double pass solar air heater was about 7-19.4% more efficient than single pass solar air heater depending on the air mass flow rate. Furthermore, for a double pass solar air heater, increasing the height of the first pass decreased the thermal efficiency of the system.

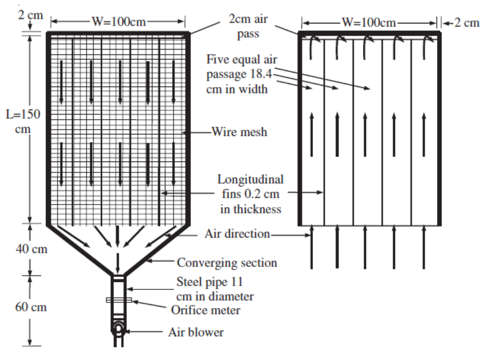

Figure 3.Schematic diagram of SAH with longitudinal fins [7]

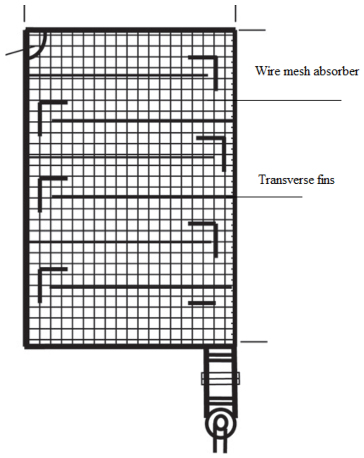

Fig. 4.Schematic diagram of SAH with transverse fins [4]

Chamoli et al.[14] has been studied the solar air heater with extended surfaces, packed bed, corrugated absorber and found more increase in the thermal efficiency in comparison to conventional double duct solar air heater. These studies includes the design of double pass solar air heater, heat transfer enhancement, flow phenomenon and pressure drop in duct. The thermal efficiency of single glazing conventional air heater is between 18 and 25% lower than the counter flow air heater without porous matrix .El-khawajah et al. [15] has been investigated the thermal performance of a double pass solar air heater with 2, 4, and 6 fins attached. Wire mesh layers were used between the fins instead of an absorber plate. The indicated results show that the efficiency increases with increasing the mass flow rate for the range of the flow rate used in this work between 0.0121–0.042 kg/s. Moreover, the maximum efficiency was obtained by using 6 fins at the same mass flow rate. The maximum efficiency obtained for the 2, 4, 6 fins of SAH were 75.0%, 82.1% and 85.9% respectively for the mass flow rate of 0.042 kg/s.

V. SOLAR AIR HEATER WITH RECYCLING

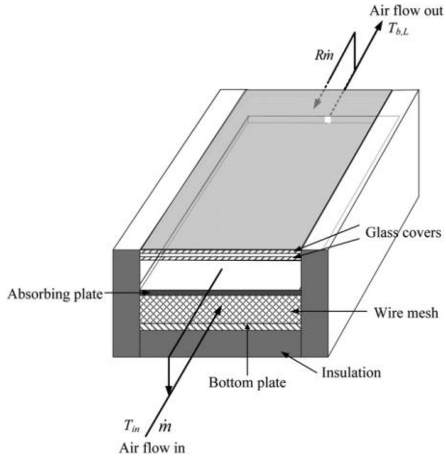

Fig. 5. Schematic diagram of solar air heater with wire mesh absorber. [16]

Ho et al. [16] theoretically and experimentally investigated the performance of a double pass recycled solar air heater. The velocity of air was increased to enhance the efficiency of the solar air heater. They aimed to investigate the effect of recycling on collector efficiency based on the recycle ratio and to perform mathematical formulation of the recycled double pass solar air heater. In addition, the effect of the height of absorbing plates in the channel was investigated. An experimental set-up with two glass covers was used (Figure 5). It was of 300 x 300 x 50 mm in dimension. The blackened absorbing plate was inserted at the center of the collector, resulting in equal heights (50 mm) for each channel. It was found that the added recycle unit improved the efficiency of the double pass solar air heater. The performance of the double pass solar collector was enhanced as a result of the increased air velocity and the heat transfer coefficient by the recycling operation or by decreasing the equivalent diameter of the channel. The external recycling enhanced the efficiency of the collector by approximately 28-95% compared with the arrangements of sub-collectors connected in series. Although the recycle operation enhanced the convective heat transfer it reduced log mean temperature difference between the absorbing plate and the air stream.

VI. SOLAR AIR HEATER WITH PERFORATED GLASS COVER

Nowzari et al.[13] has been studied, the thermal performance of the single and double pass solar air heaters with normal glazing and with quarter perforated cover. The efficiency of the air heater with 10D perforated cover is slightly higher than the one with 20D perforated cover for both single and counter flow collectors. In this study, the thermal performance of the single and double pass solar air heaters with normal glazing and with quarter perforated cover was investigated experimentally. The solar air collector was tested with two different perforated covers in which the holes made on one cover had the center-to-center distance of 20D (6 cm) and on the other cover it was 10D (3 cm), where D (0.3 cm) was the hole diameter.

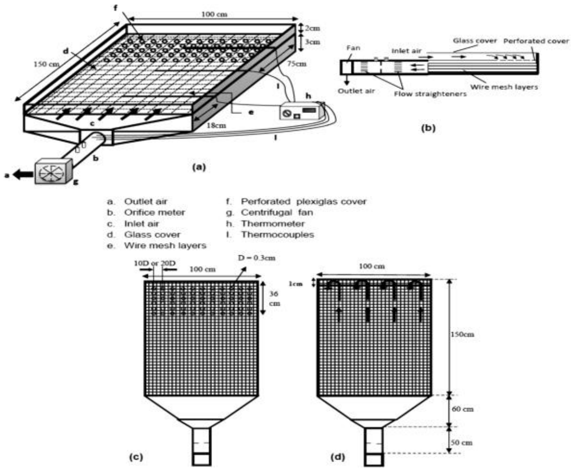

Fig. 6.Schematic diagram of SAH with perforated cover.

The efficiency of the double pass was always greater than the single pass air heater by 5-22.7%. The average efficiency of single and double pass solar air heaters with 10D perforated cover were 46.40% and 54.76%, respectively, at mass flow rate of 0.032 kg/s while at the same mass flow rate, the average efficiency of single and double pass air heaters with normal glazing were 49.36% and 51.70%, respectively.

VII. PARALLEL AND COUNTER FLOW SOLAR AIR HEATER

The counter and parallel flow packed bed solar air heaters are investigated theoretically and experimentally. Analytical model for these air heaters is presented.

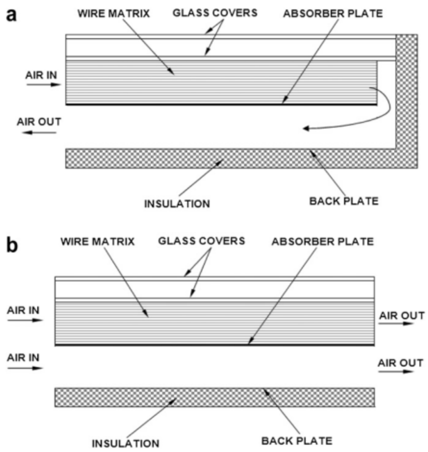

Fig. 7.Schematic diagram of solar air heater a) Counter flow b) Parallel flow. [11]

The effect of air mass flow rates and bed porosity on the thermal and thermohydraulic efficiencies of the counter and parallel flow packed bed solar air heaters are investigated. The theoretical predictions indicated that the agreement with the measured performance is fairly good. Dhiman et al. [11] has been studied the counter and parallel flow packed bed solar air heaters theoretically and experimentally. The effect of air mass flow rates and bed porosity on the thermal and thermohydraulic efficiencies of the counter and parallel flow packed bed solar air heaters are investigated. The mathematical model for double duct packed bed solar air heater is presented which can be applied to predict the thermal performance of CFPBSAH and PFPBSAH. The values of thermal efficiency predicted by analytical approach are compared with the experimental values. The average absolute deviations between these values are found to be 9.6% and 10.2% for CFPBSAH and PFPBSAH respectively. CFPBSAH is found to be more efficient compared to PFPBSAH in terms of thermal efficiency. Thermohydraulic efficiency of the CFPBSAH is higher than PFPBSAH up to the total mass flow rate of 0.03 kg/s. Increasing mass flow rate beyond 0.03 kg/s, the thermohydraulic efficiency of CFPBSAH decreases whereas it continues to increase in case of PFPBSAH until the total mass flow rate of 0.06 kg/s. PFPBSAH achieved a 10% higher thermohydraulic efficiency when air steadily flowed at differential mass rates in its upper and lower ducts compared to the CFPBSAH Therefore, parallelflow packed bed solar air heater is one of the important andattractive design to improve the thermohydraulic performance. CFPBSAH should be operated at lower total mass flux and higher porosity for higher thermo hydraulic efficiency whereas PFPBSAH can be operated at higher total mass flux and lower porosity.

VIII. DUAL PURPOSE SOLAR AIR HEATER

Venu et al. [17] has been studied dual purpose solar collector. Dual purpose solar collectors can be used for heating air and water simultaneously using incident solar radiation resulting in optimum usage of energy and space. A simulation study is undertaken to investigate the integration of a porous matrix to dual purpose collectors. The porous matrix is incorporated below the absorber plate of the collector to improve the thermal performance of the overall system. The total thermal efficiency of the modified collector is found to vary from 34.60% to 46.03% over inlet water temperature range of 30°C to 90°C. Comparison of the proposed dual purpose solar collector with an existing design clearly indicates the advantage of incorporating the porous medium in terms of enhanced heat delivery and thermal efficiency.

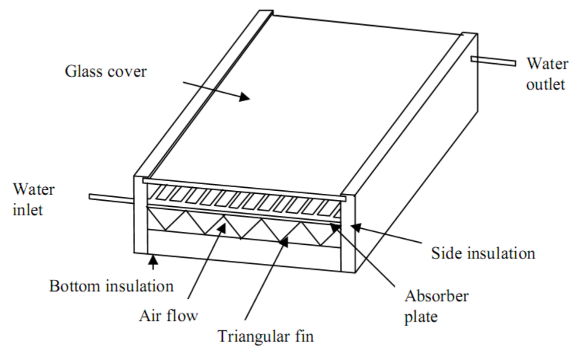

Fig.8. Schematic of dual solar air heater. [17]

IX. CASE STUDY

A. CFD analysis of smooth plate SAH with and without porous media

Modeling of 3D model of smooth plate is done in workbench 14.0. Further this model is converted into step format before importing it into ICEM CFD. For this purpose ICEM was used as preprocessor. There was a need to place very fine mesh of the plate. Quality of the mesh was checked and it was found in acceptable limit.

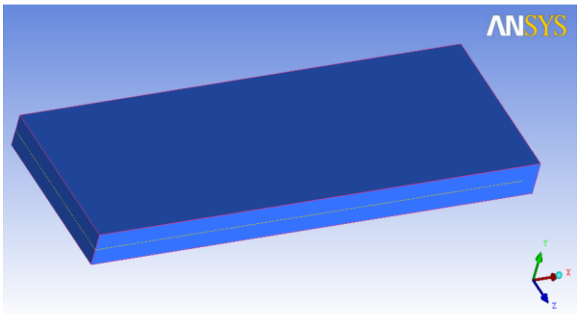

Figure 9. 3D model of duct

The boundaries and continuum as inlet, outlet, heated wall, insulated wall and the fluid zones were defined as per the experimental conditions. The whole geometry as shown in Figure 10 .was exported so that it accessible in Fluent. It is basically called a postprocessor for analyzing the CFD problems.

As the flow was turbulent, k–e model was selected as turbulent model for further analysis of the problem. Energy equation is also kept ON as a heat transfer model. Air was selected as working fluid with it's standard properties. The different boundary conditions for the geometries were selected as: air inlet velocity = .5 m/s, Outlet pressure as zero gauge pressure. Porosity 0.7 was given for porous zone in cell zone conditions. As the absorber plate was being heated from one side, the boundary condition for the wall was having uniform temperature of 322 K. All the other walls were considered to be completely insulated with zero heat flux. No slip condition is applied to all the 'walls'.

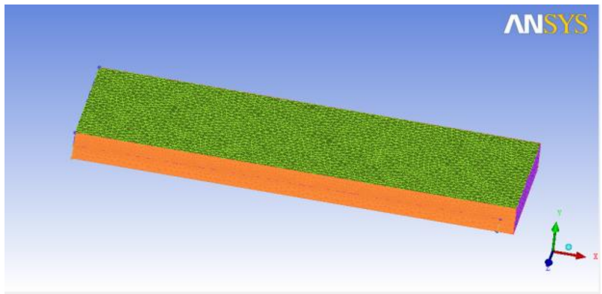

Figure10. Meshing of duct

B. Computational analysis

Table1. Computational analysis

Pre-processor	ICEM-CFD
Solver	Fluent
Post-processor	CFD-Post
Domain	3D
Solver	Pressure-Based
Time	Steady
Model	Energy and RNG k–ε model
Solution method	SIMPLE
Fluid	Air
Near wall treatment	Standard wall function
Density	Ideal gas
Plate material	Aluminium

According to the models selected earlier the equations which were considered for the solution are continuity equation or energy equation or momentum equation or equation for turbulence. The above equations have been solved under-relaxation factors.
After setting all necessary input conditions the problem was iterated for 300 iterations within which it gives well converged solution so that accurate results were displayed.

C. Results
It is observed that double pass solar heater with porous media gives maximum thermal efficiency compared to without porous media. In this case study mass flow rate was .0006125 Kg/s and Solar irradiation was 1423 W/m2. Solar Air Heater without porous media gives 79.9% thermal efficiency whereas Solar Air Heater with porous media gives 92% thermal efficiency.
Temperature contours

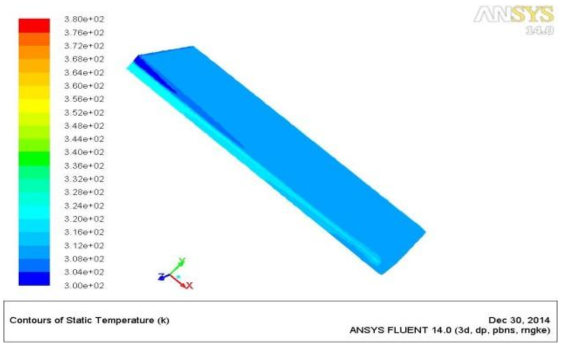

Figure11.Temperature contours of SAH without porous media.

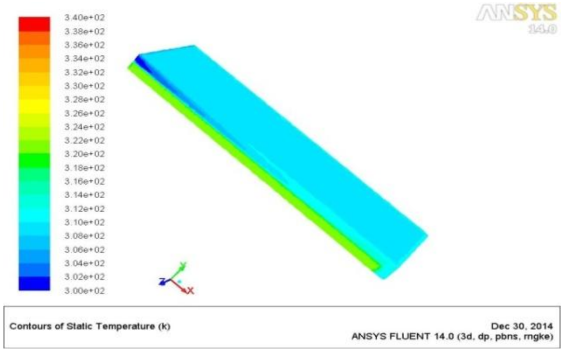

Figure12. Temperature contours SAH with porous media.

Pressure Contours

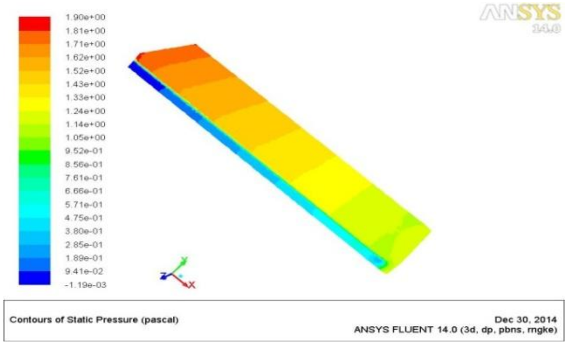

Figure 13. Pressure contours of SAH without porous media.

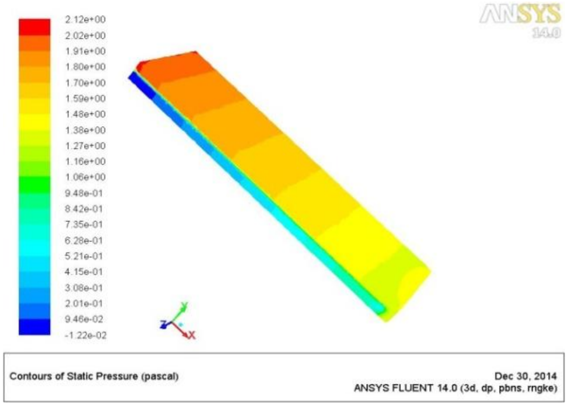

Figure14. Pressure contours of SAH with porous media.

X. SUMMARY

A number of analytical and experimental studieshave been carried out with packed bed, fins integrated doublepass solar air heater which shows significant increase of the performancecompared to the conventional system. It has been found that double pass solar air heater using porous media were widely investigated both analytically and experimentally. The mass flow rate of air and packing material porosity are considered the important parameters that affect theperformance of the double pass solar air heater packed bed systems.Increase in mass flow rate increases thermal efficiency and decrease in porosity increases thermal efficiency. The recycle ratio is found an important parameter that affectsthe performance of double pass solar air heater with external recycle. Thermo hydraulic performance of parallel flow solar air heater is slightly higher than counter flow solar air heater. Longitudinal fins which are used with porous media found to be source of heat loss. Which affects the thermal efficiency of solar air heater but use of transverse fins with porous media increases thermal efficiency. There is tremendous scope for solar air heater with absorber plate roughened on both sides or roughened on one side and porous media on the other side.

REFERENCES

[1] Mohamad AA., High efficiency solar air heater, Solar Energy, 1997, 60, pp.71-76.

[2] Paisarn N., Effect of porous media on the performance of double-pass flat plate solar air heater, International Communication in Heat and Mass Transfer, 2005, 32, pp.140-150.

[3] Sopian K, Alghoul MA, EbrahimAlfegi M, Sulaiman MY, Musa EA., Evaluation of thermal efficiency of double-pass solar collector with porous-nonporous media, Renewable Energy, 2009, 34, pp. 640-645.

[4] Aldabbagh LBY, Egelioglu F, Ilkan M., Single and double pass solar air heaters with wire mesh as packing bed, Energy, 2010, 9, pp. 3783-3787.

[5] Ramani BM, Akhilesh G, Ravi K., Performance of double pass solar air collector, Solar Energy, 2010, 84(11), pp. 1929-1937.

[6] Mittal MK, Varshney L., Optimal thermalhydraulic performance of a wire mesh packed bed solar air heater, Solar Energy, 2006, 80, pp. 1112-1120.

[7] Omojaro AP, Aldabbagh LBY., Experimental performance of single and double pass solar air heater with fins and steel wire mesh as absorber, Applied Energy, 2010, 87, pp. 3759-3765.

[8] Thakur NS, Saini JS, Solanki SC., Heat transfer and friction factor correlations for packed bed solar air heater for a lower porosity system, Solar Energy, 2003, 74, pp. 319-329.

[9] Lalji MK, Sarviya RM, and Bhagoria JL., Experimental Investigations on Packed Bed

Solar Air Heater, Current World Environment, 2011, 6(1), pp. 151-157.

[10] Elradi A. Musa, K. Sopian and Shahrir Abdullah., Heat Transfer Analysis and Pressure Drop correlations for the Double-Pass Solar Collector with Porous Media, Journal of Energy & Environment, 2004, 3, pp. 15-24.

[11] Dhiman P, Thakur NS, Chauhan SR., Thermal and thermohydraulic performance of counter and parallel flow packed bed solar air heaters, Renewable Energy, 2012, 46, pp. 259-268.

[12] Alejandro L. Hernández, José E. Quiñonez., Analytical models of thermal performance of solar air heaters of double-parallel flow and double-pass counter flow, Renewable Energy, 2013, 55, pp. 380-391.

[13] Nowzari R, Aldabbagh LBY, Egelioglu F., Single and double pass solar air heaters with partially perforated cover and packed mesh, Energy, 2014, 73, pp. 694-702.

[14] Chamoli S, Chauhan R, Thakur NS, Saini JS., A review of the performance of double pass solar air heater, Renewable and Sustainable Energy Reviews, 2012, 16,pp. 481– 492.

[15] EL-Khawajah MF, Aldabbagh LBY, Egelioglu F., The effect of using transverse fins on a double pass flow solar air heater using wire mesh as an absorber, Solar Energy, 2011, 85, pp. 1479–1487.

[16] Chii-Dong Ho, Chun-Sheng Lin, Yu-Chuan Chuang, Chun-Chieh Chao., Performance improvement of wire mesh packed double-pass solar air heaters with external recycle, Renewable Energy, 2013, 57, pp. 479-489.

[17] Venu A, Arun P., Simulation Studies on Porous Medium Integrated Dual Purpose Solar Collector, International journal of renewable energy research, 2013, 3, pp. 114-120.

[18] Tiwari P, Kumar A, Sarviya RM., Thermal performance of packed bed solar air heater, IEEE, 2013, 978(1), pp. 438-442.

[19] Karmare S.V. and Tikekar A.N., Analysis of fluid flow and heat transfer in a rib grit roughened surface solar air heater using CFD, Solar Energy, 2010, 84, pp. 409 – 417.

[20] Kumar S. and Saini R.P., CFD based performance analysis of solar air heater duct provided with artificial roughness, Renewable Energy, 2009, 34 (5), pp. 1285-1291.