Research Paper Engineering

Study of Solar Air Heaters with Different Operating Configurations

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ABSTRACT

This paper is intended to assist anyone with the different operating configurations as applied to solar air heaters. The solar energy is converted into thermal energy by using the absorber plate with different materials and the partitions in channel. Solar air heaters have been observed to have generally poor convective heat transfer coefficient from absorber plate to the air. This low heat transfer coefficient results relatively higher absorber plate temperature leading to higher thermal losses to the environment and hence lower thermal efficiency. It has been found that the main thermal resistance to the convective heat transfer is due to the formation of boundary layer on the heat-transferring surface.

Keywords : Heat transfer, solar energy, solar radiation, porous media and non-porous media

NOMENCLATURE

$\overset{o}{m}$ Mass flow rate of air (kg/s)

η Thermal efficiency

F_R Heat removal factor

τ Transmittivity if glass

α Absorptivity of glass cover

U_L Total heat loss coefficient, W/m2 s

T_f Fluid temperature in channel, o C

T_a Assumed air temperature, 30 o C

I Solar radiation, W/m2

C_P Specific heat of air, (J/kg oC)

r_1 Inner radius of the collector, (m)

r_2 outer radius of the collector, (m)

INTRODUCTION

Due to rapid rise in the population, the world seems to drawn into major energy crisis. The condition would go from bad to worse if this trend continues with the same pace. The conventional sources of energy like coal, petroleum and natural gas are depleting at a very fast rate to fulfill the demand of the growing population & their needs. So there is a need to look for some other energy sources that could meet this growing demand. One such source is solar energy, which is cheap available in abundance. The amount of solar radiation striking the earth's surface not only depends on the season, but also depends on local weather conditions, location and orientation of the surfaces.

The average value of this radiation is about 1000 W/m2 when the absorbing surface is perpendicular to the sun's rays and the sky is clear. There are several methods exist to absorb and use this free, clean, renewable and very long lasting source of energy.

Solar energy has been utilized in many ways. Some of its thermal and power generation applications are listed below.

In thermal applications Water heating, Space heating, Space cooling and refrigeration, Water distillation, Drying and Cooking are different applications generally used through the solar energy.

Solar air heater is the easiest and cheapest way to store the solar radiations in the form of heat energy according to previous results. Many researchers had been carried out research work on solar air heater with different number of passes, different porous and non-porous media in channel, and partitions in the flow channel; among them some are discussed within this paper.

LITERATURE SURVEY ON SOLAR AIR HEATER:

There were many research and investigation work done on solar air heater, with single pass and multi pass. The efficiency of solar air heater depends on the heat transfer rate which is further depends on the contact surface area. Here is some research works discussed.

M. M. Sorour and Z. A. Mottaleb (1984) experimentally investigated the effects of the design parameters on the performance of the channel type flat plate solar air heater.

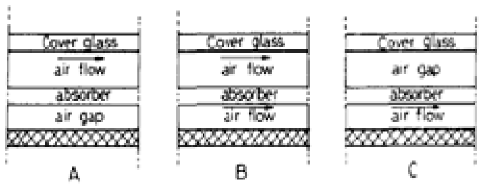


Figure 1: Air heating solar collectors classified by the flow channel locations [1]

That was done by changing in the position of the absorber plate with respect to the cover plate and back plate and also made changes in the number of glass covers. The changes in flow arrangement were done as over, and/or under the absorber plate. These changes in the flow arrangements were as shown in the fig. 1.

N. K. Bansal and D. Singh (1985) worked on cylindrical plate matrix solar air heater. A complete analysis for a cylindrical matrix air heater was discussed. The theoretical derivation

(Eq. 1) [2] was deduced with the help of a set of assumptions and closed form expressions had been obtained for the collector parameters such as heat removal factor and the heat loss coefficient.

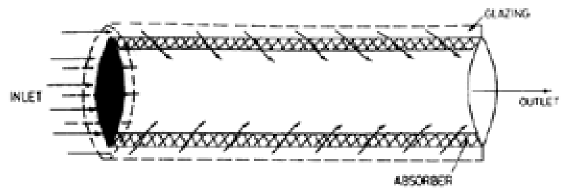


Figure 2: matrix type cylindrical air heater [2]

Figure 2 shows the arrangement for the matrix type cylindrical air heater used by the inventor for this research work.

$$F_R = \frac{\overset{o}{m} C_p r_1^{-b'}}{U_L r_2^{-b'} + \overset{o}{m} C_p r_1^{-b'}} \quad \text{Eq. (1)}$$

The efficiencies obtained with such geometry will naturally be the highest.

Ratna Verma (1992) obtained the thermal efficiency for the 10 different designs of solar air heater. The different designs undertaken were flat absorber type with and without cover glazing; single, double and triple pass etc. It was found that there exists an optimum mass flow rate corresponding to an optimum flow channel depth, for each design considered. The thermal efficiency of the solar air heater is,

$$\eta = F_R[(\tau\alpha)_e - U_L \frac{(T_f - T_a)}{I}] \quad \text{Eq. (2)}$$

K.M. Yousif and B.E. Smith (1996) described the development and testing of an educational solar air heater. The flat-plate solar air heater had been used as a teaching rig for undergraduate students in measurements laboratory sessions, during which the collector efficiency was determined. The results of indoor testing of the solar collector were presented, together with some details of the test facility.

S.O. Enibe (2003) presented the transient thermal analysis of a natural convection solar air heater. The experiment setup considered the heater consists of a single-glazed flat plate solar collector integrated with a paraffin type phase change material (PCM) energy storage subsystem. The PCM was prepared in modules, those modules placed in series equally divided. The underside of the absorber plate together with the vertical sides of the PCM module container, served as air heating vanes. The airflow rate was determined by balancing the buoyancy head resulting from thermally induced density differences and the friction head due to various flow resistances.

B. M. Santos et al (2005) applied the use of solar air heating for crop drying process. A design procedure was proposed for sizing solar-assisted crop-drying systems and assessing the combination of solar collector area and auxiliary energy needs that meets the requirements of the load. A case study as performed in the city of Campinas in southeastern Brazil.

M.M. Sahu and J.L. Bhagoria (2005) carried out the experimental study of the heat transfer coefficient the broken transverse ribs on the absorber plate of the solar air heater. During the experiment the comparison of heat transfer coefficient and friction factor done between the smooth plate solar air heater with and the roughened walls having the pitch ranges from 10 to 30 mm and height of 1.5 mm in the similar flow condition.

Hikmet Esen (2008) presented the experimental analysis of the novel flat plate solar air heater.

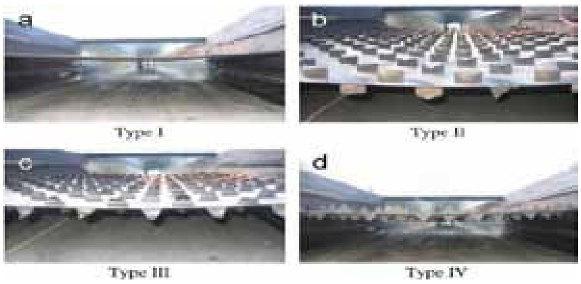
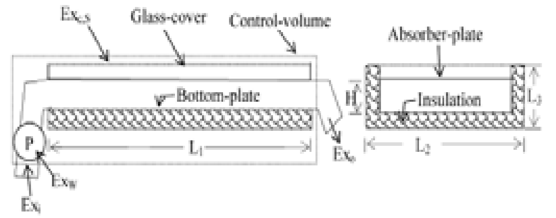


Figure 5: Arrangements of the obstacles in flat plate solar air heater [8]

Arrangement of the absorber plates and the obstacles used in the channel for increasing the heat transfer area in the flow channel was as shown in the figure 5. To increase the available heat transfer area, air was flowing simultaneously and separately over and under from the air heater channel.

Test results give higher efficiency values for Type IV than for Type I (without obstacles) flat plate collector.

M.K. Gupta and S.C. Kaushik (2009) investigated the performance of solar air heater using artificial roughness on absorber plate. The arrangement of the roughness in the channel was as shown in the figure 7. The study of artificial roughness geometry of this metal mesh type in the absorber plate had been carried out and compared with smooth duct.



It was also found from the results that augmentation ratios increase with increase in duct depth and intensity of solar radiation.

Filiz Ozgen et al (2009) experimentally investigated the performance of double flow solar air heater with the aluminum cans in channel. They used total three types of arrangements for their experiment as shown in the figure 8. As they conclude the performance of double-flow type SAHs, in which air was flowing simultaneously over and under absorbing plate was more efficient than that of the devices with only one flow channel over or under the absorbing plate.

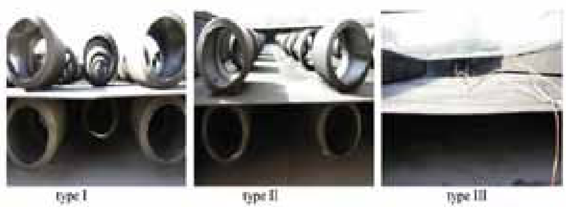


Figure 8: aluminum can as obstacle in double flow solar air heater [10]

The collector efficiency went higher in type I (non-arranged cans) compared to type III (without cans).

Ebru Kavak Akpinar and Fatih Kocyigit (2010) presented the results of an experimental investigation of the performance for a new flat plate solar air heater (SAH) with several obstacles (Type I, Type II, and Type III) and without obstacles (Type IV).

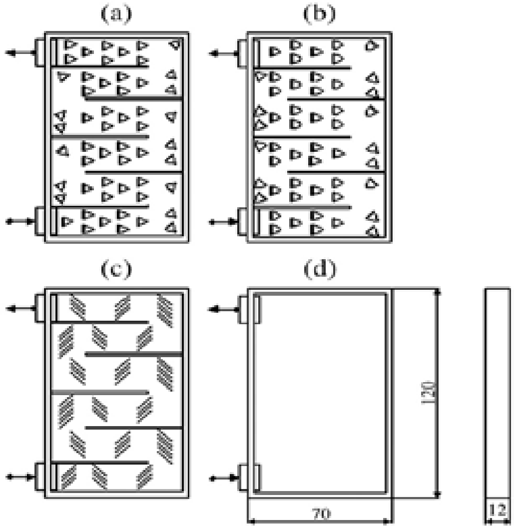


Figure 10: schematic view of absorber plates [11]

The optimal value of efficiency was determined for the solar air heater with Type II absorbent plate in flow channel duct for all operating conditions and the collector supplied with obstacles appears significantly better than that without obstacles.

SUMMARY

The research work on solar air heaters are shown in the present review paper. Most of the researchers are found to be working with the single operating configuration.

Air heaters were commonly concentrated on the number of fins, height of fins, absorber material or working conditions.

The spacing between the two adjacent partitions was not taken into considerations. Also the configurations of the flexible pipe so that the inlet and outlet of the air can be changed either the suction of air from the outlet of air heater or blow air to the inlet of heater were not observed before.

CONCLUSION

This paper identifies the advantages of the double pass solar air heater.

The efficiency of the air heater mainly depends on the heat transfer capacity and the friction factor of the absorber plate. So this capacity of the heat transfer is less in case of the single pass solar air heater than that of the double pass solar air heater.

In many of above researches different types of materials and arrangements were used as the obstacles in channel for increasing the heat transfer rate as well as the heat transfer area which results in the increase in the thermal efficiency of the solar air heater.

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