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Research Article

Experimental Investigation of Double Pass Solar Air Heater using different type of Porous Media

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Abstract

An experimental investigation was carried out to study the effect of porous media (Glass wool and Steel wool) on double pass solar air heater. The aim is to analyse the thermal efficiency of double pass solar air heater using different type of porous media. The measured parameters were temperature difference, air velocity, pressure difference, mass flow rate of the air. Porous media provide large area for the heat transfer have high heat transfer coefficient. This increases the thermal efficiency of the double pass solar air heater with porous media (glass and steel wool) to non- porous media. In this investigation, thermal efficiency of the double pass solar air heater with porous media is more efficient than the single pass solar air heater with porous media.

Keywords: *Double pass solar air heater, Porous media, Glass wool, Steel wool Pressure drop, Mass flow rate.*

1. Introduction

Solar air heaters have been found to have a low thermal efficiency because of the low heat transfer coefficient between the absorber plate and air which leads to a high absorber plate temperature and hence a greater heat loss to the surroundings. The flat plate or non-concentrating type collectors absorb the radiation as it is received on the surface of the collector. There are two types of flat plate solar collectors, water heating solar collector and air heating solar collector. The water heating solar collector is more efficient compared to air heating solar collector. Solar air heater is less complicated as compared to solar water heater because it has free from corrosion and freezing. Solar air heater has no need of heat transfer fluid as air is used directly as the working fluid. Solar air collector can be mounted in variety of ways, depending on the type of building, application, and size of collector.

The pressure inside the solar air collector is not high than less chances to leakage air. It is compact, simple in construction and requires very little or no maintenance. Solar air heater provided free interior heating complement conventional climate control systems. It is important to note that the output from solar heater is reduced when clouds reduce the amount of sunlight. A typical solar heater collector panel would assist in heating of small room. Solar air heating is potentially suitable for any building that requires heating, providing the collector panel can be placed on an appropriate un-shaded south facing (in the northern hemisphere) roof or wall.

2. Literature Review

Adit Gaur et al. An experimental investigation of novel design of double pass solar air the main aim of using of using double pass arrangement is to minimize the heat loss to ambient from the front cover of collector and thus improving the thermal efficiency of the system. Bashria et al. performance of the double flow of solar air heater is studied and compare with the performances of single pass and it is found that double pass operation increases the efficiency of solar collector. Bashria et al. A mathematical simulation to predict the effect of different parameter on system thermal performance and pressure drop in single and double flow mode with and without using porous media have been conducted. C. Choudhary et.al performance and cost analysis of two pass solar air heater. Fouedchabane et al. The researcher has given their attention to analysis of flat plate solar air heater by experimental method. In this paper analysis is done using smooth plate by varying different mass flow rate. Fouedchabane et al. effect of tilt angle of natural convection in solar collector with longitudinal fins, a series of experimental test carried out on plan and in this study shows that for a single pass solar air heater using internal fin inferior and absorber plate, there is a significant increase in thermal efficiency of the air heater. M. pradharaj et al. performance of solar air heater without any cover is very poor and hence at least one cover be

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used for better performance. Silvina Gonzaler et al. thermal evaluation and modify of double pass solar collector for air heating.

3. Experimental Setup

Table No 3.1 Component List

S. No	Name of Component
01	Solar collector area 1m (length)×.5m (width)
02	Glass 1.02m × .52m ×5 mm
03	Thermo-col 0.9 m× .5m × 2.5 cm
04	Internal dimension of plywood 1m× .5m × .15m
05	Outlet pipe diameter = 12
06	Fan vac 220 & amp 0.24

Figure 3.1: Experimental Setup

The experimental setup is show in figure 3.1 for the estimation of mass flow rate and efficiency of flat plate air heater under varying conditions.

Plywood is used for made the frame of solar collector in cuboidal shape of 10 mm thickness. The internal dimension was cuboidal shape 1m× 0.5 m × .15 m. The top surface of the collector was left open for glass cover.

- The installation angle of the collector was 24^0 from horizontal.
- A glazed glass sheet 1.02m×0.52m×5mm was used as the single glass cover for the apparatus.
- The thermo-col sheet 0.9m × 0.5m×2.5 cm to secured to the bottom surface of the wooden frame by nails and glue.
- The absorber was of the a plate absorption coefficient α = 0.95 , the transparent cover transmittance τ = 0.9 and absorption of the glass cover α_g = 0.05
- The inlet was a 14 mm hole dried on the side surface near the bottom.
- For the outlet section 3 holes each of 1 inch diameter was drilled on the adjacent surface near the top.
- The orifice of 12mm diameter and the pipe diameter of 1 inch.
- U-tube manometer was used for the measured pressure difference.
- Glass wool and steel wool were used as porous medium for experiment.
- For calculation solar intensity is taken 900 W/m^2.

U- Tube manometer

It is the type of simple manometer .It consists of glass tube bent in U-shape, one end of which is connected to the point at which pressure is to be measured and other end remains open to the atmosphere. The tube generally contains mercury or any other liquid whose specific gravity is greater than the specific gravity of the liquid whose pressure is to measured. The manometer also had a graduated scale (1mm least count) for measuring the difference in liquid levels.

$$Q = CA_c\sqrt{2g(P1-P2)}$$

$$C = \frac{C_d}{\sqrt{1-(\frac{d2}{d1})^2}} \qquad (1)$$

Where,

Q = volumetric flow rate (at any cross section)

C_d = coefficient of discharge

C = orifice flow coefficient

d1= diameter of the pipe, m

P1 = fluid upstream pressure, mm

P2 = fluid downstream pressure, mm

ρ = Air density, kg/ m^3

4. Methodology and Calculations

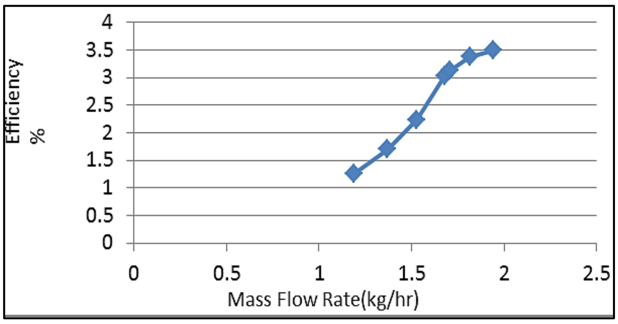

Figure 4.1: Variation of efficiency with mass flow rate

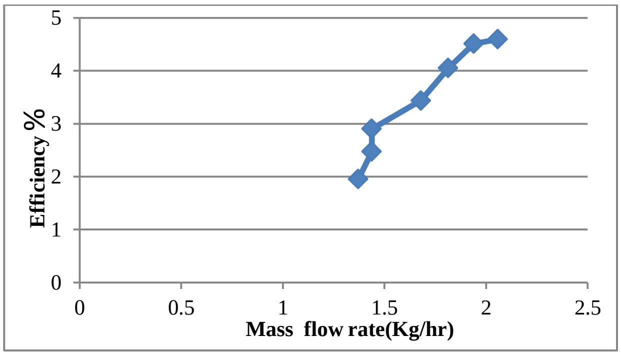

Figure 4.2: Variation of efficiency with mass flow rate.

Table No. 4.1: Performances of double pass solar collector with glass wool

Time 10:30 to 1:30	Ambient Temp (°C)	Outlet Temp. (°C)	ΔT (outlet - ambient) (°C)	P (in mm of H_2O)	Vol. flow rate (litre/min.)	Mass flow rate (kg/hr)	Efficiency (%)
10:30am	27	44	17	1.5	16.16	1.18785	1.25275
11:00am	28	48	20	2	18.66	1.37162	1.701826
11:30am	28.5	52	23.5	2.5	20.86	1.52991	2.235672
12:00pm	29	58	29	3	22.85	1.67988	3.022239
12:30pm	30	60	30	3	22.85	1.70765	3.126454
01:00pm	30.5	60.5	30	3.5	24.68	1.81448	3.37695
1:30 PM	31	60	29	3.5	26.39	1.93976	3.48973

Table No. 4.2 Performances of double pass solar collector with steel wool

Time (10:30 to 1:30)	Ambient Temp. (°C)	Outlet temp. (°C)	ΔT (outlet ambient) (°C)	P (in mm of H_2O)	Vol. flow rate (litre/min.)	Mass flow rate (kg/hr)	Efficiency (%)
10:30am	27	50	23	2	18.66	1.3716	1.9571
11:00am	28	54	26	2.5	20.86	1.4375	2.4735
11:30am	28.5	59	30.5	2.5	20.86	1.4375	2.901617
12:00pm	29	62	33	3	22.85	1.6798	3.4391
12:30pm	30	66	36	3.5	24.68	1.8144	4.05234
01:00pm	30.5	68	37.5	4	26.39	1.9397	4.51264
01:30pm	31	67	36	4.5	27.99	2.0574	4.594931

Table No. 4.3 Performances of double pass solar collector with non-porous media

Time 10:30am to 1:30pm	Ambient Temp. (°C)	Outlet temp. (°C)	ΔT (outlet ambient) (°C)	P (in mm of H_2O)	Vol. flow rate (litre/min.)	Mass flow rate (in kg/hr)	Efficiency (%)
10:30am	27	41	14	1	12.55	0.92265	0.80134
11:00am	28	44	16	1.5	16.16	1.18785	1.17909
11:30am	28.5	45	16.5	2	18.66	1.37162	1.4040
12:00am	29	50	21	2.5	20.86	1.52991	1.9978
12:30pm	30	50.5	20.5	2.5	20.86	1.52991	1.94689
01:00pm	30.5	50	19.5	3	22.85	1.67981	2.0322

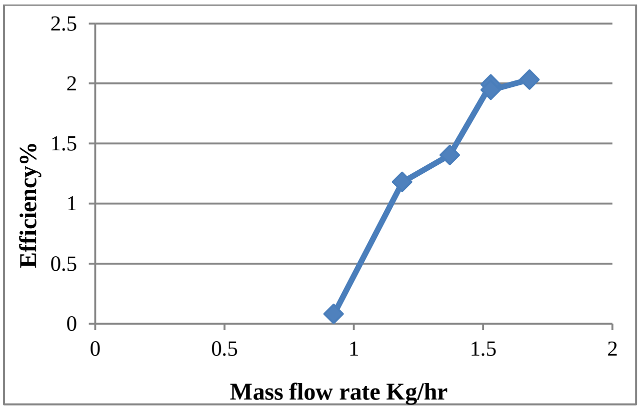

Fig. 4.3 Variation of efficiency with mass flow rate

5. Result and Discussion

The efficiency of a solar collector is defined as the ratio of useful gain to the incident solar energy, that is:

$$\eta = \frac{solar\ Energy\ Collect}{Total\ Solar\ Striking\ Collector\ Surface}$$

$$\eta = \frac{Q_{useful}}{I \times A_s} \quad (2)$$

Where Q is the accumulated energy extracted from the collector during the working period in W, A_c is collector area in m^2.i is solar radiation incident on collector.
Useful heat gain for air collector can be expressed as:

$$Q_u = m\, c_p(T_{out}-T_{in}) \tag{3}$$

Where, Cp is the specific heat of the fluid. The density of air is taken constant which is equal to 1.225 kg/m^3.

The air was heated with respect to time however the maximum temperature achieved was 50 to 50.5 ºC .The heat retentiveness of the collector was relatively poor as compare to collector having porous media .It was generally observed that the efficiency increased with the increase mass flow rate of air. The methods of conducting the porous experiment for both porous and non porous media were always same. The outlet temperature obtains for steel wool (max 68 ^{0}c) and glass wool (60.5 ^{0}C). From Fig. 5.1 we can see that the steel wool is more efficient than the glass wool. Glass wool is more efficient than the non porous media. Efficiency increase about 40.23% at mass flow rate of (0.00025629 to 0.00046635) kg/s when steel wool was used as porous media. And efficiency increased about 33.10% at same conditions when glass wool was used as porous media.

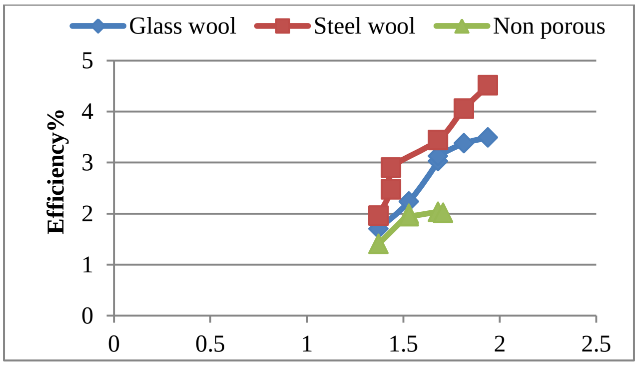

Figure 5.1: Variation of efficiency with mass flow rate

6. Conclusion

This experiment work shows that the thermal efficiency of solar collector is depend on mass flow rate of air and the pressure difference. Thermal efficiency of the solar collector increased when the mass flow rate of air increases. Performance curve of double pass solar air heater (with steel wool and glass wool was used as porous media) and conventional solar air heater have been obtained. Thermal efficiency of double pass solar air heater increases about 40.23% with steel wool and 33.10% with glass wool in comparison of conventional single pass solar air heater.

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