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Experimental Analysis of Single and Double Pass Smooth Plate Solar Air Collector with and without Porous Media

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Abstract: - This paper involves an experimental study to investigate the effect of mass flow of Air on thermal performance and pressure drop through the collector. The aim is to analyze thermal efficiency of flat plate solar air heater .The measured parameters were the inlet and outlet temperature, the absorbing plate temperature, and ambient temperature .further the measurements were performed at different value of mass flow rate of air in flow channel duct. It is concluded that smooth plate double pass solar air heater is 3-4% more efficient than single pass solar air heater. If we use the porous media in double pass solar air heater increase the air heater efficiency to be 5 % efficient than air heater in single pass, and 2-3% more in double pass without porous media.

Keywords: – *Single & double pass solar air heater, porous media, thermal performance, pressure drop.*

I. INTRODUCTION

Solar air heater is the simplest form of Flat plate solar collector in which the working medium is air. The principle usually followed is to expose a dark surface to solar radiation so that radiation is absorbed. Apart of the absorbed radiation is the transferred to fluid like air. A flat plate collector used for heating the air generally known as solar air heater. [1] 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. [2] Ajay Kumar et al. experimental investigation of solar air heater using porous media they show the effect of mass flow rate and solar radiation on efficiency of solar collector [3] Ahmad Foudoli et al. Analytical and experimental studies on the thermal efficiency of the double pass solar air collector with finned absorber the efficiency is increased to proportional to mass flow rate and the solar radiation and the efficiency is depend on mass flow rate. [4] 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.[5] 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. [6] Ben Slama et al. collector with baffle aerodynamics, heat transfer and the efficiency [7] C. choudhray et.al performance and cost analysis of two pass solar air heater.[8]] 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. [9] 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 [10] M. pradharaj et al. performance of solar air heater without any cover is very poor and hence at least one cove be used for better performance .[11] Silvina Gonzaler et al. thermal evaluation and modify of double pass solar collector for air heating.

II. COLLECTOR THERMAL EFFICIENCY

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

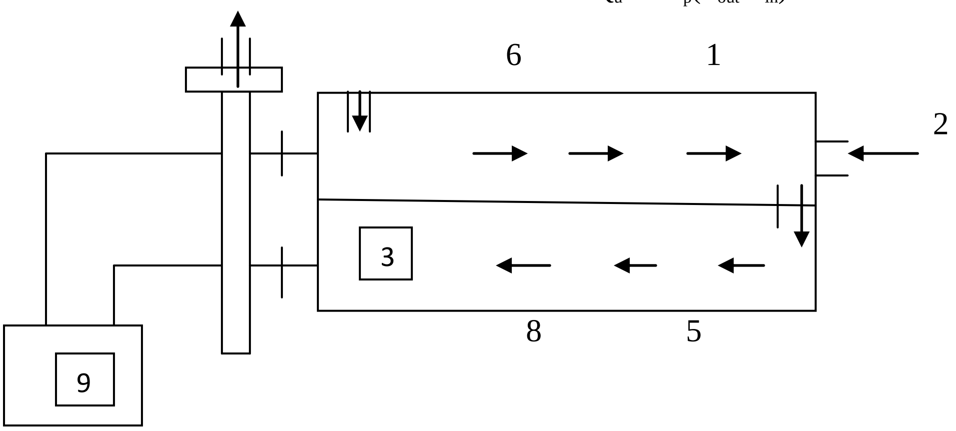
$$\eta = \frac{\text{Solar Energy Collect}}{\text{Total Solar Striking Collector Surface}}$$

$$\eta = \frac{Q_{useful}}{I \times A_s} \quad \textbf{(1)}$$

Where, Q - Accumulated energy extracted from the collector during the working period in W,
A_c - Collector area in m^2

Useful heat gain for air collector can be expressed as:

$$Q_u = m\, c_p (T_{out} - T_{in}) \quad \textbf{(2)}$$



1,2- inlet ,3- Solar Collector ,4,5- valve, 6- outlet , 7,8- thermocouple wire, 9- thermometer

Figure1: Solar Energy Distributions of the Solar Air Collector

U- Tube manometer

It is the type of simple manometer. It consist 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.

$$\mathbf{Q = C\, A_c\sqrt{2g(P1 - P2)}}$$

$$\mathbf{C = \frac{C_d}{\sqrt{1-(\frac{d2}{d1})^2}}} \quad (3)$$

Where,
Q = volumetric flow rate (at any cross section)
C_d = coefficient of discharge
C = orifice flow coefficient
d_1= diameter of the pipe, m
P_1 = fluid upstream pressure
P_2 = fluid downstream pressure
ρ = Air density, kg/ m3

III. EXPERIMENTAL SET UP

The experimental setup is show in figure 3.1 has been used to estimate efficiency 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 1 m× 0.5 m × 0.15 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 1.02 m × 0.52 m × 5 mm was used as the single glass cover for the apparatus.
- The thermocol 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 10 cm 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 was used as porous medium for experiment.
- Calculation is based on solar intensity taken as 900 w/m^2.

Figure 3.1: Experimental Set-up

Table No.1: Compo

Protractor

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

IV. RESULTS AND DISCUSSION

The performance of the double pass flow solar air heater is studied and compared with the single pass. In this analysis, it has been concluded that the double pass solar air heater is more efficient Then the single pass air heater. It can see that the efficiency of air heater greatly depends on air flow rate. The efficiency of air heater is increased up-to 1.336 kg/hr in single flow mode and upto 1.939 kg/hr in double flow mode. This figure clearly shows that the double flow mode is 3-4 % more efficient than single one. Thus, efficiency increases with double pass mode due to heat removal from two pass as compared to single pass.

If porous media is used in double flow, the efficiency has been increased 6% more as compared to single flow mode. If porous media is not used in double flow, the efficiency has been increased 2-3% more as compared to single flow mode without porous media.

Hence, the use of porous media increases the heat transfer area which contributes higher thermal efficiency. In this paper, figure 4.1 shows that efficiency variation with mass flow rate for single pass mode without porous media and figure 4.2 shows the pressure drop variation with mass flow rate for single pass mode without porous media.

Figure 4.3 show efficiency variation with mass flow rate for single pass mode with porous media. Figure 4.4 shows that pressure drop variation with mass flow rate for single pass mode with porous. Figure 4.5 show the efficiency variation with mass flow rate for double pass mode with porous figure. 4.6 shows the pressure drop variation with mass flow rate for double pass mode with porous media. Finally our result shows in figure 4.7 and figure 4.8 efficiency variation with mass flow rate and pressure drop variation with mass flow rate in the both condition (single pass mode and double pass mode) it shows that mass flow rate increase with pressure drop and efficiency increase with increase with mass flow rate.

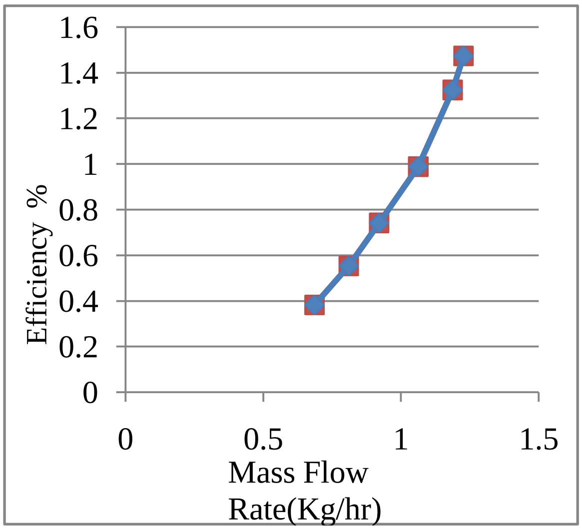


Figure 4.1: Efficiency variation with mass flow flow rate for single pass mode non porous

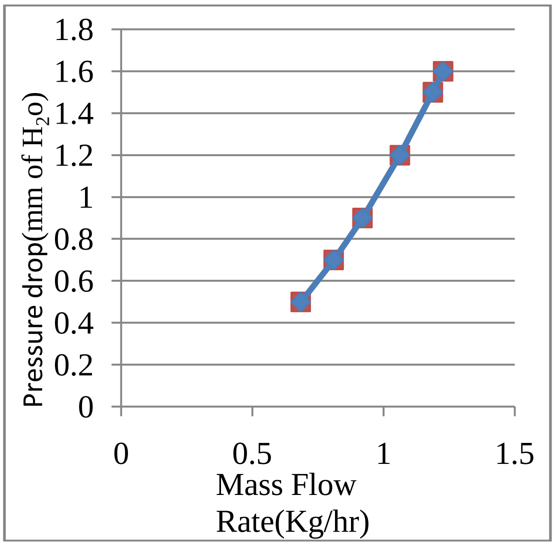


Figure 4.2: Pressure drop variation with mass flow rate for single pass mode non porous

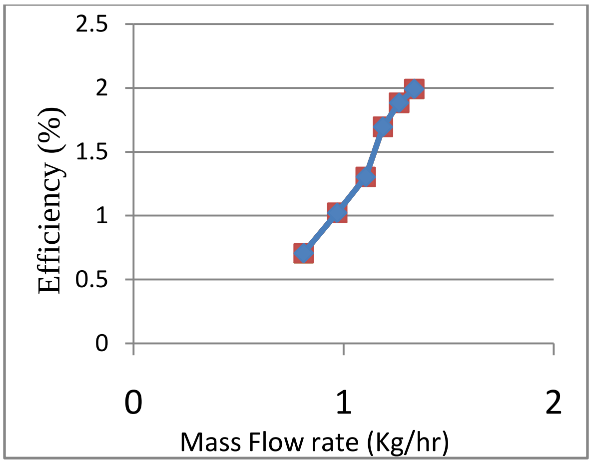


Figure 4.3: Efficiency variation with mass flow for single pass mode with porous

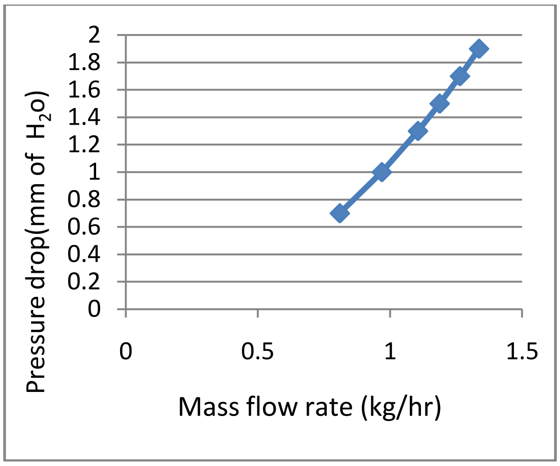


Figure 4.4: Pressure drop variation with mass flow rate rate for single pass mode with porous.

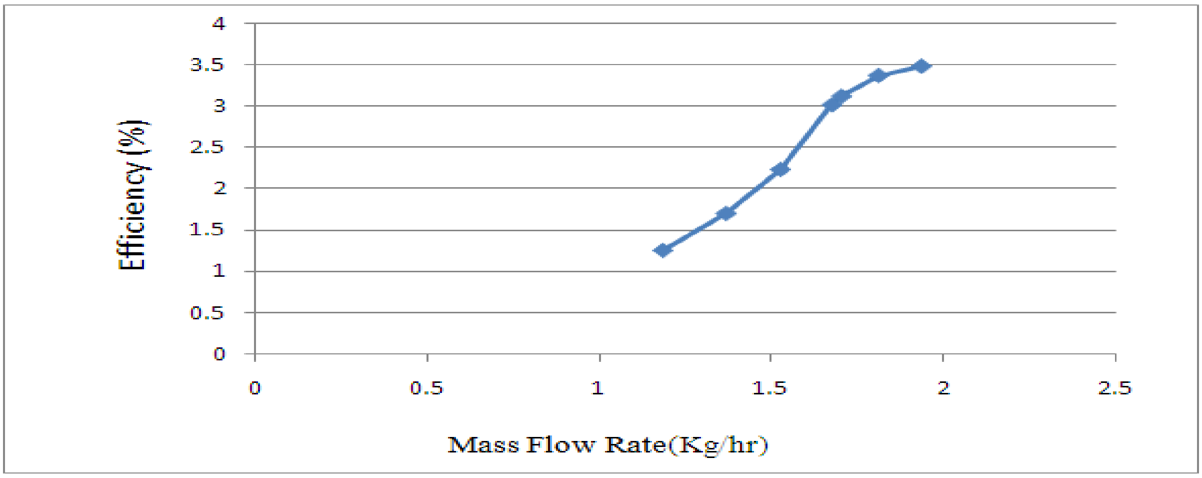


Figure 4.5: Efficiency variation with mass flow rate for Double pass mode with porous

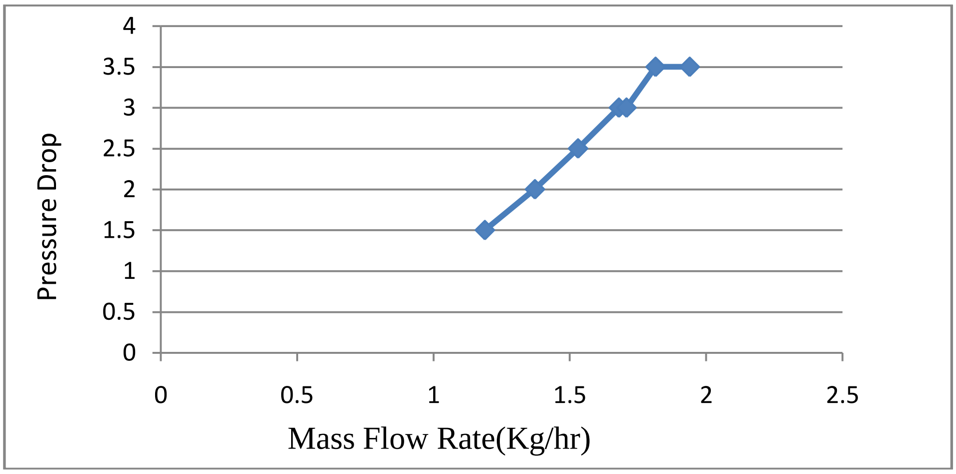


Figure 4.6: Pressure drop variation with mass flow rate for Double pass mode with porous

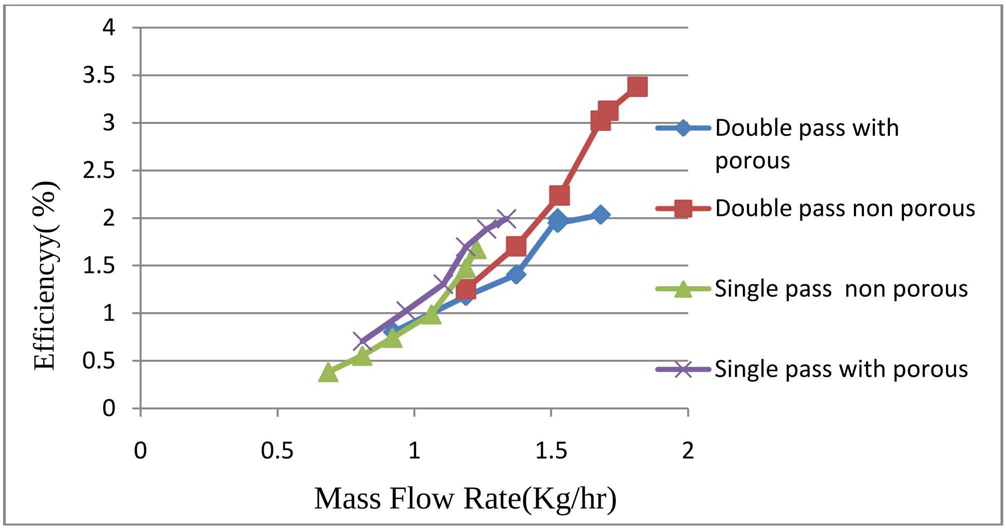


Figure 4.7: Efficiency variation with mass flow rate

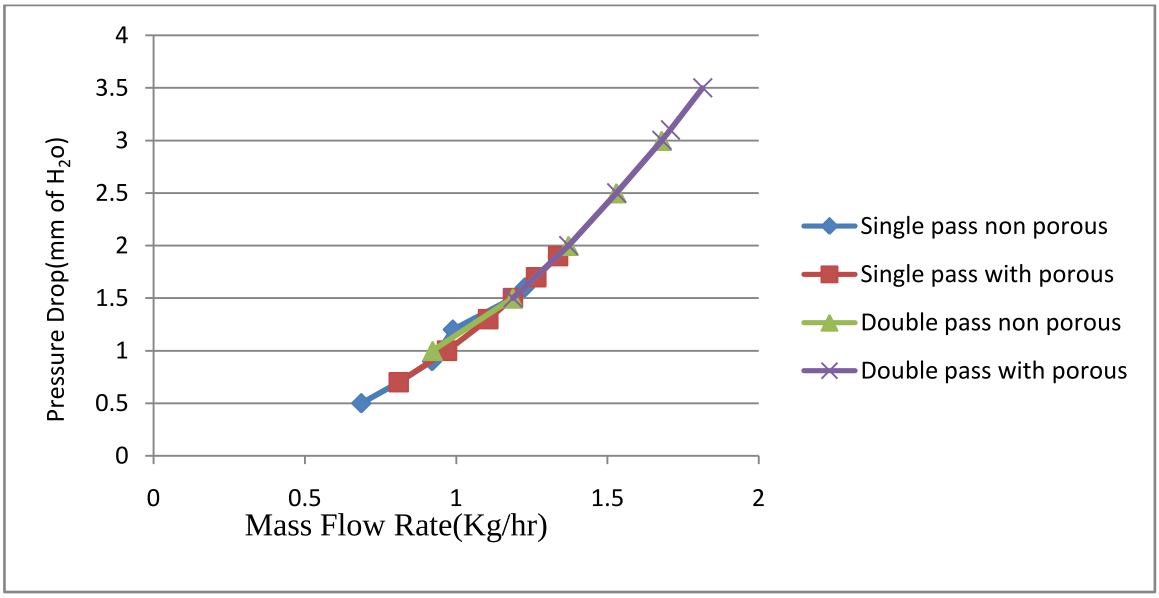


Figure 4.8: Pressure variation with Mass flow rate

V. CONCLUSIONS

An Experimental analysis is done to predict the effect of different parameter thermal performance and pressure drop, for smooth plate single pass and double pass solar air heater with and without using a porous media .It is found that thermal efficiency greatly based on mass flow rate it increase with increase mass flow rate but it also increase the pressure drop. The double flow is more efficient than the single floe made and using of porous media increase the system efficiency and the outlet temperature.

Nomenclature

A_c	*Area of Collector that absorb solar radiation, m²*	T_a	*Ambient air temperature, K*
C_d	*Coefficient of discharge of orifice*	T_c	*Cover temperature, K*
C_p	*Specific heat of air at constant pressure, J/Kg K*	T_{pr}	*Porous media temperature, K*
F	*Friction factor*	*W*	*Collector width, m*
F	*Heat removal factor*	*H*	*Fluid heat transfer coefficient, W/m²*
KI	*Solar radiation, W/m²*		

Greek symbols

L	*Collector length, m*	η	*Collector thermal efficiency*
m	*Collector flow rate, kg/sec*	ρ	*Air density, kg/ m3*
P	*Pressure drop across the duct, mm of H_2O*	Q_u	*Rate of solar energy gain, W*

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