EFFICIENCY IMPROVEMENT OF DOUBLE PASS SOLAR AIR HEATER USING FINS

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Abstract-Solar air heater efficiency can be affected by various parameters such as collector length, type of absorber plate, type of fin, mass flow rate of air and fin, inlet temperature and pressure, outlet temperature and pressure and velocity of air. It is a special type of heat exchanger which includes longitudinal fins, black coated aluminium plate, transparent glass, blower, dry chamber and it transfers energy by absorbing solar heat radiation in the air, basically heat transfer of fluid to fluid occurs by convection process. The fins are used for purpose of heating. To improve the efficiency of double pass solar air heater with longitudinal fins having the collector angle of inclination slightly 30° and there is a double flow channel. The losses through bottom and side of the heater are reduced or almost eliminated by using the insulation. An important application of solar air heater is to supply hot air to agricultural product and for heating place.

<u>Keywords:</u> Solar Collector, Solar heater, longitudinal fins, Dry chamber and Blower.

I.INTRODUCTION

Solar air system is a type which converts solar energy into heat which is an important place with solar thermal system which is widely used in many commercial applications such as buildings, agricultural and industrial drying. The jet imprigment concept is the effective method of increasing convective heat transfer in a solar air heater. The jet plane solar air heater is extensively used in space heating.[1].The solar energy is converted the solar radiation into heat energy. The solar air heater uses metallic wiry sponge which is greatest metallic porous media which is provided high contact surface area to air that is inserted into the baffles. The longitudinal fins are inserted inside the double pass solar air heater. [2]. The heat transfer in Double pass solar air heater has been enhanced by utilizing vertical fins attached to a double pass solar photovoltaic or thermal Collector and revealing the influence of the fin design thermal, electrical efficiencies by studying three different straight fins profile besides the configuration with pin fins. Influence of the number, thickness and the material

of fins on the performance of the PV/T Collector.[3].The air initially flows between heated fins in the lower channel generating rise in turbulence which helps in absorbing heat capacity. During the flow of air in top channel carrying hot air, further heat occurs to the incoming air from the absorber top channel. [4]. The analysis of exergy and energy has been done to compare the performance of designed flat plate solar air heaters with double glass cover and without fins (Type-I), with double glass cover having fins (Type-II), and with single glass cover having fins (Type-III). [5].The development of steady state model which predict the thermal double pass solar collector based on energy and exergy analysis.[6]. The absorber plate is inserted in parallel plate in an open conduit to counter current double pass solar air heater with external recycling and with fins attached by baffles proposes an alternative flow configuration. The double pass device introduced here was designed for creating a solar collector with air flowing simultaneously over and under the absorber plate. [7].The electrical performance is investigated by varying the air flow rate through duct.[8].The efficiency of double pass solar air heater with porous media acting as an absorber plate is experimentally investigated. The length and width of the collector are 150cm and 100cm. The distance between the first glass cover and the bottom of the collector is 3cm and distance between the two covers is 2cm.The porous media consists of the steel mesh layers arranged in a low pressure drop across the collector. [9]. The porous media has the benefit increase the absorber surface area per unit volume ratio but on the other hand resulting in significant frictional losses therefore more pumping power would be needed.[10].

The solar air heater has tested using various quarter and half perforated covers which contains many hole to hole spring distances. The height of the duct is fixed at 3m size in order to examine the variation of small duct height on the performance of solar air heater. [11].

The double pass solar air heater is used for drying chillies like a new model investigated solar air dryer.[12].There are different factors affecting thermal efficiency such as Collector length, Collector depth, type of absorber plate, glass cover, wind speed, Inlet temperature etc. The shape of glass cover and type of absorber plate includes as the most important parameter to design any type of air heater. [13].There are many variations in rate of evaporation in active solar still due to effects caused by different parameters and techniques.[14].Increase in fluid velocity resulting in convective heat or mass transfer enhancement whereas decrease in driving force happens due to mixing. Instead of using single pass device and operating at various flow rate, the double pass device is employed due to convective heat transfer rate increment as compensation of driving force decrement ins obtained the considerable increase in collector efficiency of solar air heater with fins.[15].The above reference papers for this topic are describes that solar air heaters using photovoltaic cell for absorption, baffles for diverting the flow of air, transverse fins and also corrugated absorber plates. In this paper, black coated absorber plate, longitudinal fins are used for this solar air heater to improve the thermal efficiency.

II.EXPERIMENTAL SETUP AND PROCEDURE

The experimental setup is shown in the Fig.1 has been used to estimate the mass flow rate and efficiency of the double pass Solar Air Heater (SAH) under the varying condition. The casing is made by mild steel at 2mm thickness. The internal dimension of cuboidal shape will be 6m x 4m x 0.2m.The inclination angle of the collector was slightly 30° from the horizontal surface and glazed glass cover sheet is used. In this set up the pipe at diameter is 2.5mm in inlet which is connected to the blower within the use of reducer at 1.5mm diameter. This contains upper channel and lower channel for recirculation of air. The absorber plate coated with black plate which is at length of 550mm is placed between upper channel and lower channel. Fig.2 shows that longitudinal fins which is made up of copper which is placed in the bottom of plate. The black plate at length of 580mm is placed in lower channel. The blower is attached to the outlet pipe of the channel and it is connected to ON/OFF controller.

Fig 1.Double pass solar air collector

The air from the atmosphere enters in the inlet through blower at the mass flow rate of 0.004585kg/s at temperature 33°C and pressure at 1.10325bar. The air is recirculated at lower channel by absorbing the heat from the fin where the heat from the sunlight is stored. The recirculated air gets lifted and passes to outlet duct through the lower channel and exhausted to atmosphere. The outlet air temperature will vary from range of 38°C to 50°C and pressure varies from 1bar to 5bar. Mass flow rate of air varies from 0.0042-0.0070kg/s. The mass flow rate of fin decreases from 0.00675-0.00673kg/s. The air flow rate was adjusted by blower regulator for different speed. Actually, the Solar Air heater operates from 09:00 AM to 03:00 PM. But Table.1 shows the test is conducted between 12 Noon to 3:00 PM at the velocity of air at 10 m/s and Collector efficiency increases. The intensity of radiation will be 5.15kwh/m^3/day.

Fig. 2 Longitudinal fins arranged at the bottom of absorber plate

TABLE 1 Variation of collector efficiency

Sl.No	Mass flow rate of Air ($\dot{m}$) x 10^{-3} kg/s	Density (ρ) x10^{-4} Kg/m^3	Air Inlet Temperature (T_{in}) °C	Inlet Pressure (p_{in}) bar	Outlet temperature (T_{out}) °C	Outlet pressure (p_{out}) bar	Specific Heat Capacity (kJ/kg)	Thermal Conductivity (K_f) W/mk	Time min	Efficiency of Collector ($\eta_{Collector}$) %
1.	4.85	1.974	33	1.1034	42.24	2.4	1.005	0.02791	20	34.48
2.	4.95	2.1295	33	1.1034	43.5	2.66	1.005	0.02792	20	42.26
3.	5.23	2.25	33	1.1034	44.55	2.88	1.005	0.02793	20	49.11
4.	5.50	2.305	33	1.1034	44.9	2.98	1.005	0.02794	20	52.69
5.	5.90	2.445	33	1.1034	46	3.235	1.005	0.02802	20	62.02
6.	6.80	2.85	33	1.1034	48.5	3.975	1.005	0.02816	20	86.96

III.MATHEMATICAL RELATIONS

The mass flow rate of air passing through collector is calculated as

$$m = \rho.A.c \text{....................................Eqn. (1)}$$

Where

ρ = Density of air kg/m^3 i.e. $\rho = P/RT$

A = Area of collector in mm^2

c = Velocity of air in m/s

p = Pressure of air in bar

T = Temperature of air in °C

Using the pressure temperature relation from thermodynamics

$$T_{a,out}/T_{a,in} = (p_{a,out}/p_{a,in})^{\gamma/\gamma-1} \quad \text{..............Eqn. (2)}$$

(Since, it is adiabatic)

Where

$T_{a,\,in}$ = Temperature of air at inlet in °C,

$T_{a,\,out}$ = Temperature of air at inlet in °C

$p_{a,\,in}$ = Pressure of air at inlet in bar,

$p_{a,out}$ = Pressure of air at outlet in bar.

Now for longitudinal fins the mass of the fins can be calculated by using the formula,

$$m_f = \sqrt{\frac{2h_f\,(L+t_f)}{k_f A_{lf}}} \quad \text{.................................Eqn. (3)}$$

Where

h_f is height of fin in m,

t_f is thickness of fin in m

L is length of a fin in m,

A_{lf} is area of longitudinal fin in m^2.

The thermal efficiency of the fin is

$$\eta_f = \frac{\tanh m_f h_f}{m_f h_f} \quad \text{..................................Eqn. (4)}$$

Where

m_f is mass of fin (kg/h),

h_f is height of fin(m).

The thermal efficiency of the collector is calculated as

$$\eta_c = \frac{\dot{m}.\,C_p.(T_{a,out} - T_{a\,in})}{I.\,A_C} \quad \text{.....................Eqn. (5)}$$

Where

$\dot{m}$ is mass flow rate in kg/s,

C_p is Specific heat of air in J/kg-K,

I is Intensity of radiation = 5.15kwh/m^3/day,

$T_{a,in}$ is air inlet temperature in °C,

$T_{a,out}$ is air outlet temperature in °C.

IV.RESULTS AND DISCUSSION

Due to use of constant air flow by the blower , mass flow rate rises and due to it, collector efficiency rises according to temperature rises occurs inside the solar air heater contains absorber plate. It has good heat transfer coefficient the temperature rise will occur, this is the main reasons for increasing the temperature rise will occur, this is the main reasons for increasing the temperature of the absorber plate inside solar heater. Fig.3 shows the variation between mass flow rate and collector efficiency. It shows that mass flow rate rise according to the efficiency of collector rises.

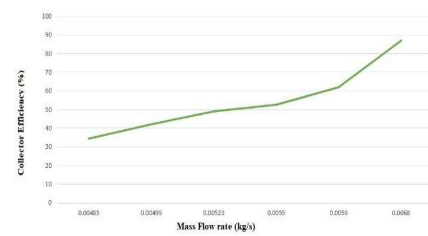

Fig 3. Variation between Mass flow rate and Collector efficiency

Fig. 4 shows the variation between temperature and time. It shows the temperature of air enters inside the atmosphere at 33° C and exits at the temperatures ranges from 42°C to 50°C. The exit temperature increases due to absorption of heat. The temperature of air heated in solar collector increases between morning 09:00 AM to afternoon 03:00 PM.

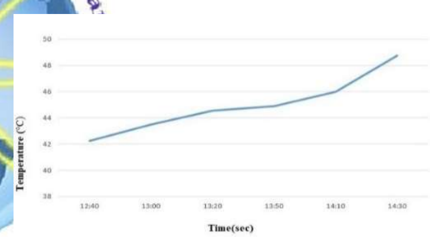

Fig 4. Variation between Time and Temperature

Fig.5 shows the variation between temperature and collector efficiency. Here if the temperature increases from morning 9 AM to afternoon 2 PM and gets decreases efficiency also increases. The efficiency will be low at morning 09:00 AM to afternoon 12:50 PM and becomes higher.

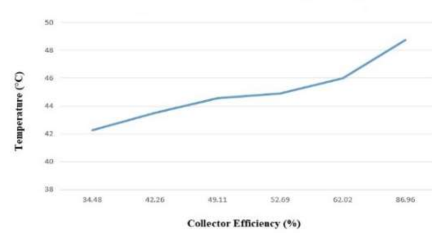

Fig 5.Variation between Temperature and Collector efficiency

Fig.6 shows the variation between time and collector efficiency. Collector Efficiency also plays a critical role in performance of solar air heater. Hence, the thermal efficiency from morning to evening increases because it depends on solar intensity. It is lowest at morning 09:00 AM and becomes higher at afternoon 01:00 PM and then it gradually decreases .Highest Thermal Efficiency will be more than 40%.But in this project, the solar intensity will be constant according to climate in Thanjavur. But Fig.6 shows the collector efficiency increases according to time even the mass flow rate and temperatures increases in the channels of collector.

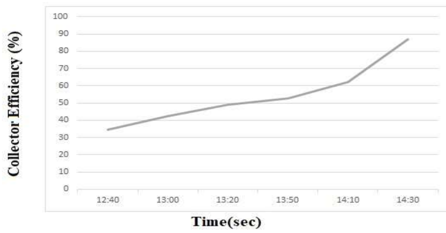

Fig 6 .Variation between Time and Collector efficiency

V.CONCLUSION

It is concluded based on the experimental results of the followings:

- The thermal efficiency of solar air heater greatly depends on time, solar intensity and mass flow rate of air.
- Solar air heater having the thermal efficiency of varying from 0.34 to 0.86 during morning 9 AM to 1PM then it's gradually decreases.
- Solar air heater absorber plate temperature increases with increases mass flow rate of air when the solar intensity constant.
- During experimental analysis we have seen that outlet temperature increases with constant solar intensity as well as increases time from morning to evening.
- The results on every aspect of the solar air heater were conveyed.
- The efficiency of the solar air heater was found to be of 86 % under test conditions. The Efficiency of longitudinal fins was found to be 29.71% under test conditions. Hence this solar air heater can be used for laboratory purposes.

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NOMENCLATURE

C_p	Specific heat of air, kJ/kg.K
$\dot{m}$	Mass flow rate of air, kg/s
ρ	Density of air, kg/m^3
A	Area of collector, mm^2
c	Velocity of air, m/s
p	Pressure of air, bar
T	Temperature of air, °C
ΔP	Pressure difference, N/m^2
Q	Volume flow rate, m^3/s
$T_{a,\,in}$	Temperature of air at inlet, °C
$T_{a,\,out}$	Temperature of air at inlet, °C
$p_{a,\,in}$	Pressure of air at inlet, bar
$p_{a,\,out}$	Pressure of air at outlet, bar
ρ	Density, kg/m^3
$\eta_{collector}$	Thermal efficiency of collector (%)
η_{fin}	Thermal efficiency of fin
I	Intensity of solar radiation, W/m^2
k_f	Thermal conductivity of fin, W/mK

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