Research Paper Engineering

ENERGY ANALYSIS OF SOLAR AIR HEATER BY USING DIFFERENT TYPES OF ABSORBER PLATES

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ABSTRACT

The key case in this report is to do the energy analysis of solar air heater by using different types of absorber plates and Whole research is done on a model of solar air collector. Firstly, measurements concerning collector with flat absorber plate like air flow,temperature of absorber plate and temperature of air in the collector are performed. Additionally parameters describing weather like wind speed, solar radiation and outdoor temperature are checked. Secondly measurement concerning collector with corrugated plate absorber plate are performed. In both case the mass flow rate was maintained constant and solar radiation was varied. Also, in order to check the performance of the collector the heat balance and efficiency was determined in both cases. In order to optimize the performance, the results like thermal efficiencies and temperature of absorber plate are compared in both cases.

Keywords : Solar air heater, Thermal efficiency, Double pass solar air heater, air flow blower.

1. INTRODUCTION:

With the rapid rise in the population and the living standards, the world seems to engulf into major crisis, called energy crisis. If this growth continues with the same pace the condition would go from bad to worse. The reverse of conventional sources of energy like coal, petroleum and natural gas are depleting at a very fast rate to fulfil the demand of the growing population. 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. Solar energy has been utilized in many ways.

Some of its thermal applications are as follows:
1. Water heating
2. Space heating
3. Power generation
4. Space cooling and refrigeration
5. Distillation
6. Drying, and
7. Cooking

1.1 SOLAR AIR SYSTEM:

Solar air system is a type of system which collects solar energy and transforms it into heat. The general idea is that the air is flowing through solar collector and heat from sun naturally raises the temperature of the air. In other words cold, outside air is heated and delivered to the room. The collector has on outer layer of glazing/polycarbonate which is exposed to sun. Circulation of the air in the building can be by natural driving forces (buoyancy effect) or by fan which is more certain.

2. WORKING MODEL:

Figure 2.1 Working model of Solar air heater.

Figure 2.1 Shows experimental set up of double pass solar air heater. In this study, absorber plate made of stainless steel with black chrome as a selective coating material to increase absorptivity of solar radiation. Dimension of solar air heater is 2 meter × 0.75 meter × 3 m respectively. Instead of normal window glass, toughened glass has utilized in this research work. Thermal losses of cover due to convection as well as radiation process are assumed as constant Here, Thermocouples were positioned evenly, on top of surface of absorber plates, at identical position along the direction of flow, for both directions. Intel as well as outlet temperatures were measured with help of two K Type thermocouples. Insulation is made with help of thermocole of 5 mm thickness. Ambient temperature was measured by Mercury thermocouple. Total sun radiation measured by pyrenometer. Here, blower is placed to flow to flow the hot air inside solar air heater, Test began at 10 am and ended at 5 pm. Solar air heater performance tests were conducted on days with clear sky condition means without clouds in the sky, hence the amount of Direct radiation will be more. The angle of slope is 40 degree which is suitable for geographical condition of Mehsana. Here, mass flow rate remains constant, but solar insolation is variable inside the solar still.

3. THERMAL ANALYSIS:

In this section, a review has been done on the theoretical modelling of Single glazing and double pass solar air heater. Theoretical modelling of this solar air collector is derived comprehensively in this section.

3.1 Energy balance of the collector:

In order to define the energy balance of the solar air collector the following equation shall be used:

Qu = Ac FR [S - UL (Tfm - Ta)] [Watt] (3.1)

Where:

Ac – collector area [m2],
Fr – heat removal factor,
S – absorbed solar radiation per unit area [W/m2],
UL – collector overall heat loss coefficient [W/ (m2·K)],
Tfm – mean fluid temperature [K],
Ta – ambient temperature [K].

3.1.1 Heat removal factor:
Heat removal factor – relates the actual useful energy gain of a collector to the useful gain if the whole collector surface were at the fluid inlet temperature.

Radiation heat transfer coefficient:

$$h_r = \frac{4 \times \sigma \times T_{fm}^{\ 3}}{\frac{1}{\varepsilon_g} + \frac{1}{\varepsilon_p} - 1} \text{ [W/m2K] (3.2)}$$

Where:

σ – Stefan-Boltzmann constant [W/m2K4],
Tfm – Mean air temperature [K],
εg – Emittance of glass,
εp – Emittance of plate.

Convective heat transfer coefficient:
Reynolds number

$$R_e = \frac{\dot{m} \times D_h}{A_f \times \mu} \quad (3.3)$$

Where:

$\dot{m}$ – Flow rate [m3/s],

Dh – hydraulic diameter; for flat plates is twice the plate spacing [m],

Af – fluid area (air channel depth times width) [m2],
μ – Dynamic viscosity [kg/(s·m)].
Nusselt number
Nu = 0.0158 × Re0.8 (3.4)

Convective heat transfer coefficient

$$h_c = N_u \times \frac{K}{D_h} \text{ [W/m2K] (3.5)}$$

Where:

K – Thermal conductivity of air [W/m·K].

Heat removal factor

$$F_1 = \left[1 + \frac{U_L}{h_c + \left(\frac{1}{h_c} + \frac{1}{h_r} \right)^{-1}} \right]^{-1} \quad (3.6)$$

$$F_2 = \frac{\dot{m} C_p}{A_c U_L F_1} \left[1 - \exp\left(-\frac{A_c U_L F_1}{\dot{m} C_p} \right) \right] \quad (3.7)$$

Where:

$\dot{m}$ – Flow rate [Kg/s],

Cp – Specific heat [KJ/Kg K].

Heat removal factor

$$F_R = F_1 \times F_2 \quad (3.8)$$

3.1.2 ABSORBED SOLAR RADIATION:

S = (τα) GT (3.9)

GT is the incident solar energy per absorber plate area unit; (τα) is effective product transmittance-absorptance that is equal to the optical efficiency ηo.

3.1.3 Collector overall heat loss coefficient:

$$U_L = U_t + U_b + U_e \text{ [W/m2K] (3.10) Where:}$$

Ut – top loss coefficient [W/m2·K],

Ub – the energy loss through the bottom of the collector [W/m2·K],

Ue – edge losses [W/m2·K].

3.1.3.1 TOP LOSS COEFFICIENT (Ut):
In a steady state, the heat transferred by convection and radiation between (a) the absorber plate and the cover (b) the cover and the surroundings must be equal.

$$U_t = \left[\frac{N}{\frac{C}{T_{pm}}\left[\frac{T_{pm}-T_a}{N+f}\right]^e} + \frac{1}{h_w} \right]^{-1} + \left[\frac{\sigma\left(T_{pm}+T_a\right)\left(T_{pm}^{\ 2}+T_a^2\right)}{\left(\varepsilon_p + 0.00591 N h_w\right)^{-1} + \left(\frac{2N+f-1+0.133\varepsilon_p}{\varepsilon_g} - N\right)} \right]$$

(3.11)

Where:

Ut – top loss coefficient [W/m2·K],
N – number of glass covers,
f = (1 + 0.089hw – 0.1166hwεp) (1 + 0.07866N),
C = 520(1 – 0.000051β2),
e = 0.430(1 - 100/Tpm),
β – Collector tilt (degrees),
εg – Emittance of glass,
εp – Emittance of plate,
Ta – ambient temperature [K],
Tpm – mean plate temperature [K],
hw – wind heat transfer coefficient [W/m2·K],
V = Wind speed [m/s],
σ – Stefan – Boltzmann constant [W/m2·K4].

Wind Heat transfer coefficient at the top cover:
The wind heat transfer Co-efficient can be calculated by following relation:

hw = 5.7+3.8V (3.12)

Where V is the wind speed in m/s.

3.1.3.2 BOTTOM LOSS COEFFICIENT (Ub):
The bottom loss coefficient is calculated by considering conduction and convection losses from the absorber plate in the downward direction. Thus, neglecting the convective resistance at the bottom surface of the collector casing.

$$U_b = \frac{K_i}{\delta_i} \quad \text{(3.13) Where:}$$

Ub – Bottom loss coefficient,
ki – Insulation thermal conductivity [W/m·K],
δi – Thickness of insulation [m].

3.1.3.3 EDGE LOSS COEFFICIENT (Ue):
The edge loss co-efficient can be calculated by:

$$U_e = \frac{\left(L_1 + L_2\right) L_3 K_i}{L_1 L_2 \delta_i} \quad (3.14)$$

Where:
L1 – Length of Collector [m],
L2 – Width of collector [m],
L3 – Height of collector [m],
Ki – Thermal Conductivity of Insulation [W/mK],
δi – Thickness of edge insulation [m].

3.2 EFFICIENCY OF SOLAR AIR HEATER:
Efficiency of the solar air heater is calculated by the following equation,

$$\eta = \frac{Q_u}{A_p G_T} \times 100 \quad (3.15)$$

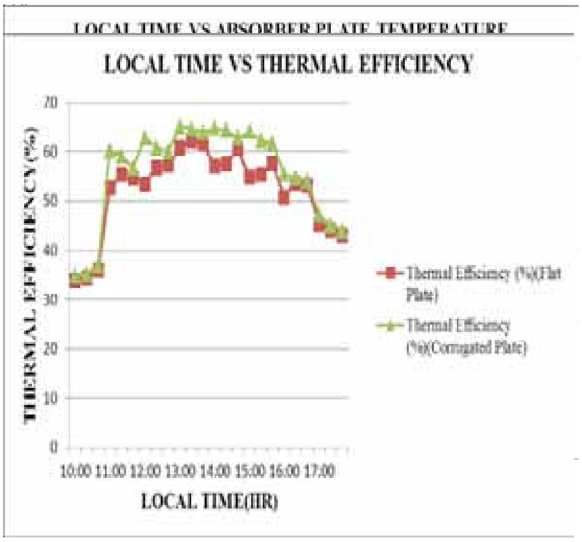

Figure 4.2 Comparison between Local Time and Thermal Efficiency

- The Highest thermal efficiency of solar air heater achieved by Flat plate is 62.32% and the thermal efficiency of solar air heater achieved by Corrugated absorber plate is 65.10%. So, the thermal efficiency of solar air heater achieved by Corrugated absorber plate is more than Flat absorber plate.

5. CONCLUSION:
Followings are the conclusions of my whole project work:

- The absorber plate temperature of solar air heater obtained with Corrugated absorber plate temperature is more than Flat absorber plate.
- Solar air heater Absorber plate temperature increases with increase of Solar insolation when mass flow rate remains constant.
- The Thermal efficiency of solar air heater obtained with Corrugated absorber plate is more than Flat plate absorber plate.
- The Thermal efficiency is greatly depends on Local time and Solar isolation.

REFERENCES

• G.D Rai, Khanna Publication, "Solar energy Utilization". • S.P.Sukatme, "Solar Radiation". • Gupta, D., Solanki, S.C., Saini, J.S., "Thermohydraulic performance of solar air heaters with roughened absorber plates". • Hossein Ajam, Saeid Farahat and Faramarz Sarhaddi, Vol. 8 (No. 4),"Exergetic Optimization of Solar Air Heaters and Comparison with Energy Analysis". • Hikmet Esen, "Experimental energy and exergy analysis of a double-flow solar air heater having different obstacles on absorber plates". • Ehsan Mohseni Languri1 and Davood Domairry Ganji," Thermal Aspects of Solar Air Collector". • Choudhury, C., Anderson, S.L., Rekstad, J., "A solar air heater for low temperature applications", Solar Energy, Vol. 40, pp. 335-344, 1988. • Gupta, D., Solanki, S.C., Saini, J.S., "Thermohydraulic performance of solar air heaters with roughened absorber plates", Solar Energy, Vol.61, pp.33-42, 1997. • Zhao, Q., Salder, G.W., Leonardo, J.J., "Transient simulation of flat-plate solar collectors", Solar Energy, Vol.40, pp.167-174,1988.