Experimental Investigation of Thermal Performance of Double-Flow Solar Air Heater Having Cylindrical Fins

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Abstract— Present study experimentally investigates thermal performance of Solar Air Heater (SAH) having three different types of absorber plate (Type-I, Type-II, and Type-III) in presence of natural solar intensity. Type-I is a simple absorber plate without any surface augmentation. While in Type- II black painted cylindrical aluminums cans as cylindrical fins are attached on the flat plate with vertical-staggered position and Type-III is similar to type-II but fins having holes on its surface. Experimental investigation reveals that the average daily thermal efficiency is highest in Type-III in presence of solar intensity.

I. INTRODUCTION

In the renewable energy side, Sun is the mother for all sources and harnessing the solar energy in proper way scan eliminates the energy crisis of the world.

The simplest and the most efficient way to utilize solar energy are to convert it into thermal energy for heating applications by using solar collectors. In solar air heater, solar energy is collected by means of an absorbing plate and the collected heat energy is transferred to heat transferring medium such as air [1, 3].

Energy storage is not only plays an important role in conservation the energy but also improves the performance and reliability of wide range of energy systems, and become more important where the energy source intermittent such as solar. In field of solar heating systems, water is still used as a heat storage material in liquid based systems, while a rock bed is used for air based system, but when you compare the volume requirements for the storage of heat energy between water and phase change material, you will see that the water heat storage requires almost five times amount of space as the latent heat storage material (Paraffin wax, PCM heat storage), this space savings would result in reduced costs for insulation and construction [4].

The main applications for SAHs are:

- Space heating
- Paint spraying, Drying for agriculture purposes
- Seasoning of timber, curing of industrial products,
- Curing/drying of concrete/clay building components, etc.

There are different factors affecting the SAH efficiency:

- Collector length
- Collector depth
- Type of absorber plate
- Type of glass covers plate
- Number of glass covers plate
- Number of fins
- Mass flow rate
- Wind speed, etc.

Increasing the absorber plate shape area increases the heat transfer to the flowing air, but on the other hand, it increases the pressure drop in the solar air heater which increases the required power consumption to pump the air flow crossing the collector [5].

This investigation presents an analysis of efficiency evaluation of a double-flow SAH. An experimental set-up, described in the next section, is constructed and tested at Sri Sad Vidhya Mandal Institute of Technology, Bharuch (latitude 21.70 °N, longitude 72.97 °E), and Gujarat. The efficiency of the SAH determines from the experimental measurements and compared with different absorber plate augmentation.

II. EXPERIMENTAL SET-UP AND MEASUREMENT PROCEDURE

Collector performance tests are conducted on geographical location of Barouche (latitude 21.70 °N, longitude 72.97 °E) at SVMIT Engineering College, Barouche.

In order to avoid fabrication of several solar air collectors for different absorber plate configurations, a collector frame with interchangeable absorber plate is designed. Another objective of this design is to prevent thermal performance difference, which might occur due to construction differences.

In this study, three types of absorber plates have been used. The absorber surface which is the most important part of the SAH consisted of a Flat plate

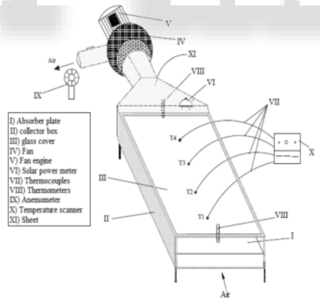
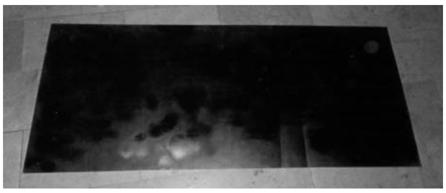
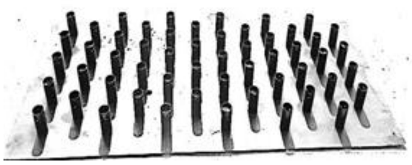


Fig. 1: A Schematic Assembly of the Solar Air Heater (SAH) System [9]

in SAH-I, 54 aluminum hollow cylindrical fins (Cans of“AMUL COLD COCO”) having surfaces coated with black color attached on top surface (above channel only) of flat plate in vertical–staggered position in SAH-II as shown in fig.2.Type-III absorber is similar to type-II but the fins (aluminum cans) having holes on its surface as shown in fig.3.



Type -I Absorber Plate for SAH-I



Type -II Absorber Plate for SAH-I fig. 2. Photographs of Constructed Different Absorber Plates of Solar Air Heater (SAH) System

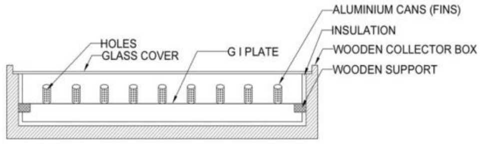


Fig. 3: Schematic of solar air heater (SAH-III) System having Type-III absorber plate.

All Waste aluminum cans of “AMUL COLD COCO “are heated to remove paint (barrier) on surfaces and then deposited carbon (converted from paint by heating) is removed by HCL (hydrochloric)-Acid and cleaned with water. Now these processed aluminum cans surfaces are coated with black color known as cylindrical fins as shown in fig.4.

Fig. 4: Photographs of constructed Fins from waste aluminum cans of “AMUL COLD COCO”

The absorbers are made of galvanized iron with black color coating. Dimension and plate thickness for three absorber plate is 200.3 cm, 90.2 cm and 0.6 mm. The cylindrical fins having diameter 4.5 cm and length is of 10.0 cm. There is 54 cylindrical fins arranged in vertical staggered position, having center to center distance between each fins is 18.0 cm. Collector box is made of wooden ply sheets of thickness 1.7 cm. Normal window glass of 5 mm thickness is used as glazing. Single cover glass is used in all three collectors. Thermal losses through the collector backs will mainly due to the conduction across the insulation (Thermo coal sheet of thickness 1.3 cm) and those cause by the wind and the thermal radiation of the insulation are assumed negligible. Thermocouples are positioned at inlet and outlet of SAH along the direction of flow for Inlet and outlet air temperatures measurement. Air is supplied to SAH at different mass flow rate using adaptor by changing voltage. Air speed is measured with using digital Anemometer. The total solar radiation incident on the surface of the collector is measured with a digital solar power meter. This meter was placed adjacent to the glazing cover, at the same plane, facing due south. The measured variables recorded at time intervals of 30 min and include: insulation, inlet and outlet temperatures of the working fluid circulating through the collectors, air flow rates (by digital anemometer). The air is provided by a radial fan with a maximum 0.5 kW power. The radial fan placed at the outlet of the collectors in exhaust duct which suck the air from atmosphere.

Constructed SAH-I Fig. 5. Photographs of performance of SAH system having Type-II absorber plate under natural solar intensity

After installation, the three SAHs were left operating several days for normal weather conditions for analysis of thermal efficiency under natural solar intensity as shown in Fig.5. All tests for measuring the performance of practical thermal efficiency were began at 9:30 AM and ended at 4:00 PM. After work out on SAH-III, 7 kg Grid were inserted into the fins of SAH-III to analyze the efficiency with ESM during day time compare to that of without energy storage material (ESM).

Fig. 5: Photographs of performance of SAH system

III. THERMAL PERFORMANCE ANALYSIS

During day time solar flux (solar radiation) impinge on SAH and some amount of it absorbed by SAH and other remaining portion of total flux go waste without use.

A. PRACTICAL THERMAL EFFICIENCY

The practical thermal efficiency of SAH is the ratio between absorbed solar flux to total solar flux impinge on solar collector

The practical thermal efficiency of the solar collectors (η_{th}) is defined as the ratio between the energy gain and the solar radiation incident on the collector plane,

$\eta_{th}= [\dot{m}.\ C_{pa}.\ (T_{a,\ out}\ -\ T_{a,\ in})]\ /\ [\ I_T.A_C]$ (1.1)

$\dot{m}=\rho_a.A_D.\nu_a$ (1.2)

Where,

η_{th} = Practical thermal efficiency of SAH,

$\dot{m}$ =Mass flow rate of flowing air on SAH (kg/sec)

C_{pa}=Specific heat of air (J/kg .k)

$T_{a,\ out}$ = Heated air temperature (°C)

$T_{a,\ in}$ = Ambient air temperature (°C)

ρ_a= Density of air(kg/m^3),

I_T = Intensityof Solar radiation (Watt/m^2),

A_C = Absorber area (m^2),

A_D= Area of exhaust duct (m^2),

ν_a= Speed of flowing air on absorber (m/sec)

IV. RESULT AND DISCUSSION

Solar air heater performance tests were conducted on geographical location of Bharuch (latitude 21.70 °N, longitude 72.97 °E). The solar air heater slope was adjusted to 5° to get more solar radiation. The collectors were instrumented with K-type thermocouples for measuring temperatures of flowing air at inlet and outlet of the collector. The collector efficiency improvements for double-flow type SAHs were calculated using Eq. (1.1). Air mass flow rate 0.0425 kg/s investigated at the experiments.

Experimental studies had been performed during April-May, 2014.

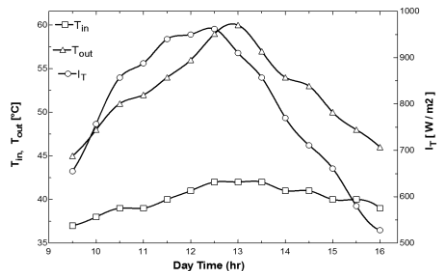


Fig. 6: Temperature variation of SAH-I at ṁ= 0.0425 kg/s state on 24th April, 2014

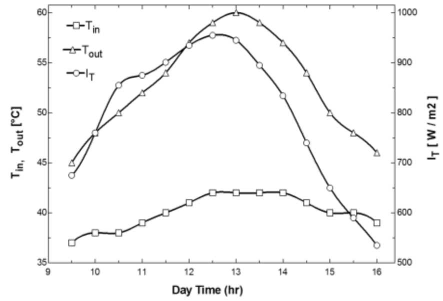


Fig. 7: Temperature variation of SAH-I at ṁ= 0.0425 kg/s state on 25th April, 2014

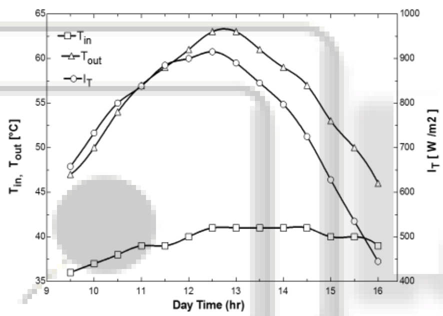


Fig. 8: Temperature variation of SAH-II at ṁ= 0.0425 kg/s state on 28th April, 2014

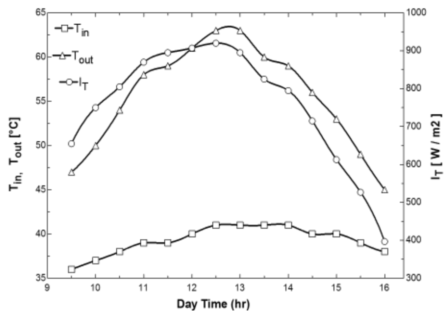


Fig. 9: Temperature variation of SAH-II at ṁ= 0.0425 kg/s state on 29th April, 2014

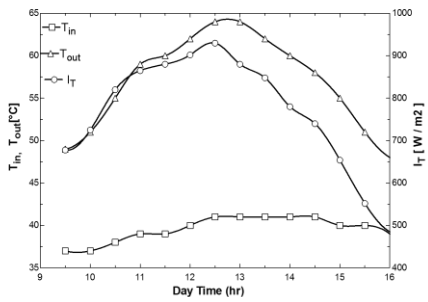


Fig. 10: Temperature variation of SAH-II at ṁ= 0.0425 kg/s state on 2nd May, 2014.

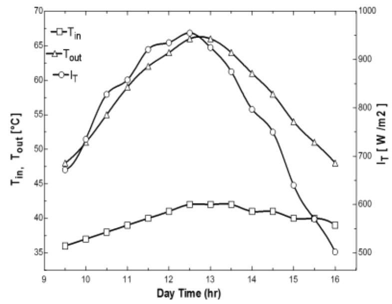


Fig. 11: Temperature variation of SAH-III at ṁ= 0.0425 kg/s state on 3rd May, 2014.

The measured incident solar radiations are shown in Fig.6 to Fig. 11,as expected, solar radiation increases in the morning to a peak value at noon and starts to decrease in the afternoon.

Figs. 6 and 7shows the variations of temperatures of SAH-I and mass flow rate is 0.0425 kg/s, during the experiments on 24th and 25th April, 2014 respectively. The difference between the mean daily air temperatures (Ta, in and Ta, out) of Type I collector at 0.0425 kg/s mass flow rate is measured as 12.29°C and 12.71°C on 24th and 25th April, 2014 respectively.

Figs. 8 and 9 shows the variations of temperatures of SAH-II and mass flow rate is 0.0425 kg/s, during the experiments on 28th and 29th April, 2014 respectively. The difference between the mean daily air temperatures (Ta, in and Ta, out) of Type II collector at 0.0513 kg/s mass flow rate is measured as 16.29°C and 16.21°C on 28th and 29th April,2014 respectively.

Similarly Figs. 10 and 11 shows the variations of temperatures of SAH-III and mass flow rate is 0.0425 kg/s, during the experiments on 2nd and 3rd May, 2014 respectively. The difference between the mean daily air temperatures (Ta, in and Ta, out) of Type III collector at 0.0425 kg/s mass flow rate is measured as17.42857 °C and 17.71°C on 2nd and 3rd May, 2014 respectively.

Efficiency versus day time with various collector types at air mass flow rate of 0.0425 kg/s is shown in Fig. 12. It is shown in fig.14 that the efficiencies increase with increase in solar radiation and maximum value at 12:30–13:30 PM in the noon, and then they start to decrease in the afternoon.

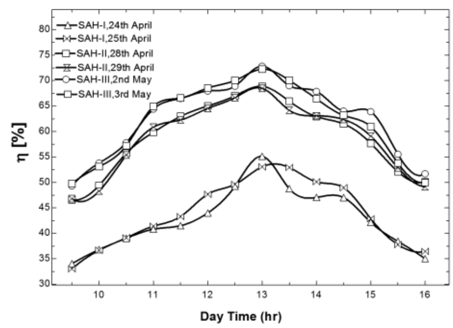


Fig. 14: Efficiency versus time with all types of SAH

The efficiency of the SAH-III (great turbulence, great vortex, double heat transfer surface area of fins) is higher than that of SAH-II (great turbulence, less heat transfer surface area of fins) and that of SAH-I (no turbulence, without fins), respectively. The study has shown that the solar collector supplied with SAH-III than SAH-I lead to a very significant improvement in the efficiency–temperature rise couple. It is because SAH-III leads to very great turbulence and great vortex in the collector.

The calculated mean thermal efficiencies for 0.0425 kg/s mass flow rates are calculated as, 43.35% for SAH-I, 58.91% for SAH-II, and 62.15 % for SAH-III respectively.

IV.CONCLUSION

According to the results of the experiments, the double-flow type of the Solar air heaters (SAHs) with aluminum cans as cylindrical fins has been introduced for increasing the heat-transfer area in SAH-II and that of doubled in SAH-III, more staying time of air due to turbulence in SAH-II than SAH-I and that of higher due to vortex and turbulence in SAH-III leading to improve thermal efficiency.

Efficiency for all SAHs varies with time due to position of Sun and efficiency decreases because of shadow of side walls of collector box and highest at around noon.The efficiencies increase with increase in solar radiation and maximum value at 12:30–13:30 PM in the noon, and then they start to decrease in the afternoon.

The efficiency of SAH-III is highest and that of SAH-II is higher than SAH-I. The daily average efficiency of SAH-III is highest equal to62.15 % .Similarly that of for SAH-II and SAH-I is found equal to 58.91% and 43.35%.

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