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Fabrication of Low Cost Solar using Polypropylene (PPR) Pipes – An Investigation

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Abstract: ***The conversion of solar energy into thermal and electrical form is possible is possible by the using photovoltaic modules and solar collectors. Solar collector absorbs the direct solar radiation and converts it into thermal energy, which can be stored in the form of sensible heat/ latent heat and a combination of both diffused in the working fluids. Present work deals with the performance evaluation of solar power based air heater fabricated using polypropylene (PPR) pipes foiled with aluminium. The use of PPR polymer results in the reduction of total initial cost of fabrication. The working fluid, which was air, is introduced into the collector system made of polypropylene pipes and were the fluid (air) is heated by using solar energy. The outer surface of the PPR pipes were paint in black color to maximize the absorption of incoming solar radiation. The air absorbs the entrapped heat of the pipe and the heated air was comes out of the system. Further, to minimize heat losses from the front collector, glass is used as a top cover. The change in temperature of the fluid with respect to time was observed. The effectual inlet load of fluid (air) on the performance of solar heater was investigated by varying the mass flow rate (MFR) of the fluid (air)***

Keywords— air solar heater, PPR pipes, mass flow rate, efficiency

I. INTRODUCTION

Solar Air Heaters (SAHs) are based on solar energy which is a renewable, abundant supplied and low cost resource of thermal energy. SAHs will results in the direct conversion of solar energy into thermal energy. They are found their applicability in the environment where the requirement of air temperature is below 60oC (Kurtbas and Turgut, 2006). Due to their simple design, easy to fabricate, easily maintained and requirement inexpensive material for construction, solar heaters are used extensively. The use of solar heaters can be understood as: in drying of industrial and agricultural purposes and space heating (Gupta and Kaushik, 2008). Some studies have reported the utilization of solar heaters for the purpose of water desalination and purification (Kabeel and El-said, 2013)

The major disadvantages of SAHs are that they uses low density air as working fluid, which has low thermal capacity. Hence, air based solar heaters required to handle large volumes of air to get desired heating value.

Different researchers have developed theoretical methods and designed parameters to optimize the desired heating value with respect to the inlet air load (Karsli, 2007;chow,2010).The work further illustrates the evaluation of designed parameters using experimental data. Further, the various factors on which affect the solar efficiency of the solar heater are: number of pipes, collector length, collector depth, types and shapes of plate, wind speed, material of insulation, frame dimensions etc.

SAHs have many advantages compared to liquid heaters with respect to the heat transfer medium. The efficiency of a SAH is coupled with the heat transfer between the absorber plate and the aircurrent and hence the absorber plate should be intended to a design such that it extracts maximum thermal energy.

The most prevalent way ofintensification of heat transfer is by increasing the turbulence inside the air heater. This most practiced technique and the modified arrangement will improve the absorptivity of the absorber plate. El-Sebaii and Al-Snani (2010) carried out a study on the effect of different selective coatings like black paint on performance of conventional flat plate SAH.

Initially solar heat collectors had very low thermal capacity of air due to its low convective heat transfer coefficient factor that was prevailing between the absorber plate and the air current in the duct. Hence various modifications have been made to enhance the thermal capacity rate, such as extending the surface in the form of fins or using artificial roughness. However, in this approach we will be using Polypropylene random copolymer pipes. These pipes are coated in aluminum intensify the heat transfer rate effectually. The use of plastics lowers the initial investment required, hence reduction in the payback period. The main disadvantage of plastic is that it cannot withstand a temperature of above 80oC. Because of this its use is limited to domestic or low temperature applications. Thus in the present study, aluminium foiled PPR schedule 40 material is used to construct SAH which can withstand temperature up to 90oC. The publication proposes the study, design, fabrication and testing consequences of a solar air collector.

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II. MATERIALS AND METHODOLOGY

2.1 Investigational Site and condition

All the experiments were conducted at Manipal University Dubai Campus(25°08'00.1"N 55°25'31.0"E) in the month of April 2017 to compare efficiency of aluminium foiled PPR solar air collector formerly with and of late without glass cover at a tilt angle of 30o.

2.2 Design of solar air collector

The SAH is fabricated with 40 schedule PPR pipes. The PPR pipes are fitted with 10 tee joints having inner diameter of 25 mm on both sides. The pipes are of 1000 mm length and outer diameter of 25 mm. The diameter is then reduced from 25 mm to 23.5 mm using a lathe machine. The pipes are then fitted with the tee joints using a welding machine. A coating of PVC cement is applied so as to prevent any leakage. All the pipes were sanded before being painted black. Matte black spray paints were used for painting. Plywood, 10.2 mm thick, is used to fabricate a wooden frame of dimensions 1117.6 x 685.8 x 40 mm. The above-mentioned pipe assembly is placed into the plywood box.8 mm thick aluminium coated thermocol insulation is provided below and 25.4 mm thick aluminium coated thermacol along the sides of the collector to reduce bottom heat losses. A glass cover of 4 mm thickness is screwed on the frame at a distance of 68.7 mm from the pipes with the help of L brackets.. The cover protects the collector surface from the dust particles that would settle on the collector and also minimizes the amount of wind blowing over the collector surface, therefore, reducing the convection losses, which increases efficiency.

2.3 Air Blower capacity and installation

A centrifugal blower having 3600 rpm (variable speed) was used to rush the air into the system. The flowrate was organized by a fan regulator. Temperature and air velocity were measured by an EXTECH Mini Thermo Anemometer. The intensity is found to be 950 W/m2and is measured using a Dr.Meter SM206 Digital Solar BTU power Meter. A comparison of efficiency in terms of mass flow rate of airformerly with and of late without cover is also studied. The blower is fitted with a 3 inch diameter PVC pipe of length 250 mm which is then reduced using a reducer to 2 inch diameter PVC pipe of 350 mm length. This pipe is further reduced to 1 inch diameter and fused to the inlet. PVC cement is then applied to prevent leakages and then wrapped around using duct tapes.

Figure 1. Working model of solar heater

III. RESULT AND DISCUSSION

The experiments were conducted on a PPR solar collector formerlywith top glass cover and of late without top glass cover. Experimental analysis shows that at a mass flow rate of 0.03 kg/s, the efficiency of the collector without cover is 4%. For the same mass flow rate of air, the efficiency of the collector with the glass cover was found to be 8%. For a constant flow rate of air at 0.03 kg/s, an experiment is conductedformerly with and of late without cover. The rise in temperature is plotted against time. The experimental results are shown in figure 2 and 3, respectively. The efficiency is derived as given below.

$$Q = \dot{m} \times Cp \times \Delta T \qquad (1)$$

$$\eta_c = Q/\ (A \times I) \quad (2)$$

Figure 2 and figure 3 show the efficiency vs the mass flow rate(MFR)formerly with and of late without the glass cover.

It is predominant that for the same mass flow rate, 0.035 kg/s, the efficiency of the collector with the glass cover is 13% and without the glass cover it is 9%. Hence this shows that the efficiency is greater with the glass cover, than without it. The maximum efficiency is 18.2% at an MFR of 0.05 kg/s with the glass cover, and 12% at 0.06 kg/s without glass cover.

Table 1. Efficiency values of PPR collector without glass

Time	m	C_p	dT	Q (w/m^2)	I	Efficiency (%)
9am	0.00354	1.0063	17	60.18	950	8.80
10am	0.00496	1.0063	16	79.36	950	11.60
11am	0.00548	1.0063	14.6	80.00	950	11.72
12pm	0.00567	1.0063	14	79.38	950	11.60
1pm	0.00587	1.0063	14	80.18	950	12.01

Table 2. Efficiency values of PPR collector with glass cover

Time	m	C_p	dT	Q (w/m^2)	I	Efficiency (%)
9am	0.00354	1.0063	26	92.04	950	13.54
10am	0.00496	1.0063	25	124.00	950	18.13
11am	0.00548	1.0063	23	126.04	950	18.43
12pm	0.00567	1.0063	22	124.24	950	18.23
1pm	0.00587	1.0063	21	123.27	950	18.02

- Cp : Specific Heat at constant pressure
- dt : Temperature difference (oC)
- Q: The rate of heat transfer (W/m^2)
- I : Current in Amps

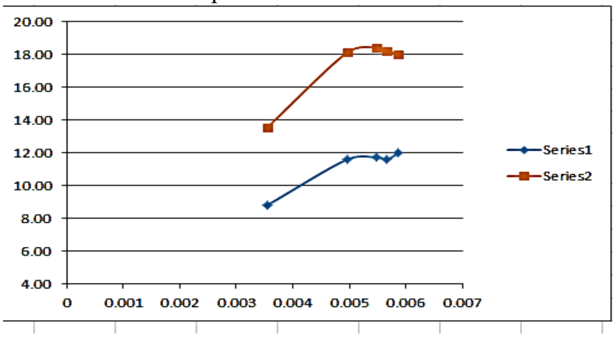

Figure 2. Time vs efficiency [1-with out glass, 2-with glass]

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Table 3: Efficiency and heat flow values with glass without glass

S.No	Time	Ambient Temp (°C)	Inside Temp (°C)	Outlet Temp (°C)	Temp. Difference (°C)	Q Heat flow rate(W/m²)	η Efficiency
1.	9 am	30	30	38	8	16.33	2.36
2.	10 am	34	34	45	11	22.46	3.24
3.	11am	38	38	49	11	22.46	3.24
4.	12pm	40	40	54	14	28.58	4.12
5.	1pm	41	41	56	15	30.62	4.42
6.	2pm	39	39	53	14	28.58	4.12
7.	3pm	35	35	46	11	22.46	3.24
8.	4pm	32	32	42	10	20.42	2.94

Table 4: Efficiency and heat flow values with glass.

S.No	Time	Ambient Temp (°C)	Inside Temp (°C)	Outlet Temp (°C)	Temp Difference (°C)	Q Heat flow rate(W/m²)	η Efficiency
1.	9 am	34	60	53	19	38.79	5.59
2.	10am	37	65	57	20	40.83	5.89
3.	11am	40	70	65	25	51.04	7.36
4.	12pm	43	75	69	26	53.08	7.65
5.	1pm	45	82	72	27	55.12	7.95
6.	2pm	45	83.1	71.6	26.6	54.31	7.83
7.	3pm	44	80.7	69.1	25.1	58.24	7.39
8.	4pm	41	77	64.9	23.9	48.77	7.04

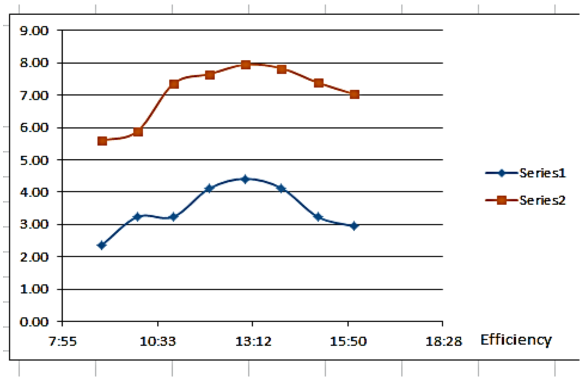

Figure 3. Time vs Efficiency for constant air flow rate of 0.03 m/s [series 1: without glass, series 2: with glass]

IV. CONCLUSIONS

This publication deals with experiments conducted on a SAHsetup to estimate and elucidate the consequences of mass flow rate of air on collectors. The SAH is fabricated and tested without and with top cover. The efficiency without cover is 4% and with cover 8% as estimated through the results. Collector efficiency of SAH is amplified with cumulative upsurge in mass flow rate of air. Maximum efficacy is18.2% with top cover was obtained at mass flow rate of 0.05 kg/s.

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