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CONFERENCE PROFRAMME

Thursday, June 04	Friday, June 05	Saturday, June 06
	Breakfast	Breakfast
14.00-15.00 Registration of participants	08.30-09.30 Registration of participants	09.00-13.00 Possible trip
15.00-15.30 Opening ceremony	09.30-11.00 Oral presentations "Sections 1 and 2"	13.00 – 14.00 Brokerage Section ”Green Partners”
15.30-18.00 Plenary session	11.00-11.30 Coffee break	14.00- Participants departure
18.00-20.00 Welcome cocktail	11.30-13.00 Oral presentations Section 1 and 2"	
	13.00-14.30 Lunch	
	14.30-16.00 Oral presentations "Sections 1 and 2	
	16.00-16.30 Coffee break	
	16.30-17.30 Workshop1:”Conceptual models of energy recovery from waste leather industry” Workshop 2: ”Education and training in Hydrogen based economy”	
	19.30-22.00 Conference dinner	

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SECTION 1: THERMAL EQUIPMENT AND RENEWABLE ENERGY

SECTION 2: RURAL DEVELOPMENT AND RENEWABLE ENERGY

SECTION 3: ENERGY RECOVERY FROM INDUSTRY WASTE

AN EXPERIMENTAL COMPARISON BETWEEN CORRUGATED AND POROUS PLATES OF SOLAR AIR HEATERS AT VARIOUS FLOW RATES

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ABSTRACT

Solar air heater systems are used both for domestic and industrial applications. Efficient solar heaters are depending basically on the absorber plate type and shape and the air mass flow rate. The present paper presents some experimental results on two solar air collectors: one with porous absorber and the second with one corrugated absorber. The two collectors have identical geometry. The tests were made in climatic conditions of Bucharest - Romania (44° 26' 0" N / 26° 6' 0" E). The parameters were sampled for both collectors in the same time, in order to obtain a direct comparison between their behavior. The measurements of ambient temperature, solar irradiance, wind speed, absorbing plate temperature and the inlet and outlet air temperature were performed for various air flow rates throughout the collector. The result shows that the efficiency of the collector with porous absorber is higher than the one with corrugated absorber for the same air flow rates and in the same outdoor conditions.

Keywords: Solar air collector, Thermal efficiency, Porous absorber, Corrugated absorber

1. INTRODUCTION

The solar energy technologies have a relatively low cost and are environmentally friendly. One of these technologies is referring to solar air heater system. They are simple devices that heats air by utilizing solar energy from the sun. There are various factors affecting the air heater efficiency like the type of the absorber plate, glass cover, air mass flow rate, collector size, wind speed, air inlet temperature, etc. Among all, the absorber plate shape factor is the most important parameter in the design of any type of air heater. Several designs for solar air heaters have been proposed and some of them provided good performance. Research was performed in order to experimentally investigate the efficiency of a single and double pass solar air heater having fins attached and using a steel wire mesh as absorber plate [1]. The study reported higher efficiency values for double pass collector in comparison with single pass ones by 7–19.4%. Other researcher investigated the case of porous baffles with different thicknesses soldered on the collectors' back [2]. The results indicated that the highest collector efficiency and air outlet temperature are achieved by solar air heating system with a thickness porous baffles of 6 mm and an air mass flow rate of 0.025 kg/s. Both experimentally and numerically investigation are known for the thermal efficiency of the single pass solar air collector with offset strip fins attached on a plate in the air flow pass [3].

Another study experimentally investigated the thermal performance of double and single flow for three types of solar air collectors, namely flat plate, finned and "V" corrugated [4]. The

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double pass operation of the collector leads to further improvement of the efficiency compared to the single pass of operation in all three types.
In [5] it is presented an experimental investigation on the thermal performance of a solar air heater with three different shapes of obstacles and without obstacles. The test results always yield higher efficiency values for the type with obstacles than for the type without obstacles flat plate collector. The obstacles ensure a good air flow over and under the absorber plates, educe the dead zones in the collector and create the turbulence. Experimental research was performed to determine the effect of an artificial roughness on a surface on the heat transfer to fluid flow in the duct of a solar air heater [6]. The absorber plate is the most important component due to its role in a solar collector for air heating. The thermal efficiency of the solar thermal collector is increased by increasing the absorber area. Different modifications have been suggested and applied to increase the surface area of the absorber plate [7 , 8].

The first objective of this research was to experimentally determine the performances of two different solar air collectors. In this study were analyzed two types of solar air collectors with high thermal performance suitable for air heating:- first one with porous absorber made of soft steel and the second with U-corrugated absorber made of aluminum. The second objective of the research was to provide a comparison between the performances of these two types of solar air collectors at various air flow rates.

2. COLLECTORS DESCRIPTION AND EXPERIMENTAL SETUP

The two geometrically similar collectors, one with a porous absorber plate, and the other with “U”- corrugated absorber are presented in figure no. 1. The dimensions of two collectors are 1.4 m × 0.7 m × 0.08 m. Two types of absorber plates were used the first one was made of soft steel with two layers of a mesh wire and the second one was made of aluminum. The dimension and plate thickness for all two collectors were 1.52 m × 0.7 m × 0.0007 m and 1.4 m × 1.13 m × 0.00035 m respectively. Normal window glass of 4 mm thickness was used as glazing. Single cover glass was used for each of the two collectors.

The air flow throughout the collectors according to their structure was as follows: in the case of the porous plate, consisting of a doubled wire network arranged in a “V” configuration, the air current was directly oriented from the inlet to the outlet of the collector and in the case of single pass “U” corrugated absorber there were placed three baffles – figure no.1. The collectors were tested under different weather conditions; an experimental setup is constructed and tested in the Politehnica University of Bucharest, Romania.

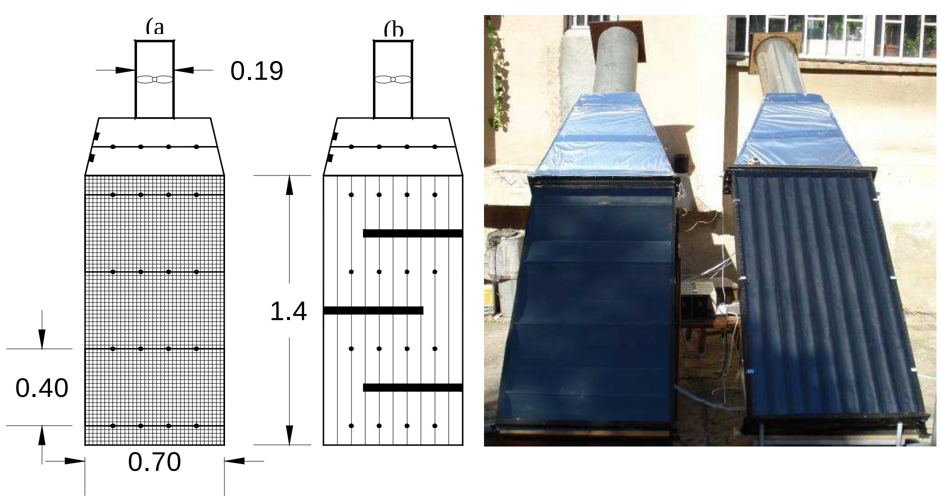

Figure 1: The experimental set-up and a schematic assembly of the solar air heater with (a) mesh absorber and (b) “U”- corrugated absorber. (all dimensions in m).

The parameters to be measured was: inlet, outlet, outdoor and indoor air temperatures, wind velocities, pressure and air flow, as well as solar irradiance intensity on the collecting area. There were used 32 thermal transducers distributed evenly, on the bottom surface of the absorber plates, at identical positions along the direction of flow for each collector. Inlet air temperatures were measured by two well insulated thermal transducers. To measure the outlet air temperatures four thermal transducers were fixed at the end section of each collector. The ambient temperature and humidity was measured by an electronic thermo-hygrometer placed behind the collectors' body. The total solar radiation incident on the surface of the collectors was measured by a pyranometer placed adjacent to the glazing cover of the collectors; all the measurement devices were connected to a computer. The measured variables were recorded at time intervals of 10 sec. and includes: absorber plate temperature at several selected locations, inlet and outlet temperatures of the air circulating throughout the collectors, ambient temperature and air flow rates. The air flow was provided by axial fans placed at the outlet of the collectors.

3. THERMAL ANALYSIS

The useful power supplied by the collector is the quantity of heat transferred to the air and can be obtained by computing the air temperature variation according to the following equation [9]:

$$Q_u = \dot{m}\, C_p\, (T_{a,out} - T_{a,in}) \tag{1}$$

where: $\dot{m}$ is the mass flow rate of air in [kg/s], given by equation (2):

$$\dot{m} = \rho \dot{V} = \rho v \frac{\pi . d^2}{4} \tag{2}$$

where: $\dot{V}$ is the volume of the air leaving the collector by the duct with diameter d, v is the air speed in [m/s] and ρ is the density of air in [kg/m^3].

The specific heat of air is assumed to vary linearly with temperature (^{o}C) by [10]:

$$C_p = 0.0057 + 0.000066(T - 27) \tag{3}$$

where: $(T_{a,out} - T_{a,in})$ is the air temperature increase between collector inlet and outlet.

The solar energy absorbed by the solar collector surface is given by:

$$Q_s = (\tau\alpha)\, I_T\, A_c \tag{4}$$

where I_T is the rate of incidence of radiation per unit area of the tilted collector surface [W/m^2], A_c the collector area [m^2] and $(\tau\alpha)$ the effective product transmittance– absorptance. The term $(\tau\alpha)$ represents the fraction of the solar radiation absorbed by the collectors and depends mainly on the transmittance of the transparent glass cover and on the absorbance of the absorbent. It can be evaluated by using the following equation:

$$(\tau\alpha) = \frac{\tau\alpha}{1 - (1-\alpha)\rho_g} \tag{5}$$

The thermal efficiency of a solar air collector is defined as the ratio of the power supplied by the collector to the total energy absorbed by the solar collector surface, efficiency of a collector is expressed as [9]:

$$\eta = \frac{\dot{m}\, C_p\, (T_{a,out} - T_{a,in})}{A_c (\tau\alpha) I_T} \tag{6}$$

After measuring the ambient temperature that is equal with inlet air temperature, the outlet temperatures, solar radiation, outlet air velocity and timing the intervals, the heating characteristic of the collector, the air flow rate, the heat flux and finally the conversion efficiency of solar energy in thermal energy were computed.

4. RESUALTS AND DISCUTION

Two different types of solar air collectors described in the previous sections were tested under the same outdoor conditions in the 2014. In the table no.1 are presented the average air temperatures measured during the day for each of the 4 lines inside the solar collector where thermal transducers was mounted and for a flow rate of 0.33kg/s: $T_{s,1}$, $T_{s,2}$, $T_{s,3}$, $T_{s,4}$- air temperatures for the first, second, third and fourth lines respectively of the collector with mesh absorber and $T_{a,1}$, $T_{a,2}$, $T_{a,3}$, $T_{a,4}$- air temperatures for the first, second, third and fourth lines respectively of the collector with "U"- corrugated absorber. Also $T_{s,o}$ and $T_{a,o}$ -outlet temperature - for mesh and "U"- corrugated absorber respectively was measured..

Table 1. Average air temperature on 01-10-2014

Time (min)	$T_{s,1}$	$T_{s,2}$	$T_{s,3}$	$T_{s,4}$	$T_{s,o}$	$T_{a,1}$	$T_{a,2}$	$T_{a,3}$	$T_{a,4}$	$T_{a,o}$
0	25	29	31	34	46	24	25	28	32	32
5	28	39	42	50	46	27	29	35	39	39
10	29	41	47	57	45	30	32	39	43	43
15	29	42	49	59	45	30	32	41	46	45
20	31	43	51	61	46	32	34	43	48	47

Figure no. 2 shows the efficiency of "U"-corrugated and porous collectors - as single pass and through-pass modes at 935 W/m^2 solar irradiation. It can be seen that the efficiency of the air collectors is strongly dependent on the air flow rate. The thermal efficiencies of both air collectors increased constantly up to 0.7 kg/s and then tend to approach a constant value. This figure clearly shows that the porous collector is more efficient than the corrugated plate. The air flow passing throughout the holes of the porous collector contribute to increase the surface per unit volume ratio and therefore increase the thermal efficiency in comparison with the "U"-corrugated collector. The "U"-corrugated collector has the significant advantage of absorbing a greater quantity of solar radiation than porous collector because of multiple absorption and reflections of incident radiation. This study shows that the porous collector is 2–10% more efficient than the "U"-corrugated plate collector. These two collectors were tested in the same experimental facility and under the same meteorological conditions, the comparison is considered to be a true reflection of the performance.

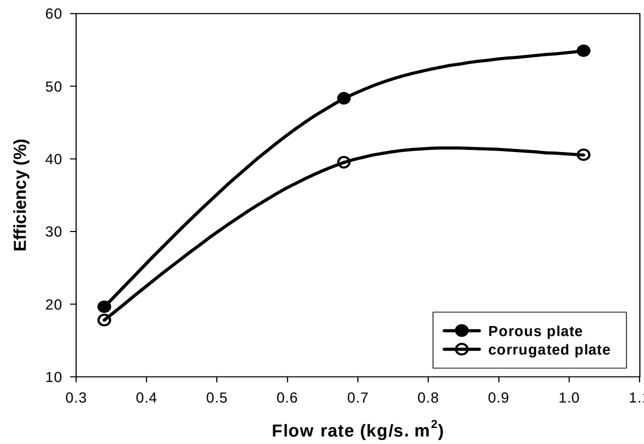

Figure 2: Comparison of two collector efficiency at the same flow rate.

In figure no. 3 is presented the temperature spectrum inside the collectors at three different air flow rate 0.33, 0.66 and 1 kg/s (0.34, 0.68 and 1.02 kg/s m^2). Figure no. 3a indicates that the high temperature zone exactly corresponds to the porous absorber while the low temperature zone corresponds to the corrugated absorber -as shown in figure no. 3b. The high temperature zone is caused by the large area contact between the air and network holes. From figure no. 3a and b, the results shows that by increasing the mass flow rate simultaneously the air temperature drops in collectors.

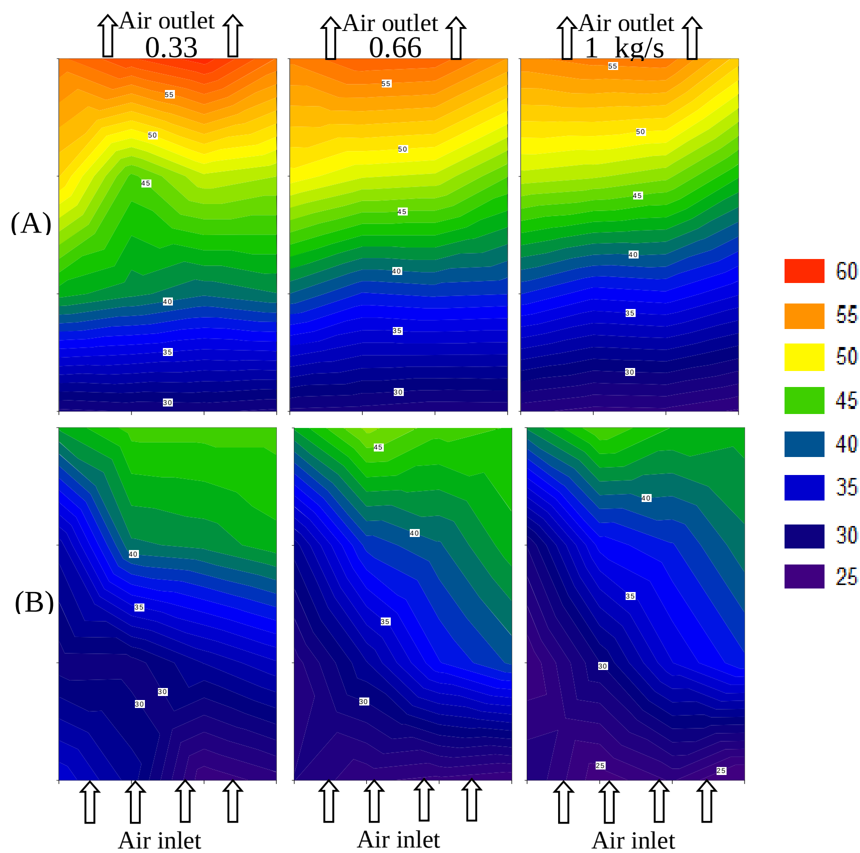

Figure 3. Temperature distribution of the absorber plat at different flow rate; A) porous absorber plate and B) “U” corrugated absorber plate.

5. CONCLUSION

Two types of solar air heat collectors with porous absorber and with "U"- corrugated absorber were studied comparatively in order to assess their performances. The test results showed that the efficiency of solar air collectors can be improved by using porous media. Also the results shows that the average performance of the solar air heater with porous absorber is approximately 6% higher than the collector with "U"- corrugated absorber. The effects of the air mass flow rate to the efficiency of collector were investigated and the collectors were tested in three different mass flow rates 0.33, 0.66 and 1 kg/s (0.34, 0.68 and 1.02 kg/s m^2). The thermal efficiency of the heater improves with increasing air flow rates due to an enhanced heat transfer to the air flow and an optimum value was obtained.

Acknowledgments

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