EXPERIMENTAL RESEARCH ON HIGH EFFICIENCY SOLAR AIR HEATING COLLECTORS

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Abstract: *The paper presents a comparison between two solar air heating collectors: a single passage and a through-pass one with the same geometry, cross section and materials used. Both collectors were exposed to the sun in the same conditions of irradiation, angle of inclination, wind speed and internal air flow rate. Thermal transducers were mounted in the same position for both collectors in order to obtain the inlet temperature spectrum. According to the experimental data the through-pass collector reported a higher efficiency for the same operating conditions and a more favorable pattern for the inlet air flow. Still, the noise level due to the fan is higher in the case of the through-pass collector.*

Keywords*: solar air heating collector, solar ventilation, solar collector heat transfer*

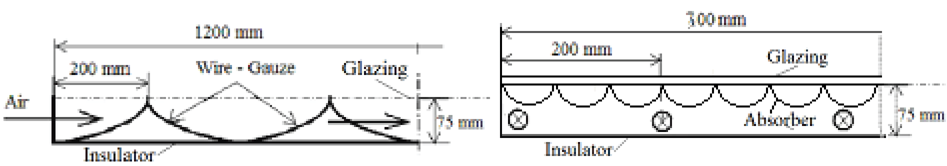
1. Introduction

Studies concerning the efficiency of the solar air heating collectors was conducted for: (i) identifying optimal geometry and structure such as single, double or multiple pass solar air collectors ex. [1-5]; (ii) enhancing the convective heat exchange using obstacles or baffles in order to divert the flow and raise the turbulence coefficient ex. [6-9] including the influence of the roughness on heat exchange ex. [10-14]; (iii) materials and criteria for selecting them ex. [15-19]. The studies provided basic information regarding: (i) the best geometry of the collectors (ex. the optimum depth of airflow channel should be 2.5 x10^{-3} times the length of the channel [1] indicating that the depth should be 2.5 mm when the length is 1 m.); (ii) optimum material selection (ex. [20] pointed out that using the solar selective coating on the absorber plate may not have significant positive impact [20]); (iii) maximum heat transfer enhancement (ex. [21] obtained good results for the effect of dimple shaped artificial roughness and [22] for multi "V" shape with a gap as the roughness element).

Starting from these points of view, the present paper presents a comparison between two types of solar heating collectors: one is a single passage collector with straight channels made of extruded aluminum, the other is a through-pass collector with a double wire net made of soft steel arranged in an "V" configuration. The analysis of the two collector efficiency was made under the same warm up conditions. The comparison between the two collector types allows calculation of the overall efficiency and the internal temperature spectrum.

2. The solar air heating collectors and setup structure

The two solar heating air collectors was manufactured with the same dimensions BxLxh = 0.7x1.4x 0.08 m - the cross section is the same - Figure nr. 1. Temperature transducers was mounted on the back side of each collector (16 pcs. /collector) in the same position and other 4 transducers was placed in the confusor section at the outlet– in the same section hummidity and pressure was measured using transduceres in order to make correction of the density of the air flow. The inclination angle for the collectors was 55^0 and the pyranometer used for measuring solar irradiation was placed also at the same inclination. The inlet air flow was provided by two fans electronically driven for a constant velocity of 1 m/s – air velocity was measured at the outlet section of the circular tube (the tube has the same cross section as the rectangular one from the inlet). Wind speed was measured with an anemometer. All the 50 parameters was sampled every 10 sec. - solar irradiation (1), humidity (2) and internal pressure (2), rotating speed of the fans (2), inlet temperature for each collector including the confusor(20x2), wind speed (1), external temperature near esch collector (2)– Figure nr. 2.



a. through-pass collector C1; b. single passage collector C2

Fig.1 Solar thermal air collectors (left: through-pass collector C1; right: single passage collector C2)
a. Shape of the through-pass collector C1; b. shape of the single-pass collector C2

Fig.2The thermal transducers for both solar thermal air collectors

The absorber for the the single pass collector is an aluminium sheet of 0.5 mm thick and for the through pass collector it was used a double leyered wire net of fine mesh of about 0,12 mm

3. Experimental research

The experiments was conducted for the warming up phase starting at the outdoor temperature t_0 =17.6^{0}C, relative humidity u_0 = 44.7 % and atmospheric pressure p_0 =1022 mbar. During the experiment the external pressure remained stable but temperature and humidity changed hence air density was re-calculated in order to derive volumetric air flow rate through the collectors. The data sampled at every 10 sec. was used for calculating the warming variation process T(t), the efficiency of the collectors η(t) and the temperature spectrum at 6 moments: at t_1= 3 min; t_2= 9 min; t_3= 17min; t_4= 56 min and t_5= 78min. In Figure nr.3 there is presented the temperature spectrum for each of the 6 moments both for single pass (C2) and through pass (C1) collectors. The results shows that collector C1 is more efficient due to the dense wire mesh absorber which provide more effective heat transfer than the collector C2 even this one has 3 barriers. In fact, it can be seen that in the second stage of C2 in the left hand of the thermic spectrum and in the third stage on the right side there are stagnation areas. In these areas the flow section is decreasing and the air velocity is increasing hence heat transfer less efficient. On the contrary for C1 there are no such stagnant flow areas and the heat transfer is better developed.

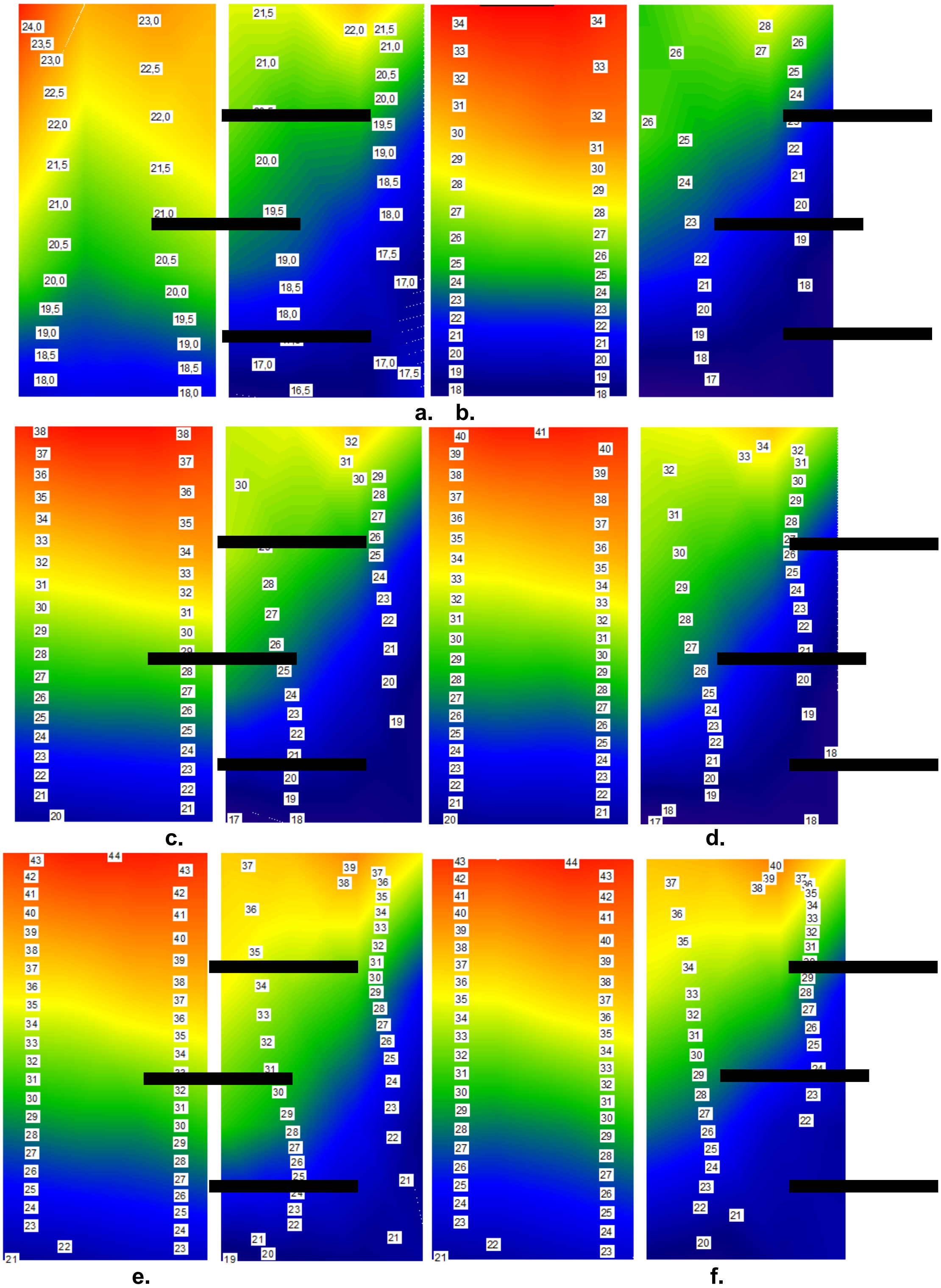
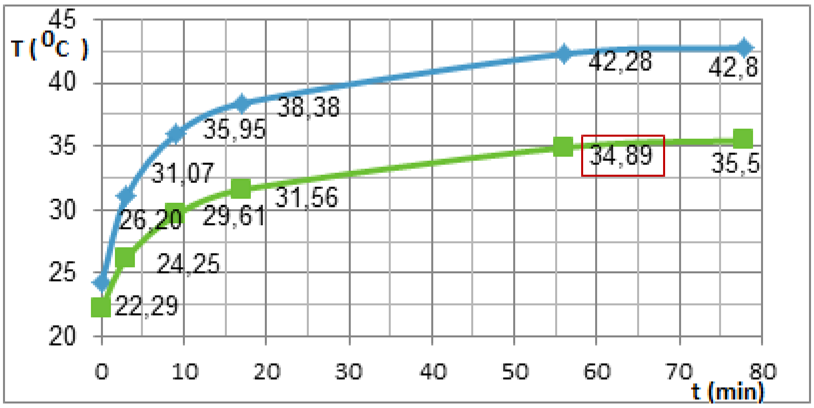


Fig.3 The thermal spectrum of the collectors at:
a. t_1= 3 min; b. t_2= 9 min; c. t_3= 17min; d. t_4= 56 min e. t_5= 78min
(left: through-pass collector C1; right: single passage collector C2)

In figure nr. 4 a,b are presented the warming up process and the overall efficiency of the collectors. The results shows a clear difference between the two collectors where C1 has a better behaviour even after 10 min form the starting moment of the testing.



a.

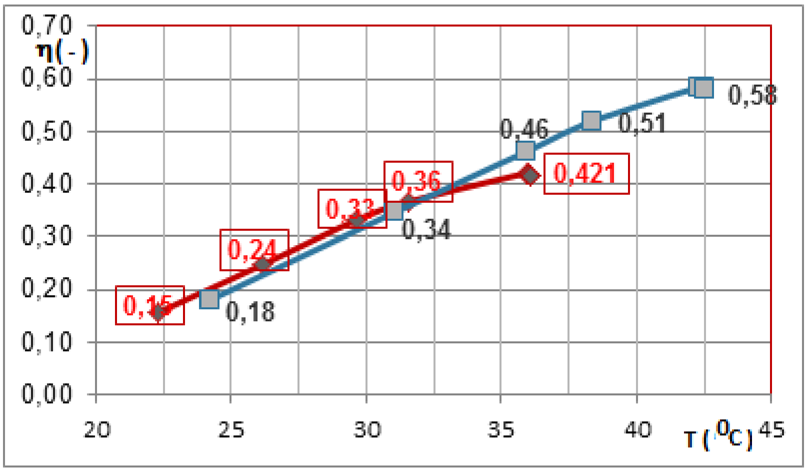


Fig.4 The thermal spectrum of the collectors at:
a. Worming up process; b. Efficiency of the collectors
(blue: through-pass collector C1; red: single passage collector C2)

The results shows that the collector C1 is close to an effciency of 58% since collector C2 reaches only 42%. Also it can be seen that after 10 minutes form starting the measurement process, the temperature difference between the collector C1 and C2 is about (6-7) ^{0}C and this value is mantained for all the 78 minutes during the testing process. Since the solar irradiation was about 900-950 W/m^2 it can be accepted that in natural conditions collector C1 is more efficient than C2 collector.

Conclusions

The paper presents a comparison between two solar air heating collectors: a single passage and a through-pass one with the same geometry, cross section and materials used. According to experimental data the through-pass collector reported a higher efficiency for the same operating conditions and a more favorable pattern for the inlet air flow. The warming up process shows a better behavior for collector C1 which is reaching a higher temperature (7^0 C) then collector C2 and about 16% more in terms of overall efficiency. More research must be performed in order to develop better flow pattern inside collectors in order to enhance heat transfer.

REFERENCES

[1] Hegazy AA. Performance of flat plate solar air heaters with optimum channel geometry for constant/variable flow operation. *Energy Conversion Management*, 2000;41(4):401e17.
[2] Ming et al., 2010 Experimental analysis on thermal performance of a solar air collector with a single pass Building and Environment 56 (2012) 361e369.
[3] Parker B.F., Lindley M.R., Colliver D.G., Murphy W.E., (1993), Thermal performance of three solar air heaters, *Solar Energy*, **51**, 467-479.
[4] Ramani B.M., Gupta, A., Kumar, R., (2010), Performance of a double pass solar air collector, *Solar Energy*, **84**, 1929-1937.
[5] Wijeysundera N.E., Lee Lee Ah, Lim Ek Tjioe, (1982), Thermal performance study of two pass solar air heaters, *Solar Energy*, **28**, 363-370.
[6] Abene A., Dubois V., Le Ray M., Ouagued A., (2004), Study of a solar air flat plate collector: use of obstacles and application for the drying of grape, *Journal of Food Engineering*, **65**, 15-22.
[7] Ben Slama Romdhane, (2007), The air solar collectors: Comparative study, introduction of baffles to favor the heat transfer, *Solar Energy*, **81**, 139-149.
[8] Choudhury C., Gary H. P., (1993), Performance of air heating collectors with packed airflour passage, *Solar Energy*, **50**, 205-221.
[9] Peng D., Zhang X., Dong H., Lv K., (2010), Performance study of a novel solar air collector, *Applied Thermal Engineering*, **30**, 2594-2601.
[10] Biondi P., Cicala L., Farina G., (1988), Performanceanalysis of solar air heaters of conventional design,*Solar Energy*, **41**, 101-107.
[11] El-Sawi A.M., Wifi A.S., Younan M.Y., Elsayed E.A.,Basily B.B., (2010), Application of folded sheet metalin flat bed solar air collectors, *Applied ThermalEngineering*, **30**, 864-871.
[12] Gupta D., Solanki S.C., Saini J.S., (1993), Heat and fluidflow in rectangular solar air heater ducts havingtransverse rib roughness on absorber plates, *SolarEnergy*, **51**, 31-37.
[13] Lanjewar A., Bhagoria J.L., Sarviya R.M., (2011),Experimental study of augmented heat transfer and friction in solar air heater with different orientations ofW-Rib roughness, *Experimental Thermal and Fluid Science*, **35**, 986-995.
[14] Messaoudi H., Ahmed-Zaid Le Ray M., (1997), *The role ofgeometry on improvement or reducing the exchange ofthermic turbulences in solar captors for air (inFrench)*, Proc. 3th Congress of Mechanics, TheMaroccan Society of Mechanical Sciences from theUniversity Abdelmalek Essaadi, Faculty of Science -Tetouan, , vol. **VI**, 637-644.
[15] Chiou J.P., El-Wakil M.M., Duke J.A., (1965), A slit-andexpanded aluminum-foil matrix solar collectors, *Solar Energy*, **9**, 73-80.
[16] Digel R., Fisch N., Hahne E., (1988), *High Efficiency SolarFlat Plate Collector with Capillary Structures*, In: *Advanced in Solar Energy Technology* vol. II, Bloss.
[17] Farooq M., Hutchins M.G. (2002), A novel design in composities of various materials for solar selective coatings, *Solar Energy Materials and Solar Cells*, **71**,523-535.
[18] Hachemi A., (1999), Technical note comparative study on the thermal performances of solar air heater collectors with selective absorber plate, *Renewable Energy*, **17**, 103-112.
[19] Mittal MK, Varun Saini RP, Singal SK., (2007),Effective efficiency of solar air heaters having different types of roughness elements on the absorber plate. *Energy*;32(5):739e45.
[20] Moummi N, Youcef-Ali S, Moummi A, Desmons JY., (2004), Energy analysis of a solar air collector with rows of fins. *Renewable Energy* 2004;29(13):2053e64.
[21] Saini, RP.VermaJitendra. (2008). Heattransferandfrictionfactorcorrelationsfora duct havingdimple-shapeartificial roughnessforsolarairheaters.*Energy* 2008;3:1277–87.
[22] KumarAnil,SainiR.P.,Saini, J.S., (2013), DevelopmentofcorrelationsforNusseltnumber and frictionfactorforsolarairheaterwithroughenedducthavingmultiV- shaped withgapribasartificial roughness. *Renew Energy*2013;58:151–63.