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A review of solar air collectors with baffles and porous medium: Type and applicatios

Mustafa Fouad Yousif* and **Maathe A. Theeb**

Mechanical Engineering Department, College of Engineering, Mustansiriyah University, Baghdad, Iraq

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ABSTRACT

The use of different types of porous media and barriers inside solar air heaters is our goal in this survey article. The influence of different barriers and porous materials of various shapes and types within the solar air collectors and the impact of different engineering parameters on heat transfer procedures and fluid movement had been discussed by examining their thermal and hydraulic performance. Numerical and experimental analyses were presented on different types of flat solar air collectors containing differently shaped baffles or various porous media with different strategies to enhance heat transfer such as fluid flow measurement, pressure drop control, and checking their thermal and hydraulic performance by measuring the increase in air temperature at intensity Solar radiation and fluid mass flow. Studies show that the presence of porous media enhances the heat transfer process and increases the efficiency of solar air collectors. The types different of solar air collectors have been shown. There are outstanding applications of solar air collectors in the industrial projects such as cooling and heating various buildings, heating air for combustion processes, and drying coal and paper.

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1. Introduction

The solar air collector is a simple thermal system used for low-temperature heating purposes. It consists of a transparent material plate such as glass and an absorption plate, and all the walls and other sides are thermally insulated. Solar air collectors have lower manufacturing and service costs, and they are less likely to wear and leak compared to liquid heater solar collectors [1]. Interest has emerged in recent years as a result of new global changes in heat dissipation using porous media, which achieve significant heat dissipation through thermal conduction and forced convection [2].

2. Solar air collectors with different baffles

Numerous researchers have studied solar air collectors with baffles numerically and empirically to improve their performance. H.Parsa et al. (2021) carried out a numerical study to improve turbulent convection heat transfer in a solar air collector containing interlocking cubic barriers located on the absorber panel, see 'Fig. 1. In this work, heat transfer and pressure drop characteristics are examined, and optimization is carried out founded on Taguchi's experience to obtain an optimal design and geometric arrangement of the barriers. The best thermal and hydraulic performance factor for solar air collector baffle is 3.43, 2.80, and 2.38 at Reynolds number 5080, 7620, and 10160 correspondingly. The best ratio of thermal Vijayakumar et al. (2021) carried out an experimental education that used baffles to augment the performance of a solar air collector by incorporating artificial roughness through baffles placed on an absorbent platter, see "Fig. 2". Different air mass movement rates of 0.02078, 0.02778, and 0.0346 kg/s were used to educate and analyze their effect on the solar air collector with and deprived of baffles. The results display that the baffles on the absorption panel in the solar air collector stretch the highest thermal efficiency and valuable energy gain by 89.3 percent and 1321.3 watts at an air mass movement amount of 0.0346 kg/s, 13%, 12% more advanced than the solar air heater without baffles. and hydraulic performance factors of

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* *Corresponding author.*
E-mail address: ehph017@uomustansiriyah.edu.iq (Mustafa Fouad Yousif)

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the planned baffle is 17.5 percent likened to the performance of the greatest design stated in the works.

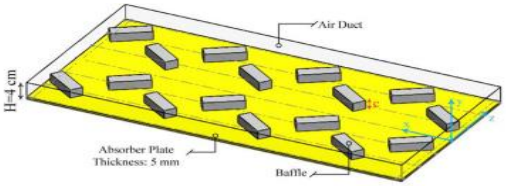


Figure 1. Diagram opinion of the solar air collector channel and barriers cuboid baffles attached over the absorber. [3]

Figure 2. Flat-platelet solar air collector and baffles V-shape tailored plate. [4]

Pham et al. (2021) carried out a numerical studied a solar air collector containing barriers on a backplate, see "Fig 3". In this study, the Reynolds number from 5000 to 20000, barrier angle from 300 to 1200, barrier obstruction ratio (Br) from 0.375 to 0.75, and barrier arrangement ratio (pr) from 2 to 8 were used to evaluate their effect on friction factor, Nusselt number, and thermohydraulic performance factor. The results of CFD analysis and Taguchi's method show that the optimal geometry of a = 900, pr= 6, and Br= 0.375 achieved the highest thermal and hydraulic performance factor. The highest thermal and hydraulic performance factors were 1.01 at Re= 5000.

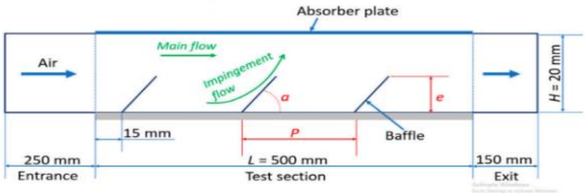


Figure 3. Solar air collector duct baffled on the backplate [5].

Ataollah et al. (2020) carried out a numerical and experimental education to analyze the performance of a solar air collector, see "Fig. 4". This work used a similar-flow solar air collector with double barriers and a similar-flow solar air heater deprived of baffles. The airflow rates used in this study are 0.009 and 0.011 kg/s. The fallouts display that the regular thermal efficiency of the solar air collector with and without barriers is 62.10-66.32%, 65.72-69.62%, and 71.12-75.11%, respectively. At the highest air mass movement amount, the uppermost prompt efficiency was got by 84.30 percent. The all-out nonconformity between the numerical and experimental results is 9.5 percent.

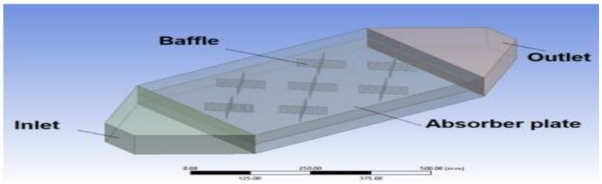


Figure 4. The geometry of designed solar collectors [6].

Charaf et al. (2020) carried out a numerical and experimental study of a solar air collector using baffles to enhance its thermal and hydraulic performance, see "Fig. 5". Air mass movement charges from 0.017 to 0.06 kg/s were used based on Reynolds numbers reaching about 2370 to 8340. The results display that the effective hydraulic and thermal performance is not fair to the purpose of the form of vicissitudes in the regular parameters of the new baffle positions. The best hydraulic and thermal performance factor is in the circumstance of the baffle in the primary portion of the air station, which inhabits 50 percent of the solar air collector.

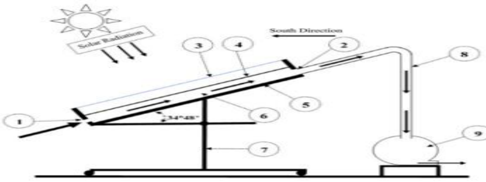


Figure 5. Picture and diagram of the trial setup. Inter harbor (1), Exit harbor (2), Lid glass (3), Absorber plate (4), Cloistering material (5), Air channel (6), Metallic provision (7), Cloistered pipe (8), Blower (9). [7]

Foued et al. (2019) carried out an experimental study of a solar air collector that aims to focus on the lack of heat transfer between the absorption panel and flow movement, for this purpose, a flat solar thermal collector was manufactured with some modifications, see "Fig. 6". The air mass movement rates used are 0.015, 0.026, and 0.036 kg/s. The thermal efficiency is greater for the transverse barrier in the solar air heater compared to another mode, using the same number of barriers and air mass movement degree. Finally, the pressure drops with the upsurge in the air mass movement amount, and the number of baffles is discussed.

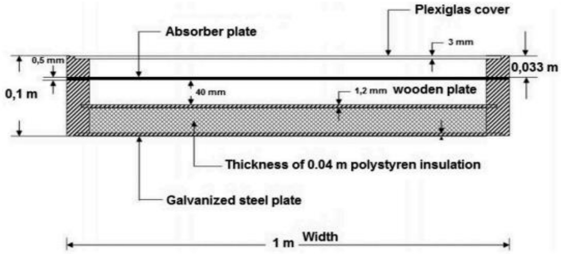
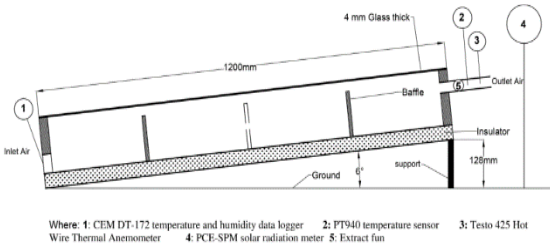


Figure 6. Longitudinal section of the solar collector with barriers. [8]

Ramadhani (2018) carried out an experimental education comparing a solar air heater with different numbers of barriers and a solar air heater without a barrier, see "Fig. 7". This study evaluated the efficiency of the combined solar air collector with barriers 2, 3, 4, and 8 and the solar air heater without bulkheads. The results show that the presence of baffles with a solar air heater significantly increases the efficiency of the system. The solar air collector containing 2, 3, 4, and 8 needed an average efficiency of 29.2, 31.3, 33.1, and 33.7 percent, correspondingly, while the solar air heater without barriers had 28.9 percent.



Where: **1**: CEM DT-172 temperature and humidity data logger **2:** PT940 temperature sensor **3:** Testo 425 Hot Wire Thermal Anemometer **4**: PCE-SPM solar radiation meter **5**: Extract fun

Figure 7. Schematic side view of collector model. [9]

3. Solar air collectors with different porous medium

Numerous researchers have studied solar air collectors with porous media numerically and experimentally to improve their performance. Amar et al. (2022) carried out a numerical study of a dual-pass solar air collector with the porous medium of magma rocks, see "Fig. 8". A mathematical type founded on energy balance equations was developed and resolved numerically using MATLAB software. The results show that the highest efficiencies obtained are in the variety between the intensity of 500 w/m^2 and 800 w/m^2 to 64 percent, correspondingly, the best air mass flow amount was 0.035 kg/s. The best porosity is 89 percent aimed at the solar air collector by taking into account the thermal efficiency and pressure drop. The optimum exit temperature was between 41.7 0C and 48.3 0C and was suitable for drying food and agricultural applications.

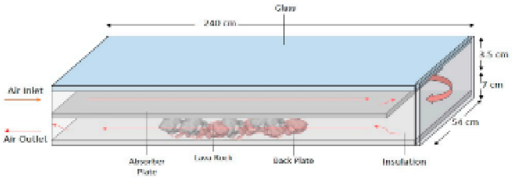


Figure 8. cross-section of double pass solar air heater with lava rock [10]

Mothana et al. (2021) carried out an experimental education of a dual-pass trapezoidal solar air heater with dual glass covers below forced and natural air passage conditions from its performance by totaling a porous media overhead the surface of the absorbent plate on one of them for comparison between them, see "Fig. 9". The air mass flow rates rummage-sale in this effort are 0.032, 0.046, and 0.061 kg/s. The highest efficiency gotten for the dual-pass solar air collector is at natural convection. The peak efficiencies of the solar air collector for the porous material and the absence of the porous medium were obtained as 87 percent and 82 percent for the case of natural convection and 67% and 81% for the forced convection circumstance of low mass flow, correspondingly.

Figure 9. Photograph dual-pass solar air collector with porous material [11]

Jalal et al. (2021) carried out an experimental study of thermal efficiency using porous media of stainless-steel mesh and steel wool in the inferior duct of a dual-push solar air collector, see "Fig. 10". The influence of air mass movement rate, radiation intensity, the porosity of wire mesh, and thermal conductivity of porous media was investigated in this study. The results show that the attendance of the porous medium in the dual-push solar air collector gives better thermal efficiency than the dual-push solar air collector without the porous medium. Thermal efficiency reached 79.82% when using steel wool as a porous medium.

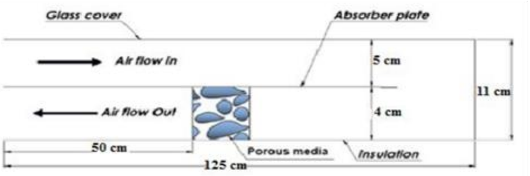


Figure 10. experimental test of solar collector [12]

Abhishek et al. (2020) approved an experimental education to improve solar air heaters, see "Fig. 11". Two models were developed for this study, one reference model of a solar air collector (A), and another modified perfectly of a solar air heater (B) combined with paraffin wax as the least-costly energy storage material. Moreover, the second type of solar air collector (B) was modified into a new model of the solar air heater (C) combined with an exact mixture of paraffin wax and gritty carbon dust. The results show that the modified third model (C) is better than the other models. The thermal efficiency of the model (C) is 97.1%, while about 57.41% of model (B) and about 50% of the model (A) were found.

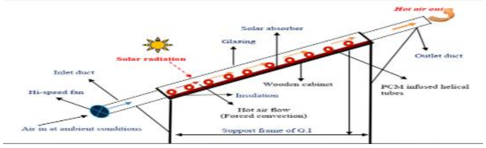


Figure 11. Schematic opinion of the experimental system of the novel Solar collector [13].

Murali et al. (2019) performed an experimental education on a solar air collector using aluminum cans and aluminum scraps. Porous media, was rummage-sale as a reasonable warmth storage material in a solar air collector, see "Fig. 12". This work used air mass stream amounts of 0.025 kg/s and 0.0916 kg/s. The results show that by using porous material in the solar collector, the outlet temperature is 1.5 ^{0}c times higher than the ambient temperature after sunset. It was found that the best heat transfer coefficient and thermal efficiency were at the mass stream amount of 0.025 kg/s with aluminum scraps compared to other cases.

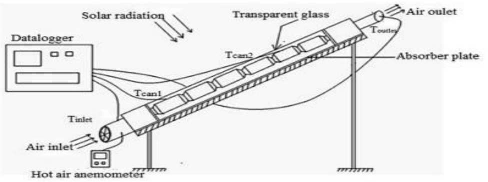


Figure 12. cans aluminium in solar air collector [14].

Satyender et al. (2019) carried out an experimental study of a double-pass solar air heater with mesh fins, see "Fig.13". The convergence fins in the inferior channel are 16 mounted at an angle of approximately 110 below and above the absorber plate and rear plate, respectively. In the second channel are placed 10 coatings of wire grid with a porosity of 0.96. The results show that the solar air heater's highest thermal and hydraulic efficiency was 93 and 80 percent, correspondingly, and the air mass movement degree is 0.03 kg/s and 0.023 kg/s. The best-heated air for a solar air collector at a temperature of 55 0C conforming to an air mass movement amount is 0.01 kg/s and solar radiation is around 823 w/m^2.

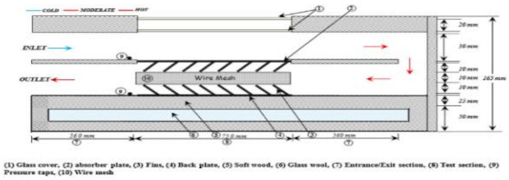


Figure 13. Diagram of the trial setup of solar air heater [15].

Dissa et al. (2016) carried out an experimental education of a solar air heater design using a composite absorber, see "Fig.14". The composite absorbent is produced by a porous absorbent complete from an aluminum grid and a non-porous absorbent made of a corrugated firm piece. The results show that the total thermal efficiency of a solar air heater is approximately 61 percent at midday solar, with all-out temperatures of 77, 142, 107, and 73 0C, correspondingly, for the glass shelter, porous absorbent plate, non-porous absorbent plate, and air.

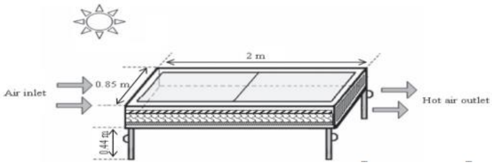


Figure 14. Experimental test of solar collector [16].

Sopian et al. (2009) carried out a theoretical and experimental study of a double-pass solar air heater with porous media, see "Fig. 15". The porous media in the bottom duct of a dual-pass solar collector provides a higher outlet temperature compared to a single-pass solar collector that does not contain porous media. To increase heat transfer, area density, and overall heat transfer rate, porous media in different pores were used in this study. Through the results, it was found that the attendance of the porous medium in another channel upsurges the exit temperature and thus upsurges the thermal efficiency.

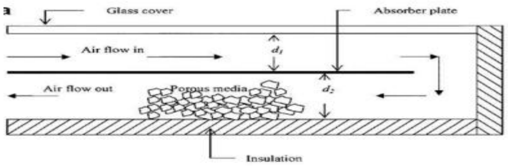


Figure 15. Schematic of the dual-flow solar collector with porous media [17].

4. Kinds of solar air collector

Solar air collectors can be confidential into single-flow or dual-flow with or without heat storage. In a single-flow solar air collector, air moves in one direction moreover overhead or below the absorber panel from the air inlet to the exit., though, in a dual-flow solar air collector, the air flows in two passages that may be either opposite or parallel [18], as shown in "Fig. 16". [19].

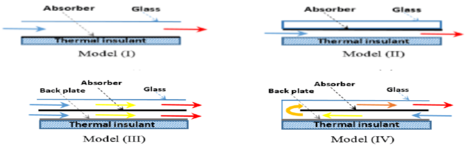


Figure 16. Airflow pass types of solar air collector: (I) an obverse flow-single pass, (II) a spinal flow-single pass, (III) a parallel movement-dual pass, (IV) countermovement dual-pass

5. Application of solar air collector

The application of solar air collectors in national space heating and crop drying (grains, fruit, vegetables, etc.) is extensive. Developments in the design and manufacturing of materials have run to higher efficiency and little cost, so solar air heaters can discover novel applications in industry such as [1] [20]:
1-Air preheating for combustion processes covering thousands of applications.

2-Drying charcoal, paper, bricks, etc. particularly brown coal, which is substantial for power generating stations.
3- Space heating for supplies, factories, schools, etc.
4- Air heating in cold seasons.
5- Air conditioning.

6. Conclusions

The issue is very important because solar air collectors are characterized by low manufacturing and service costs, it is also rarely exposed to erosion and leakage. Solar air collectors are rummage-sale in a wide diversity of fields and sectors. The heat exchange between the fluid movement and the absorbent panel mainly depends on the heat transfer coefficient. Improving the performance of solar air collectors is done by adding baffles and porous media inside a solar air collector between the fluid movement and the hot surfaces. Consequently, it is a determined effort to work on this topic. In this education, we surveyed the use of dissimilar types of baffles and different types of porous media by highlighting two main groups: solar collectors with different baffles, and solar collectors with different porous media. The results showed that the presence of porous materials or baffles inside the solar air collector enhances the heat transfer marvel between the fluid air and the absorption panel, therefore increasing the system performance and ensuring the optimum temperature increase. The different models of porous media and barriers were presented with strategies to improve heat transfer for the solar air collector in different stages, such as modeling and airflow measurement, heat transfer determination, pressure drop control, and thermal performance evaluation by measuring the increase in air temperature at solar radiation and under a certain flow. We concluded this review to present various applications of solar air collectors such as cooling and heating various buildings, heating air for combustion processes, and drying coal and paper.

Authors' contribution

All authors contributed equally to the preparation of this article.

Declaration of competing interest

The authors declare no conflicts of interest.

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