Performance Evaluation of a Double-Pass Solar Air Heater with Recycled Materials as Absorber Plate

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Abstract — The double pass solar air heater or DPSAH is a device that is integrated with the solar air heater in order to facilitate the transfer of heart energy from one part of the device to another part of the device so that the heart's energy can be transferred efficiently. Solar air heaters with just one pass are said to have a lesser impact on the generation of thermal energy since they lose out on the energy during the transfer process and, as a result, they generate less thermal energy. On the other hand, DPSAH exhibits a superior thermal efficiency, as this is the result of doubling the area of heat transfer, which is attributed to its energy-efficient design that allows it to achieve better thermal efficiency. The absorber plate located behind the collector of a DPSAH helps in the collection of solar energy by absorbing the light from the sun. There are many situations where a part such as this will be painted black in order to increase the absorption of solar energy, as this colour has a direct impact on the generation of a higher absorption of solar energy. It is intended that as part of the study, the use of recycled materials will be observed in the construction of the absorber plate, as well as the efficiency that is generated from the use of such materials. It should be noted that the majority of absorber materials which are usually used for this application are semiconductors or dyes, which can come in both organic and inorganic forms.

Keywords: Double Pass Solar Air Heater, DPSAH, Absorber Plate, Recyclable Materials, RACs.

I. Introduction

It has been seen that the solar air heater is a solar thermal technology, which has been used for heating or cooling air inside buildings, as well as use its application for the processing of heat in apparatus, as well as in the processing of heat in the production of electricity [3] [4]. The use of solar air heating systems can also be seen in agricultural backgrounds, where the warming of the edible crops and pulses helps to reduce the moisture content of those crops.

S. No.	Design materials/ parameters	Specifications
Collector		
1.	Tilt angle	9° 11' (south facing)
2.	Glass area	0.375 m^2
3.	Collector glazing	Window glass with 4 mm thickness
4.	Absorber plate	Width: 460 mm, length: 650 mm
5.	Bottom plate	Width: 460 mm, length: 725 mm
6.	Bottom insulation	20 mm thickness of glass wool
7.	Side insulation	20 mm thickness of glass wool
Storage material		
1.	Pipe, inner diameter	4 cm
2.	Pipe, outer diameter	4.6 cm
3.	Pipe length	60 cm
4.	Total no. of pipes	6
5.	Weight paraffin per capsule	0.595 kg.

Fig. 1: Physical factors present in solar heating devices[5]

The DPSAH is a more advanced form of solar air heater, which is seen to be more energy efficient that the single pass solar air heater[1] [2]. In the solar heating devices, a range of physical components are present such as the glass area, the bottom plate, the piping system, the absorber and the collector plates, along with others, which enables the effective build- up of the solar devices [6].

Further, [56- 67] Anand Patel et. al [68] HD Chaudhary includes thermal performance studies on solar water/air heater and solar cooker by varying the geometry of the absorber plate. The solar energy utilization is not limited to solar water/air hear & solar cooker and to be used in [69] [70] Patel Anand et al. for heat exchangers and [71] SK Singh et al. [72] Nikul K Patel for biofuels.

II. Objectives

1) The objectives developed for the article are as follows:
2) To inspect the working of a double pass solar air heater or DPSAH [9].
3) To analyse the usage of absorber plate in DPSAH [10].
4) To examine the efficiency of recyclable materials as the absorber plate in DPSAH [11].

III. Methodology

In the case of the SAH, the effective utilization of the two passageways for transferring heat energy has helped in the generation of hot air or in the conditioning of the warm air inside the designated passageway by allowing it to flow more freely. The cost effectiveness of the DPSAH is also one of the major features of the system, as it does not increase even when the efficiency of the device is increased because of the doubling of the transfer area of the device. [7]. An analytical and RSM or "Response Surface Methodology" combined approach has been used to identify the function of the DPSAH.

Using recycled materials as an absorber plate, a double-pass solar air heater can be evaluated using the following methodology. It begins with the design and construction of the experimental setup, including the configuration for double-pass flow, the air ducts, the absorber plate assembly, and the measurement instruments. To create the absorber plate, recycled materials are collected, cleaned, and processed [13] 14].

The next step is to conduct a series of performance tests under varying operating conditions. A number of parameters are measured throughout the system, including solar radiation, air temperature, air velocity, and pressure drop. In order to calculate solar air heater thermal efficiency, the heat absorbed by recycled material absorber plates is compared to the incident solar radiation [15].

By monitoring the temperature rise of the air as it passes through the heater, the heat transfer characteristics of the recycled material absorber plate are evaluated. Temperature difference between the air entering and leaving the system is used to determine the system's heat output [16] [17].

Comparing the solar air heater with the recycled material absorber plate to one using traditional absorber plate materials, such as aluminum or copper, is conducted. Using this comparison, we can determine how effective and efficient the recycled material absorber plate is at capturing and transferring solar energy.

Using recycled materials as absorber plates is also evaluated for its environmental impact and economic feasibility.

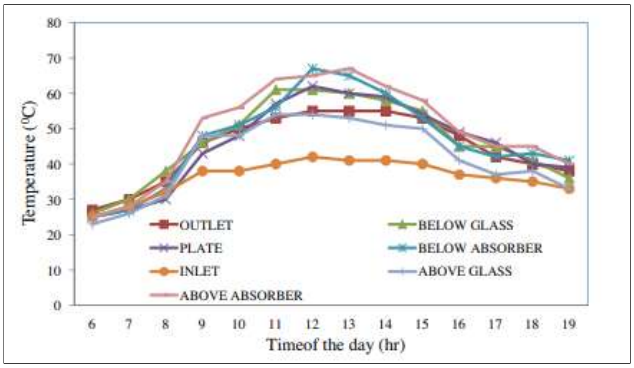

Fig. 2: Difference in temperature in the solar heater[2]

Depending on the daily time span, the variations in the temperature due to the absorbing heat capacity is observed in the above figure. It can be identified that the temperature below the absorber has been seen to be containing the highest temperature, instigating the fact that the absorber is the item which withholds the heat energy for the device [2].

IV. FUNCTIONING OF A DOUBLE PASS SOLAR AIR HEATER

In order for future generations to use clean energy, and choose renewable sources of energy, it is necessary to deploy solar energy as a mode of energy usage. SAHs have been shown to contain a glass cover that allows the solar energy to be reflected and an absorber plate that absorbs the heat caused by the solar energy refraction [8]. At the back end of the device, the back plate plays a very important role in the conduction of the heat into the air through convection [25] [26] [27].

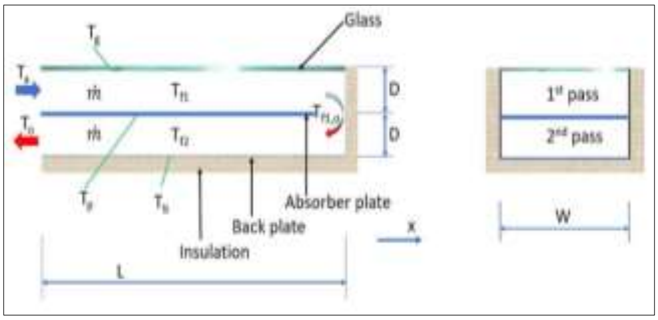

Fig. 2: Construction of a double solar air heater[3]

The temperatures present in each of the components differ, based on the absorption and the reflective capacities of solar energy [3].There is the transfer of air from the upper passage way to the bottom row of air passage, with the width of W, which helps in the formation of the two passes in the solar air heater[28] [29].

V. FUNCTION OF ABSORBER PLATE IN DOUBLE PASS SOLAR AIR HEATER

In order for the solar energy to be absorbed once it falls onto the surface of SAH, the absorber plate takes on an extremely important role in the absorption of the solar energy. It can be determined from the absorptivity of the plate acting as the absorption material, as well as its emissivity, the working capacity of the plate based on the absorptivity and emissivity of each plate. It is the passage way from one plate to another that allows the current of air to pass through, and so this is also able to produce a higher level of efficiency [36] [34] [42].

There are a number of modifications that can be made to the absorber plate in order to help in predicting the transfer of heat, such as using multiple-pass collectors in order to estimate the transfer of heat. The incorporation of finned or ribbed or baffled structures on the outer surface of the disc, along with such, also allows for efficient air recirculation by means of the finned or ribbed or baffled surfaces.[38] [43].

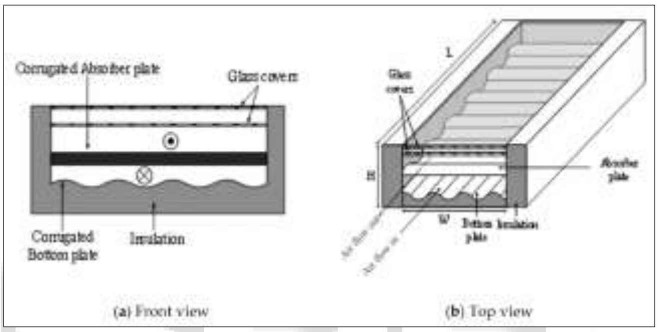

Fig. 3: Schematic view of a double pass solar air heater which is cross- corrugated in nature[1]

As noted in the above figure, the absorber plate has been developed in a wave like pattern, with a corrugated bottom plate, which helps in a greater absorbing solar heat.[14] [15].

Such an aspect is due to the fact that the wave like patterns help in the enlargement of the heat-transfer coefficient in terms of convection mode of energy transfer [10].

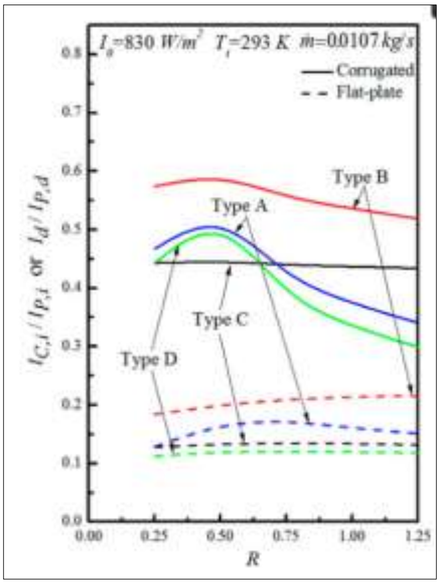

Fig. 4: Comparison of power consumption in congregated and flattened absorber plate[1]

Changing the three-dimensional configuration of the absorber plate displays a greater heat transfer for the air heaters, which is depicted by the above figure [1]. Power consumption increments has been seen to occur, which drastically increases the efficiency of the device.

VI. Efficiency of Recyclable Materials as the Plate Used as the Absorber

In most of the cases, the plate being used as the absorber in the DPSAH is constructed of metal such as copper, steel, or aluminium, where the absorption of heat is enabled by the heat absorbing capacity of the metallic items [11]. However, the implementation of recyclable materials such as recyclable aluminium cans or RACs, drastically reduce the overall cost of the device [22].

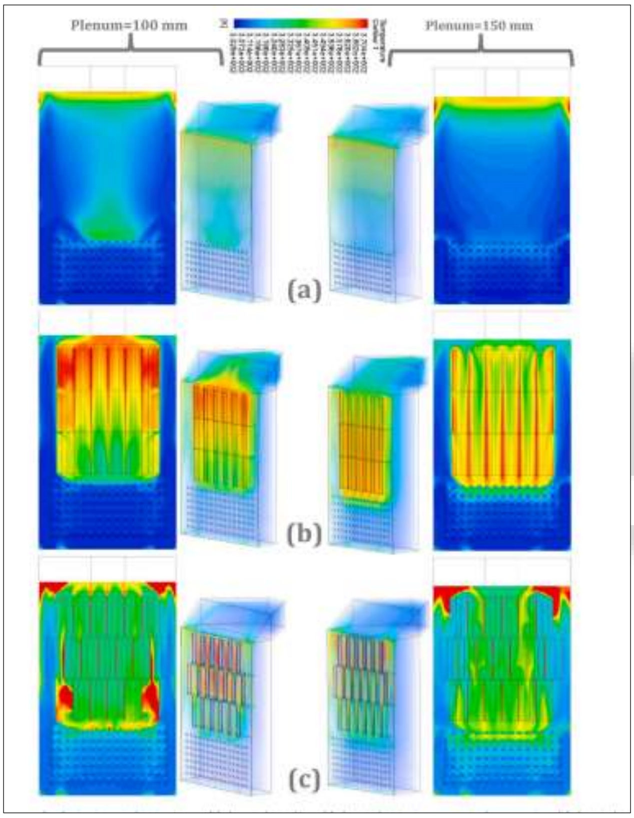

Fig. 5: Heating of RACs in the solar air heater[2]
(Source: 2)

The double-flow structure further increases the overall efficiency of heat generation and the RACs can also behave as the solar heat collectors [2] [23] [21]. With the construction of fins and plenum thickness of the absorbers, the environmental and economic cost of about 4.4 $ on a yearly basis is notified [2] [20] [24].

VII. Problem Statement

One of the major limitations that were found in this study was the lack of mathematical information associated with a deep analysis of RACs that were used as absorber plates.[50].

Additionally, there is a lack of information regarding the differences seen in the thermal efficiency of recyclable materials as compared to non-recyclable materials in the article, which makes it difficult to draw conclusions from the article [51].

There is a pressing need to investigate sustainable and cost-effective alternatives for solar air heating systems, and this study examines the performance of a double-pass solar air heater based on recycled materials as an absorber plate. In traditional solar air heaters, the absorber plate is generally made from conventional materials, which are often expensive and can have negative environmental impacts as a result of the extraction and manufacturing processes that are involved [52].

The use of recycled materials as absorber plates in solar air heaters is an interesting and potentially beneficial technology, but it needs to be investigated for its feasibility and performance, taking into account factors such as heat transfer characteristics, thermal efficiency, and overall system performance of the system [49;54;55]. The problem lies in the identification of recycled materials that are capable of efficiently absorbing and transferring solar radiation, maximizing heat transfer, and maintaining system performance while minimizing both the environmental impact and costs of the system [52] [53].

The purpose of this research is to evaluate the performance of a double-pass solar air heater using recycled materials as the absorber plate, giving valuable insight into its efficiency, effectiveness, and potential as a sustainable solution for solar air heating applications using recycled materials as the absorber plate.

VIII. Result

The thermo-hydraulic and thermal performance of DPPBSAH has been investigated using an analytical and RSM combined approach for the fixed porosity of the 95% under external recycling operation. The main reason of using the RSM or determine the optimum conditions of operation of the system. In the case of the present study, MATLAB analytical model has been used to provide a solution procedure [45].

Figure 6: Mass flow effect rate of DPPBSAH

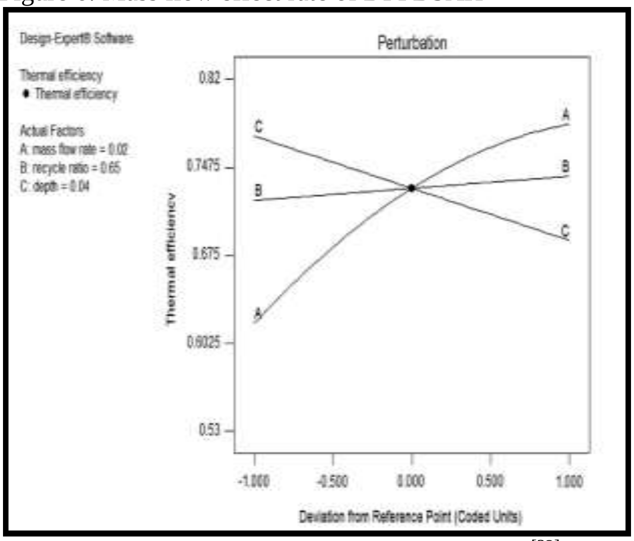

Fig. 6: Mass flow effect rate of DPPBSAH[32]

The above figure presents that the mass flow effect rate is 0.02 recycle ratio is 0.65, and channel depth is 0.04 between top glasses that cover upon the DPPBSAH thermal efficiency. Therefore, it can be said that the thermal efficiency of the DPPBSAH has risen with the increasing ratio of recycling from this rate of mass flow and the reuses channel death can be stated [32]. This can be the reason the recycle ratio is increasing the rate of mass flow within the lower and upper channels of the solar air heater. Apart from this, this depends on the rate of mass flow directly.

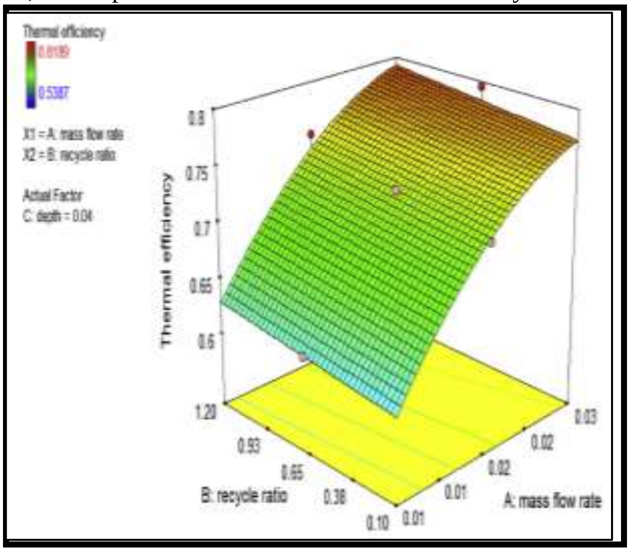

Fig. 7: Effect of the rate of mass flow and the recycle ratio of DPPBSAH[28] [29]

The above figure presents the effect of the rate of mass flow and the recycle ratio on the thermal efficiency of DPPBSAH.

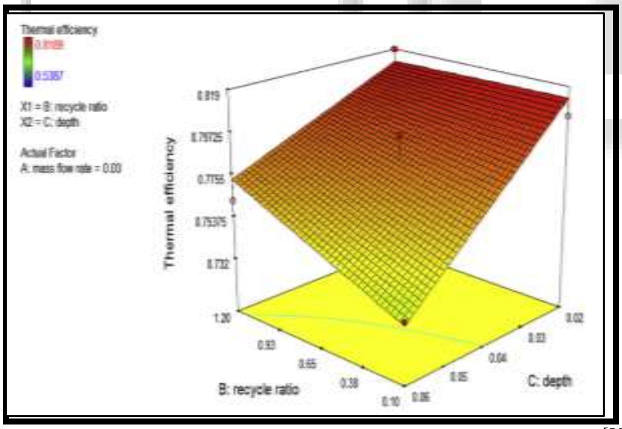

Fig. 8: Recycle ratio and the channel depth of DPPBSAH[28]

The above figure represents the recycle ratio and the channel depth among the glass cover on the "thermal efficiency of DPPBSAH". It can be clearly stated that the thermal performance of the DPPBSAH rises with the increasing amount of rate of the mass flow, the ratio of recycling however, decreases with the increased amount of channel depth. The maximum value of the "thermal efficiency" was found that 81% at G ¼ 1.2, D1 ¼ 0.02 m, and m_ ¼ 0.03 kg/s. Thermal performances concert about the transfer of heat process in the collector [32].

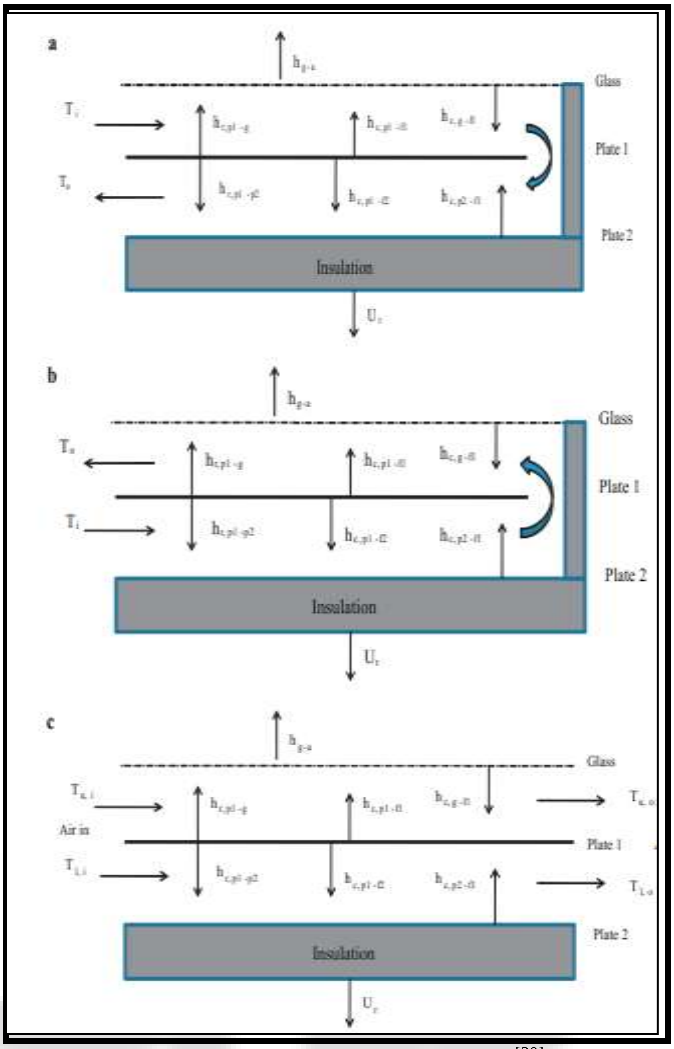

Fig. 9: Schematic diagram of DPSAH[30]

In the above figure, (a) is a Schematic diagram of the "counter flow double pass solar air heater" and (b) is a "counter flow double pass solar air heater" whereas (c) is related to the diagram of the "parallel pass double duct solar air heater"

The above figure shows the different arrangements of "double pass solar air" has been given. The DPSAH can be of two types that depend on the direction of the flow of fluid [30]. These two types of DPSAH are "parallel pass double duct solar air heater" and "return flow double pass solar air heater". The above figure is about the analysis of the arrangement of the parallel pass.

IX. DISCUSSION

Based on the above discussion it can be said that DPSAH has found that a number of studies have analyzed the effect of the different parameters upon the performance of DPSAH. The rate of mass flow of air and the porosity of the packing material are considered crucial parameters that can have an effect on the performance of the DPSAH. On the other hand, the ratio of recycling is another important parameter that also can affect the DPSAH performance along with the external recycling. From the result, it can be observed that maximum efficiency has been obtained if the ratio of mass flow and channel depth is the same in the both lower and upper ducts

[41]. Few experimental and analytical studies have investigated the packed bed, and integrated fins in the DPSAH, which can show a significant increase in the performance in the case of comparing a conventional system. However, the focus of this study is the function of the DPSAH and the use of recycling materials as the absorber plate. Designing the double pass SAH can be very complex as it depends on the duct dimensions, depth of pass as well as techniques for enhancement of the transfer of heat. Class's components can be used in most solar panels as well as recycling of glasses has already been well established in the well established across the industry. There are several other materials that can be used in the DPSAH that can be easily recyclable such as copper wire, aluminum frame, and plastic junction box [20] [21].

X. Conclusion

Therefore, the purpose of this study is to investigate the implementation of Recycled Aluminum Cans (RACs) as heat absorber plates in the development of double-pass solar air heaters. RACs are assessed as an alternative to fresh aluminum plates to determine their feasibility and performance.[44] [45] The objective of this study is to determine whether the use of RACs as heat absorber plates compromises the efficiency of the system in absorbing and transferring heat. It is possible to gain valuable insights regarding the suitability and effectiveness of recycled materials for solar air heaters by comparing their performance with those with fresh aluminium absorber plates.

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