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Augmenting the Efficiency of PVT Solar Air Heater Using DC Blower and Transverse Ribs

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Abstract

Solar air heaters (SAHs) are extensively utilized in agricultural drying, food processing industries, etc., In comparison to liquid solar air collectors (LSACs), the thermal efficacy of the solar air collectors (SAC) is very low. Therefore, there is a need to enhance the effectiveness of the SAH. Numerous researchers have proposed various methods to enhance their efficiency. Even though a lot of research has taken place to augment the efficiency of solar air heaters, still it is a thrust area where improvement is required. One of the key areas of improvement for solar air heaters is the use of a blower to cool the air heater. In this regard, this work is focused on improving the efficiency of a solar air heater by using a DC blower and transverse ribs with equal spacing. Experiments were executed at various velocities of the blower. Distinct flow rates of the air considered were 0.864 kg/s and 1.044 kg/s. Solar insolation is measured during the time span of 9 AM to 4 PM. The maximum thermal efficacy of the solar air heater obtained is for solar air heater fitted with the transverse ribs and the efficacy of the solar air collector fitted with transverse ribs provided a maximum efficacy of 42% higher than the classical solar air heater at a flow rate of the air of 1.044 kg/s.

Keywords *transverse ribs, outlet temperature, thermal efficiency, collector efficiency, panel efficiency*

1. Introduction

Solar energy is a renewable and sustainable energy source that can be utilized for free and almost year-round [1]. It is an environmental friendly energy. There are two main reasons why solar applications have gained importance. They are global warming and the depletion of fossil fuels [2]. Applications of solar energy includes from solar domestic water heating systems to solar power production systems [3]. Recently hybrid solar systems PVT systems are gaining importance [4], [5], [6]. One of the popular application of solar energy is the solar air heater [7]. The principle on which it works is that it directly absorbs solar energy and converts this energy into thermal energy. This thermal energy is transported to the working fluid [8]. They are simple in design, highly flexible and more over low cost. Moreover, they could be easily installed. But the only constraint is that the area must be free of shading and it must be ensured to have adequate sunlight on the solar air heater. Moreover, its maintenance is also less expensive. [9].

Aluminum and copper are commonly used as absorbers for solar air heaters. This is one of the drawback of solar air heaters because, the absorption capacity of these materials have low heat transfer coefficients with air. In this regard, many modifications have been carried out in the design by numerous researchers to improve the efficiency of solar air heaters. Few of them use artificial roughness [10], porous/packed beds [11], extended surfaces [12], tubular types [13], [14], [15], and different flow types. In 2013, Abhishek and Goel [16] conducted an exhaustive review of the modifications in the solar air heaters which can alter the accomplishment of a solar air heater. Some of the researchers have used phase-change materials. They used paraffin wax and composite materials that included mixed (Al2O3, ZnO2, and SiC) nanomaterials. By incorporating macro-encapsulated PCM into a dual-channel solar air heater, Mario Palacio et al [17] increased the efficiency of a solar collector. Qusay et al. [18] investigated the use of nano composites such as nano SiC, aluminium chips, and paraffin wax to increase the performance of a solar air heater. The limited heat conductivity of paraffin wax is a drawback. The advantage is that it can change phase by melting. This could be used to store energy. Heat exchangers have been employed by certain researchers to improve the efficiency of solar air heaters. Toshmamatov et al. [19] created a spiral heat exchanger solar air heater. This spiral heat exchanger was employed as an accumulator. Oil was employed as the working fluid. Few studies employed passive strategies to improve the heat transfer efficacy of solar air heaters, such as artificial roughness on surfaces, wavy surfaces, and turbulators in flow channels. Arun Kumar and coauthors [20] conducted a thorough evaluation of flow design adjustments that can increase the thermal performance of solar air heaters. The laminar sublayer behind the absorber plate has been observed to be disrupted by flow changes generated by various types of turbines. As a result, the heat transmission from the absorber plate is accelerated. Finally, this helps to increase air turbulence. Few people have employed ribs and wavy corrugated plates to improve the performance of a solar air heater. Dengjia et al. [21] improved the success of a SAH by fitting S-shaped ribs with a space in between them. Rajendra Karwa et al. [22] used ribs with V type discrete roughness on the absorber to improve the efficiency of the solar heater. Shailendra and co. [23] modified the design of a solar heater by using plates with wavy corrugations and impinging the air jet in array. Because conducting experimental investigations is an expensive and time-consuming process, several researchers ran simulations on solar heaters and attempted to make design changes. They used simulations to test multiple strategies for improving solar air heat. Few of them have created mathematical models to forecast the effectiveness of the changing configurations. Mabrouk et al. [24] used CFD simulations on rectangular SAH to induce turbulence in the flow by altering the flow passage into a curve. Ong [25] used a mathematical model to analyse the thermal achievement of SAH. Mohamad [26] altered the traditional SAH. His plan is to minimise losses over the forward cover in order to maximize heat transmission across the absorber. He added an additional cover and a porous membrane to boost heat transmission efficiency. He observed that the changed configuration outperforms the regular configuration in terms of thermal efficacy. Few academics have investigated the idea of cooling solar photovoltaic systems in order to improve their efficiency. Chandavar [27] attempted to measure the achievement of a SAH with a chimney and to offer module cooling for a solar system. SAHs have a wide range of uses in business as well as in everyday life. They are utilised in the drying of grapes, room heating, and HVAC systems [28]. Many changes have already been made to solar air heating systems in order to improve their efficiency. However, the SAHs are still unable to match the existing standards. It is, nonetheless, a possible area for improvement. The efficacy of SAHs can be increased by using a forced circulation device to circulate the air. According to available sources, a significant amount of work has been done to improve the thermal performance of solar air heaters, and several modifications have been made by numerous researchers to increase the thermal efficacy of SAH's used for drying purposes. Recently, phase change materials have been used. Due to growing energy demand and energy conservation measures, solar air heaters are unable to meet the needs. In this regard, there is a need to improve the solar air heater's efficiency. They rely on solar air warmer environments in conjunction with PV systems, particularly in rural locations where drying facilities are limited. Farmers in such areas may benefit through this. Furthermore, older PVT hybrid solar air heater systems had A.C fans to boost thermal efficiency. However, the use of A.C. blowers necessitate the use of external electricity. External electricity may not be available in isolated regions. In such instances, dc blowers are advantageous since they can be powered directly by solar energy. In this case, dc blowers not only improve the thermal efficiency of the PVT solar hybrid air heater, but also make solar integration possible. The literature rarely discusses these PVT systems. As a result, this provides motivation for this task. As a result, the goal of this work is to use a forced circulation driven by dc power while enhancing the efficacy of a SAH. Furthermore, the goal is to use two different blower air flow rates to improve the efficiency of the PV/T hybrid SAH.

2. Materials and Methods

2.1 Experimental setup

PVT/hybrid systems are becoming increasingly popular for a variety of applications such as grape drying and agricultural product drying. However, the efficacy of SAC is quite low. As a result, researchers are merging PV systems with thermal SACs to increase total system efficacy. Blowers are also installed to increase the efficiency of the SACs. The PV/T Hybrid is used in this work. An air dryer is made up of a PV cell, an air chamber, an absorber, and a blower. emanates from the thermal SAC's in order to improve the system's overall efficacy. The SAH is 1490mm long. The width is 658mm. Copper is used to make the absorber plate. One end of the air chamber is open to allow air to travel through. On one side, a blower is attached, and the other side is used for drying. The PV panel has a capacity of 100W. It is constructed from polycrystalline silicon solar cells. Charge controllers connected the solar panels to the batteries. The circuit's end is connected to an electric load. Table.1 shows the experimental setup specifications, dimensions of the solar air heater, rating of the blower, and panel. The power generated by the solar PV cells is used to operate the blower. This is done to boost SAH's efficacy. External power usage can be minimized using this way. This permits the system's total accomplishment to be boosted. The blower's air is utilized to cool the SAH. Thus, one technique for enhancing SAH achievement in this job is to provide cooling with the blower. Another approach of increasing the efficiency of SAH is to place transverse ribs in the air route at regular intervals.

Fig.1 Actual Solar air heater configuration

Fig.2 Solar air heater with blower

Table.1 Specifications of the experimental test rig

S. No	Particulars of Solar Panel	Specifications
1	Rated Power	100W
2	Voltage (Max)	20 V
3	Current (Max)	5.55 A
4	Open Circuit Voltage (VOC)	20V
5	Short Circuit Voltage (ISC)	5.8 A
6	Thermocouples	K Type
7	Inclination of panel	13^0

2.2 Methodology

A pyrometer is used to measure the sun insolation focused on the collector glass. The temperatures over the air at the intake and outflow of the solar air heater were measured using thermocouples positioned along the length of the solar air heater. These thermocouples are linked to a data logger, which records the temperature changes in the inlet and outlet air over a 30-day period. The data is averaged during this time period to determine the final data. Figures 1 and 2 show schematic views of the SAH and the data logger utilized for data collecting. The investigations were carried out without the use of a blower at first, and later with the blower fitted. Both cases had been subjected to a comparative study.

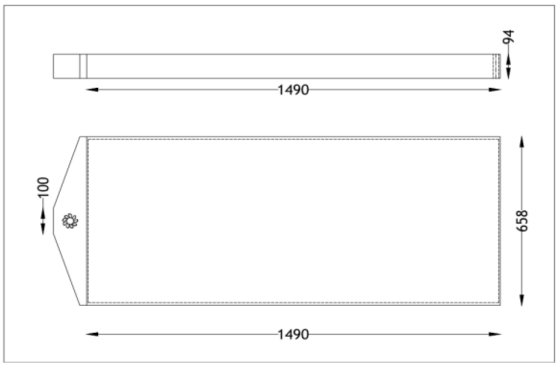

Fig.3 Plan of the classical solar air heater

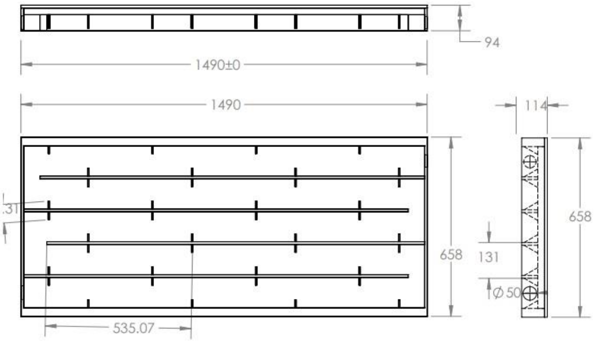

Fig.4 Schematic of the solar air heater with ribs

Fig.5 Pictorial view of the data logger used

3. Results and Discussion

The convective transfer of heat from the absorber to the circulating air above the collector determines the thermal efficiency of the SAC. The more effectively heat is transferred from the absorber to the air via convection in the collector, the more efficient the collector's thermal efficiency. Transverse ribs are inserted in the solar air collector in this study to improve the thermal efficiency of the solar air collector. Eq. (1) can be used to calculate the thermal efficiency of the solar air collector. Where Qu is the heat from the absorber plate that is used in this case for drying. As is the air flow rate given. Eq. (2) can be used to calculate Qu. Eq. (3) can be used to compute the efficiency of a solar panel. Eq. (4) can be used to calculate the overall performance of the PVT system. This can be calculated by adding the thermal efficacy of the SAC and the solar panel efficacy.

$$\eta th = \frac{Q_u}{A_s} \tag{1}$$

$$Qu = \dot{m}C(To-Ti) \tag{2}$$

$$\eta pv = \eta o[1-0.0045(Tpw-25)] \tag{3}$$

$$\eta T = \eta th + \eta pv \tag{4}$$

3.1 Effect of transverse ribbed constructions on outlet temperature

For one-month, solar insolation data is collected at various time intervals (9AM to 4PM). Temperatures at the SAH outlet were monitored throughout this time period for both the conventional SAH and the SAH equipped with transverse ribs. The average outlet temperatures were recorded for one month after thermocouples were inserted along a given distance in the absorber. Figure 6 displays the influence of outlet temperatures on conventional and transverse ribbed solar panels at different air flow rates from 9 a.m. to 4 p.m. Flow rates of 0.854 kg/s and 1.044 kg/s are considered. In this work, a dc blower was used instead of an AC blower, which was used in many cases. The opportunities for reducing fan speed in a DC blower are limited. However, a direct current source has been used to achieve a significant increase in efficiency. Only 25%, 50%, 60%, 80%, and 100% savings are feasible with a blower powered by a direct current source. Only three flow rates are possible with this % drop. In this work, only two flow rates are examined. It has been determined that the sun incidence is lowest in the morning. It was around 380 C around noon, with a flow rate of 0.854 kg/s. The exit temperature does not rise as the flow rate of air from the blower improves from 0.54 kg/s to 1.044 kg/s. This indicates that the blower and transverse ribs supplied in the SAH outperform the traditional SAH. This also demonstrates that increasing the air flow rate improves the temperature in the output to some extent. However, increasing the flow of air does not improve the exit temperature. Because the ribs hinder the air flow, the transverse ribs with regular spacing raise the exit temperature. As a result, the flow is disrupted. This promotes the transfer of heat through convection in the SAH. This causes an increase in the outlet temperature of the solar air collector. The range of values is clearly evident in the image, and it ranges from minimum in the morning to maximum in the afternoon, before decreasing in the evening. Furthermore, it was discovered that the transverse ribbed solar heater delivers the best outlet temperature of all the examples studied. The rise in temperature at the outlet is due to an upsurge in the contact area over the absorber and circulating air by providing transverse ribs and circulating air with the blower, which enhanced air disturbance.

3.2 Effect of thermal efficiency with time

Figure 7 depicts the influence of conventional and ribbed SAC performance at varying flow rates over time. Flow rates of 0.864 kg/s and 1.044 kg/s will be assessed. It suggests that the solar air collector that features transverse ribs and air circulated at a flow rate of 1.044 kg/s prevails over the conventional solar air heater circulated at flow rates of 0.864 kg/s and 1.044 kg/s, as well as the solar air heater equipped with transverse ribs and air circulated at a flow rate of 0.864 kg/s. Even with the conventional solar air collector, increasing the air flow rate with the blower boosted the efficiency of the conventional solar air collector. However, the transverse ribs have played a significant role in the advancement of the solar air collector. The combined effect of the transverse ribs and the blower has also significantly boosted the efficacy of the solar air collector. For a flow rate of 1.044 kg/s, the maximum efficiency achievable with the transverse ribs solar air collector is 42%.

3.3 Effect on power with time

Recently, experts discovered that by cooling the solar panels, the efficiency of SAH can be increased. This is accomplished by using a blower to supply air. Figure 8 depicts the power output of the solar PV panel with and without cooling. It demonstrates that the electricity produced by PV panels with additional cooling delivers 15% more power than PV panels without the cooling solution. This is due to the fact that when cooling is provided, the conversion efficiency of solar insolation into current improves. This causes the solar panels to produce more power. This layout improves the system's overall performance. The overall accomplishment of the system will improve as the performance of the PV panels improves.

3.4 Effect on efficiency of the Solar PV panel

Figure 9 compares the efficiency of a solar system with and without cooling. It suggests the efficiency of a photovoltaic system with added cooling provides greater performance than one without the cooling arrangement. The solar panels with cooling can attain a maximum efficiency of 18%. Higher temperatures have a significant influence on electronic components, and solar panels are no exception. Overheating causes energy loss. As a result, the efficiency of the solar panels decreases. When temperatures rise, so does the voltage or amount of electricity generate. This is due to the fact that electricity is produced by electrons. These electrons bounce back, resulting in a decrease in energy conversion in the solar panels. The energy efficacy of the solar photovoltaic system has been increased in this study by introducing a blower, which achieves the maximum permissible temperature in the collector, which is roughly 40^0 C in this case.

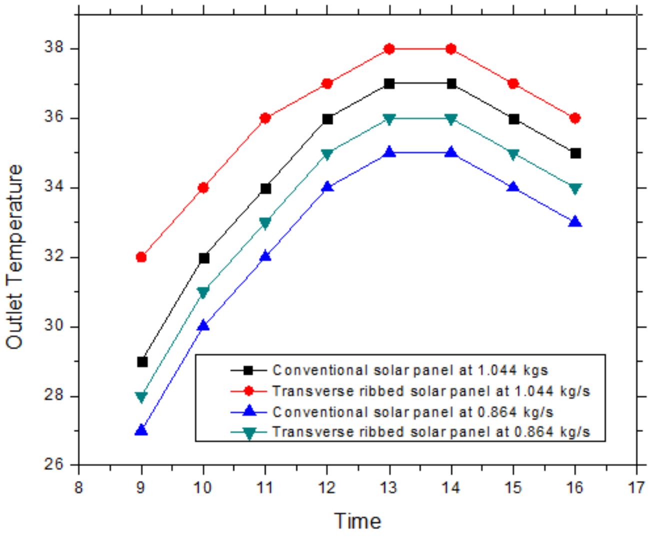

Fig.6 Effect of outlet temperature with respect to time for conventional and transverse ribbed solar panels atvarious mass flow rates of the air

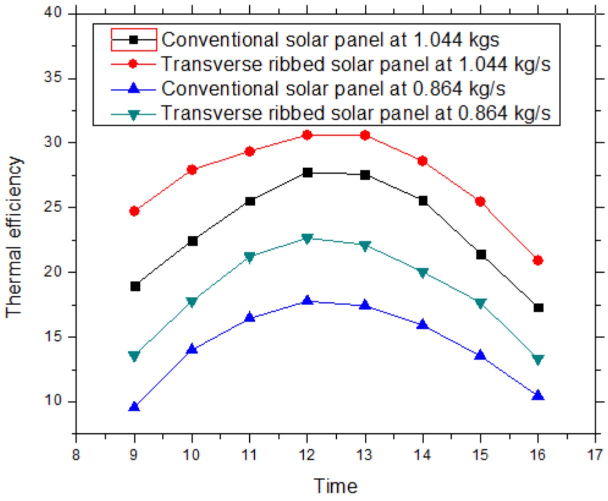

Fig. 7 Comparison of effect of efficiency with respect to time for conventional and ribbed solar air collector at various mass flow rates

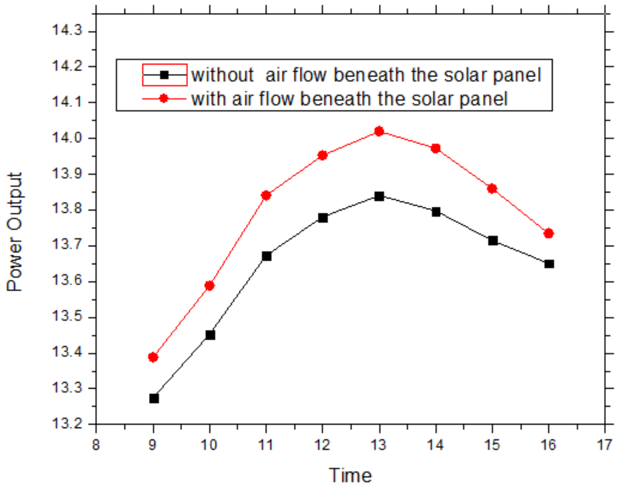

Fig.8 Comparison of power obtained from the PV panels with time for arrangement with and without cooling

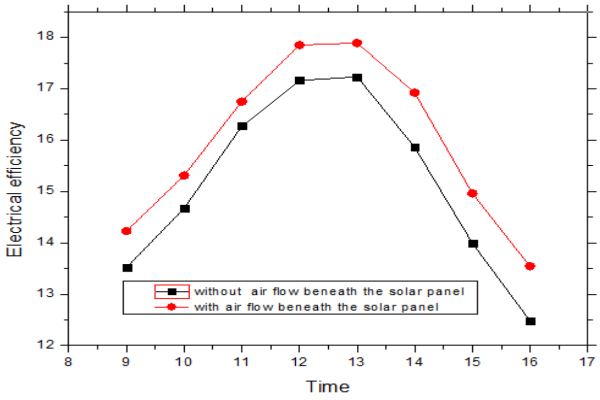

Fig.9 Comparison of photovoltaic efficiency of the solar panel for arrangements with and without cooling

4. Conclusions

The influence of a blower and transverse ribs with uniform spacing on the performance of a SAH was investigated in this paper. The combined effect of the blower and transverse ribs was investigated over time and in relation to other parameters such as outlet temperature, solar air collector efficiency, output power obtained with and without cooling arrangement, and photovoltaic efficiency of the PV panel. Conclusions were reached based on the following criteria:

(1) Maximum output temperature was achieved at a flow rate of 0.864 kg/s, and subsequent increases in air flow did not result in an improvement in SAC temperature.

(2) Air collectors with uniform spacing transverse ribs and a flow rate of 1.064 kg/s provided a greater collector efficiency of 42%.

(3) PV system with cooling arrangement provided 15% more power than PV system without cooling arrangement.

(4) The solar photovoltaic system with cooling has attained a maximum efficiency of 18%.

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