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Comparative Experimental Investigation of Simple and V-Shaped Rib Solar Air Heater

Anand Patel [*], Dr. Sadanand Namjoshi [†], Dr. Samit Kumar Singh [‡]

Email Correspondence*: akp1527@gmail.com

[1] Mechanical Engineering Department, LDRP-Institute of Technology and Research, India

[2] Mechanical Engineering Department, Madhav University, India

[3] Mechanical Engineering Department, Bhoj Reddy Engineering College for Women, India

Abstract:

Drying, desalinization, water heating, and power generation are just a few of the many ways in which solar energy can be put to use. Among the renewable energy sources, solar power has numerous advantages over fossil fuels and is thus a viable alternative energy option. The heating of air has wide industrial application and to fulfill the same generally electric heating coils are used which are highly power consuming also humidification air having typical application in dairy and pharmaceutical industries where water is sprinkled in the hot air may cause damage of electric heater. The objective of present research work is to fabricate experimental set up which gives hot air dryer using solar energy as source of heating. In the first phase of work of solar air heater with V-shaped rib will be fabricated and then generated hot air will be used for drying purposes. The K type thermocouples will be used to measure temperatures at various locations. The air blowers are used for purging air into the solar hot air heater.

Keywords: V-shaped Rib, Solar Air Heater, Alternative Energy, Air Velocity.

1. Introduction

It is possible to transform solar energy into thermal energy or electric energy. Photovoltaic modules use solar energy to generate electricity directly, whereas solar collectors transform solar energy into heat. When compared to different types of solar energy collectors, solar air heaters (SAH) offer a number of benefits.

The plate acts as a heat exchanger that absorbs heat to transfer to the working fluid in a fluid's flat plate collector, which differs from an air heater. With air heaters, there is no longer any need to move heat from one working fluid to another. Since air is being employed as the active agent, the method is less bulky and more straightforward. Solar air heaters do not suffer from the same corrosion issues that might arise with solar water heaters. Therefore, thin aluminum or steel plates can be employed with little effort. Thus, a solar-powered air heater is fundamentally more cost-effective and has a longer lifespan. Since there is no pressure in the system, thinner metal sheets can be utilized instead of the thicker ones required by liquid flat plate collectors. Leakage is also not a major issue in solar air heaters, unlike liquid collectors.

Poor transfer of heat from the absorber plate to the air is a major issue with poorly built air heating collectors. Several methods exist for increasing the air heater's heat transfer coefficients, leading to

[*]Mechanical Engineering Department, LDRP-Institute of Technology and Research, India.
[†]Mechanical Engineering Department, Madhav University, India.
[‡]Mechanical Engineering Department, Bhoj Reddy Engineering College for Women, India.

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efficiencies on par with those of liquid flat plate collectors. Due to air's low density, far more air than would be needed to capture the same quantity of heat in liquid would need to be handled. Air's poor thermal capacity is another drawback. Low-temperature commercial applications, as well as domestic use for drying seafood and clothes are just some of the many possible uses for solar air heaters.

An air heating solar collector with a finned and twisted tape absorber surface was investigated for its energetic and exergetic performances by Rajesh Kumar et al. [1]. The exergetic efficiency of a finned and baffling solar air heater (SAH) was studied by Sabzpooshani et al. [2]. Ajam et al. [3] used a MATLAB toolbox to optimize the SAH's exergy efficiency after developing a correlation for predicting its exergy efficiency. Kar [4] confirmed that there is an optimal inlet temperature for the solar collector with a flat plate in order to provide maximal exergy production at a certain mass flow rate.

The theoretical framework for modelling forced convection solar air heaters with one or dual glass cover was created by Bahrehmand et al. [5]. Ucar et al. [6] put a SAH through its paces with six distinct configurations of absorber surface fins. The study on the many forms of thermal energy storage employed in SAH was summarized by Abhishek Saxena et al. [7]. The thermal conductivity of SAHs with porous textile absorbers sandwiched between two PVC foils has been studied by Bansal et al. [8].

Double-glazed Flat plate-Solar Air Heaters (FP-SAHs) coupled in series with combined rock bedded collectors-cum-storage units were the subject of an experimental study and theoretical model provided by Bhargava et al. [9]. Experimental research towards improving the thermal efficiency of SAH by filling its duct with blacked wired-screen matrices was shown by Sharma et al. [10]. Rizzi et al. [11] developed and manufactured an FP-SAH-integrated solar collector storage (bricks) system. Fath [12] discussed the thermal efficiency of a basic SAH.

Even during periods of low sunlight, a solar dryer connected to a rock bed SAH has been tested by Chauhan et al. [13]. A passive solar powered air heating device with possible uses in agricultural drying has been designed and assessed by Enibe [14]. Abbaspour-sani [15] explains why packed bed units are the best option for SAH storage. The thermal properties of a SAH with raschig rings packed into its flow channel was studied by Ozturk et al. [16].

Heat transfer properties as well as efficiency of double-pass FP-SAH with and without porous media were investigated by Naphon [17]. The thermal efficiency of a double glass double pass SAH with a packed bed was studied by El-Sebaii et al. [18]. Wired meshing was the packing material of choice for the packed bed SAH that Prasad et al. [19] studied. Paraffin wax and hytherm oil, both with and without PCM, have been analyzed for their effects on the efficiency of a SAH reported by Tyagi et al. [20].

In order to use the sun's energy for heating air, Alkilani et al. [21] investigated the role of thermal energy storage. Due to its nominal porosity and potential usage in drying applications, wire mesh was investigated by M. A. Aravindh et al. [22] for use in a solar hot air heater. A double-layered wired mesh is used as an absorber material, allowing air to freely circulate throughout the device.

Ebru Kavak Akpinarit et al. [23] performed a controlled experiment to measure the impact that different types of obstacles have on the heating capacity of a solar air heater. In this study, we analyzed the first- and second-law efficiencies of four different types of solar air collectors. Numerical modeling has been used by Ming Yang, Xudong, and coworkers [24] to optimize the design of a solar-powered air heater with offset strip fins.

Using exergy analysis, A.A. El-Sebaii et al. [25] looked at how modifying the absorber plate coating of a solar air heater affects its performance. To ensure even heating along the whole length of the duct, Karwa et al. [26] used baffles that were both solid and totally perforated. The effectiveness of SAH with half-perforated baffles was experimentally studied by B. K.Maheshwari et al. [27].

Bhagoria et al. [28] conducted experiments to determine the impact of wedge-shaped ribs on a variety of factors. Experiments were conducted by Sahu and Bhagoria [29] on transversely cracked ribs, and their effects on heat transmission characteristics were evaluated. The impact of Discrete and Transverse ribs on SAH thermal performance was studied by Varun et al. [30].

The transfer of heat and friction factor features were investigated by Aharwal et al. [31] by experimental testing and analysis of the impact of gap width and gap position. W-shaped discrete ribs were the subject of Arvind et al.'s [32] research on the absorption plate of a single-pass solar air heater. The V-shaped ribs on the absorber plate were discovered experimentally by Hans et al. [33]. The transfer of heat and friction factor correlations with individual V-down ribs was studied by Sukhmeet et al. [34]. Manivannan et al. [35] installed artificial roughness in the manner of v-shaped ribs at 60° on a single-pass solar air heater.

For their study, Satunanathan et al. looked specifically at double-pass counter-flow solar air heaters [36]. The duct receives the flow from the space between the absorber plate and the glass [37-45]. Patel Anand et al. evaluated different geometrical shapes and dimensions of the collector in solar heater applications [49][51]. Nikul K. Patel et al. [50] and SK Singh et al. evaluated different kinds of alternate energy thermal performance [46][47][48]. Patel Anand et al. evaluated heat transfer in a heat spreader application along with techniques of heat transfer [52-60]. These documents study the experimental investigation varying geometrical parameters of V-shaped ribs on heat transfer in solar air heater with absorber plate having V-shaped ribs.

2. Experimental Setup

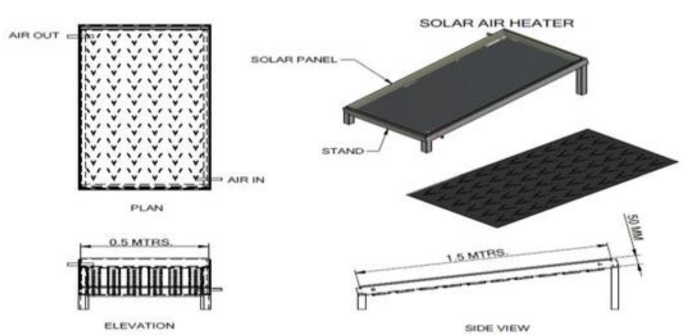

Figure-1 CAD Model of Experimental Set up

Plate-1 Experimental Set up

In this research work, initially, a wood frame with dimensions of 1.1m × 0.5m from 10 mm thick plywood sheet is formed, and the top of the frame is covered with a 2 mm transparent glass sheet. The absorber plate of the conventional solar air heater is placed at the bottom of the frame, made of galvanized steel with a thickness of 0.5 mm and painted black.

In the case of the V-shaped rib Solar Air Heater, 1 mm thick and 4" × 2" in cross-section mild steel pieces are welded on a 0.5 mm plate in V shape. Five V-shapes are placed in one row, and twelve such rows are placed at equal distances in linear and lateral positions. This absorber plate is placed at the bottom of another solar air heater with the previously mentioned dimensions.

To supply air to both solar air heaters, a blower is used. At the entry and exit of both air heaters, 12.5 mm copper pipes are attached through which air can enter and exit from both solar air heaters.

3. Experimental Methodology

First, both setups are positioned in a north-south direction with respect to the position of the sun. Then, air is supplied using a blower, and air velocity is measured using an anemometer. For set values of air velocity, measurements of air inlet and outlet temperatures, as well as collector plate temperature, are taken at time intervals of 15 minutes for both solar air heaters.

4. Results and Discussion

Table-1 Results

Straight Temperature in °C				**V- shaped rib Temperature in °C**			**High Speed**				
Time (min)	T1	T2	T3	T4	T5	T6	V m/s	Cp kJ/Kg-^{0} C	A m^2	ρ Kg/m^3	m Kg/s
0	35	35	35	35	35	35	2.60	1.005	0.00012	1.20	0.00038
15	35	58	51	35	59	56	2.60	1.005	0.00012	1.20	0.00038
30	36	70	65	36	68	64	2.60	1.005	0.00012	1.20	0.00038
45	36	81	75	36	80	77	2.60	1.005	0.00012	1.20	0.00038
60	36	92	88	36	93	87	2.60	1.005	0.00012	1.20	0.00038
							Medium Speed				
0	37	37	35	37	37	37	2.1	1.005	0.00012	1.20	0.00031
15	37	56	50	37	58	55	2.1	1.005	0.00012	1.20	0.00031
30	37	69	66	37	70	67	2.1	1.005	0.00012	1.20	0.00031
45	37	85	79	37	86	81	2.1	1.005	0.00012	1.20	0.00031
60	37	91	87	37	93	89	2.1	1.005	0.00012	1.20	0.00031
							Low Speed				

0	37	37	37	37	37	37	1.2	1.005	0.00012	1.20	0.00018
15	37	57	53	37	56	53	1.2	1.005	0.00012	1.20	0.00018
30	37	70	67	37	69	66	1.2	1.005	0.00012	1.20	0.00018
45	37	87	84	37	86	85	1.2	1.005	0.00012	1.20	0.00018
60	37	97	95	37	99	97	1.2	1.005	0.00012	1.20	0.00018

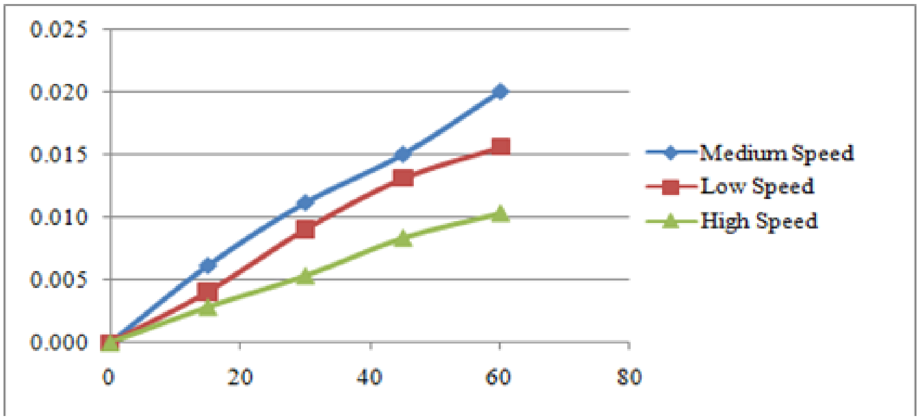

Figure-2 Heat Absorb by Air in case of Conventional solar Air Heater for Various Speed

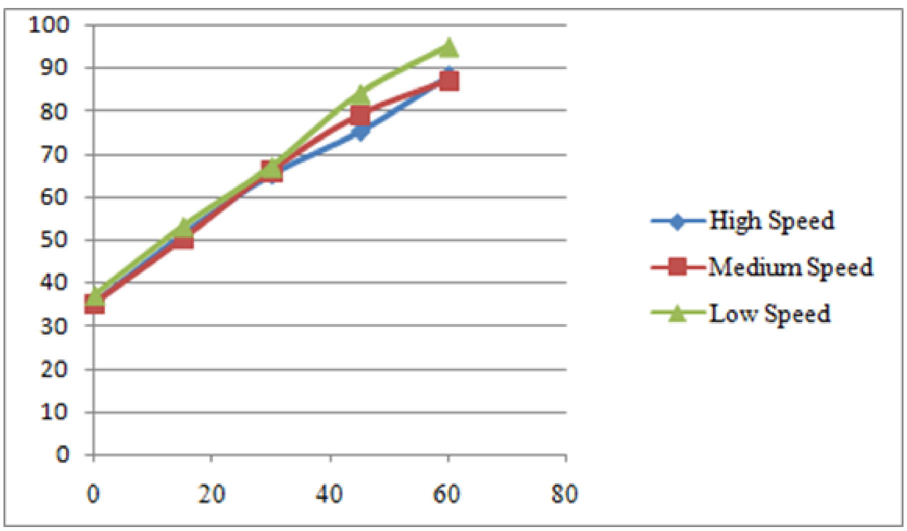

Figure-3 Air Outlet Temperature in case of Conventional solar Air Heater for Various Speed

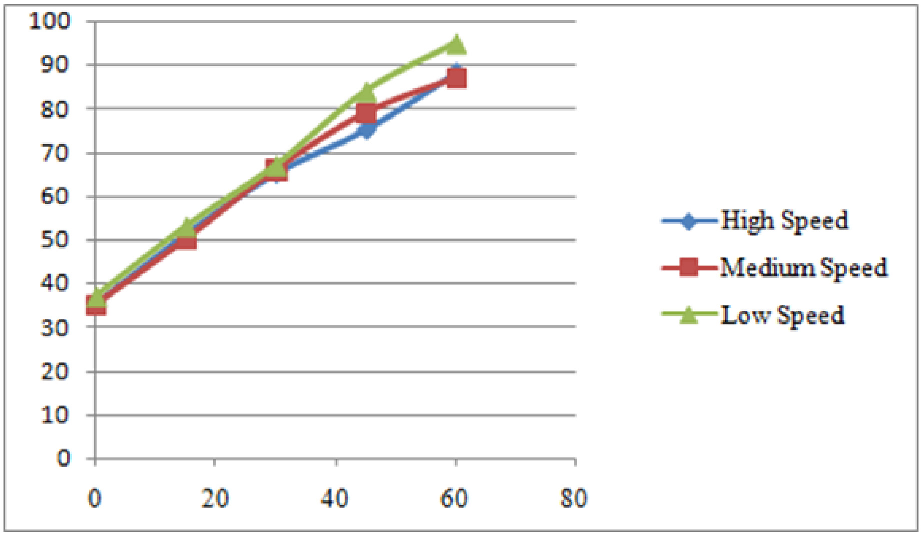

Figure-4 Heat Absorb by Air in case of V- shaped Rib Solar Air Heater for Various Speed

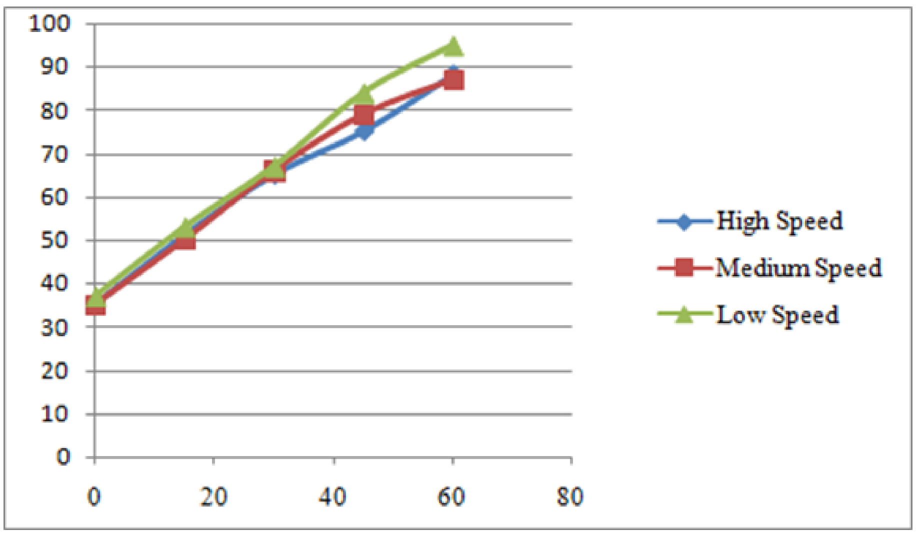

Figure-5 Air Outlet Temperature in case of V- shaped Rib Solar Air Heater for Various Speed

Table 1 represents observations of all temperature and air velocity values. Figure 3 and Figure 5 indicate outlet air temperature in the case of conventional and V-shaped rib solar air heaters respectively, while Figure 2 and Figure 4 show heat absorbed by air in the case of conventional and V-shaped rib solar air heaters respectively.

From the figures, it is clear that outlet air temperature values are higher in the case of the V-shaped rib solar air heater. This is because the V-shaped ribs create turbulence in the flow, which leads to a rise in air temperature. Also, at low air velocity, air outlet temperature values are higher in both air heaters, possibly because more retention time is available, which enhances the heat transfer rate.

5. Conclusion

The major outcome of the present work is that due to V-shaped ribs, turbulence in the air flow is created, which helps to enhance the increase in temperature of the air.

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6. Future Scope

The work can be extended by placing V-shaped ribs in reverse position and comparing the results with conventional and existing V-shaped rib solar air heaters.

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8.Conflict of Interest

The authors declare that there are no conflicts of interest regarding the publication of this article.

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