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Comparative Thermal Performance Evaluation of V-shaped Rib and W-Shape Rib Solar Air Heater

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A B S T R A C T

The sun which is most common and best source of sustainable energy also the solar energy which is available from sun in abundant amount can be used for many application like water hearing, drying and power generation. The solar air heaters are the thermal systems in which solar energy collects and transfers in the form of heat to air passing over the absorber plate of solar air heater, which is either stored or used for space heating. The collectors are often black to absorb more of the sun's energy and a conductive material, often metal, acts as a heat exchanger. The objective of present work is to design and develop such air heater whose absorber plate consists of and W shape rib and V shape rib and thermal performance of both solar air heaters are compared using K type thermocouples and blowers.

Keywords: V-shaped solar air heater, W-shape rib solar air heater, absorber plater, heat exchanger.

1. Introduction

Solar energy is always in a favorable position with respect to the depletion of fossil fuels. In a tropical country like India, most energy needs can be met by simple systems capable of converting solar energy into suitable forms. Through the application of the right technology, excellent thermodynamic matching between solar energy sources and multiple end users can be achieved. However, there are many problems associated with its use. The main problem is that it is a dilute source of energy. Solar air heating is the process of converting solar radiation into heat. The heat absorbed and carried by the air is transferred to the living or working space. The transparent nature of the air means that it does not directly absorb the effective amount of solar radiation, so an intermediate process is needed to carry out this energy transfer and bring the heated air into system. Technologies designed to facilitate this process are known solar air heaters.

Kar[1] verified that for maximum allergen efficiency of a flat plate solar collector at a particular mass flow rate, there will be an optimal inlet temperature. Bahrehmand et al. [2] developed a mathematical model to simulate a solar heater with single- and double-glazed shells under forced convection. Ucar et al. [3] tested an SAH with six different shapes and layouts of the fins mounted absorption surface. Abhishek Saxena et al [4] reviewed the work done by different researchers on the different thermal energy stores commonly used in SAH. Bansal et al. [5] studied the thermal performance of SAH consisting of a porous textile absorber between two PVC sheets. Bhargava et al. [6] presented an experimental study as well as a theoretical model of a double-layer glazed flat plate solar air heater (FP-SAH) connected in series with a storage and collection unit. integrated stone. Sharma et al. [7] presented an experimental study on the improvement of thermal efficiency of SAH whose ducts were filled with black mesh matrix. Rizzi et al. [8] designed and fabricated a simple (brick) solar collector storage system integrated with the FP-SAH. Fath [9] presents the thermal efficiency of a simple designed SAH. Chauhan et al. [10] tested a solar dryer combined with a SAH stone bed that can work even outside of sunny hours. Enibe [11] designed and evaluated the performance of a passive solar air heating system with potential application in crop drying. Abbaspour-sani [12] explains that fixed bed units are the most suitable storage units for SAH. ¨ Ozt¨urk et al. [13] studied the thermal performance of SAHs with flow channels filled with Raschig rings. Naphon [14] investigated the properties and heat transfer performance of dual-transfer FP-SAH with and without a porous medium. El-Sebaii et al. [15] investigated the thermal performance of double-layer, double-layer HSA with an encapsulated bed. Prasad et al. [16] studied a HAS packing bed using wire mesh as the packing material. Karwa et al. [17] used sturdy, fully perforated baffles that attach to the wide, uniform heatpipe wall. BKMaheshwari et al. [18] experimentally studied the performance of SAH with semi-perforated septum. Bhagoria et al. [19] conducted experiments to determine the effects of wedge-shaped ribs on many factors. Experiments were performed by Sahu and Bhagoria [20] on transverse rift coasts, and their effects on heat transfer properties were evaluated. The effect of discrete and horizontal slopes on the thermal performance of SAH was investigated by Varun et al. [21]. The factors of heat transfer and friction were studied by Aharwal et al. [22] through experimental testing and analysis of the effects of gap width and location. The W-shaped discrete ribs were the subject of research by Arvind et al. [23] on the absorption plate of a DC solar heater. The V-shaped veins on the absorption plate were experimentally detected by Hans et al. [24]. Heat transfer and the correlation between coefficient of friction with individual V-slopes were investigated by Sukhmeet et al. [25]. Arun Kumar Yadav et al [26] performed a CFD-based performance analysis of artificial raw solar air heaters. Alok Bharti et al. [27] reviewed different methods used to improve heat transfer rate with less friction in SAH. Varun Pratap Singh et al. [28] focused on the comparative evaluation of the thermal performance of several rough geometries and HSA types. Ashish Ranjan et al [29] studied the effect of half a diamond on the thermal efficiency of solar air heaters. Ekechukwu et al. [30] conducted a detailed evaluation of the different designs, structures and operating principles of various HAS for drying. Chabane et al. [31] built a one-time solar air heater and evaluated its thermal efficiency. Bayrak et al. [32] studied the performance of five collectors using a closed-cell aluminum foam baffle. El-Sebaii et al. [33] constructed a test bed for HAS twice. Gao et al. [34] constructed a two-segment baffle HAS and realized its thermal efficiency. Bouadila et al. [35] constructed a test bench to study the performance of HAS with latent storage receivers.

[36-39] Patel Anand et al. [40] HD Chaudhary et al. [41-45] Patel Anand et. al includes studies on thermal performance by variation of different geometries absorber solar collector in solar heater. The solar heater utilizes heat transfer phenomenon such as [47] Anand Patel et al. study of thermal performance of twisted heat transfer documents heat exchanger. [48-49] Nikul Patel et al. [50] SK Singh et al. includes study on biofuel which an example where heat exchange device such as solar heater and cooling tower could be utilized. [51-59] include articles about U-shaped heat exchangers in parabolic trough solar collector for air heating applications. Thermal performance evaluation of V-trough solar air heater along with a drying storage in studies [60-64].

2. Experimental set up

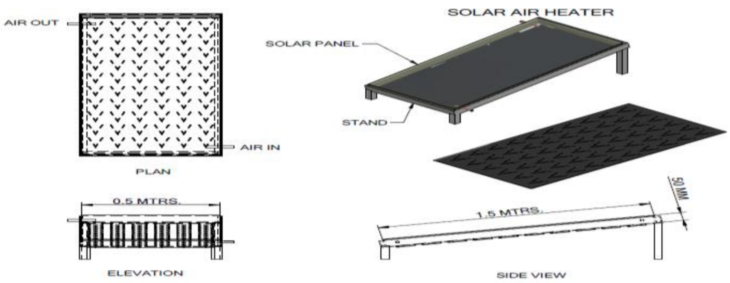

Fig 1 CAD Model of Experimental Set up

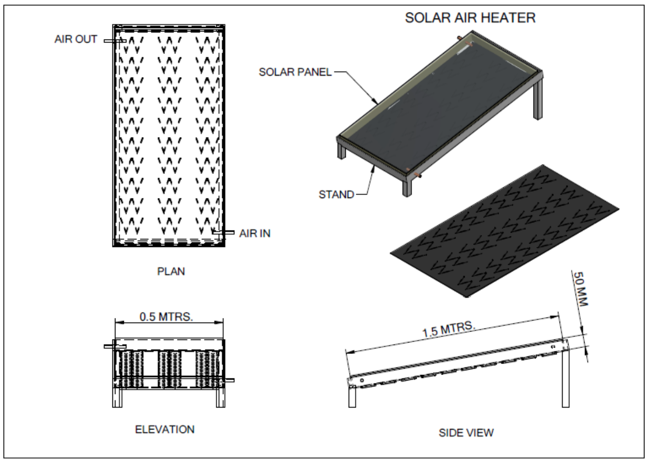

Fig 2 CAD Model of Experimental Set up

Plate 1 W Rib Experimental set up **Plate 2 V Rib on Absorber Plate**

In this study, a 1.1 m X 0.5 m wooden frame was formed from a 10 mm thick plywood sheet and the top surface of the frame was covered with a 2 mm clear glass panel. The solar collector's plate is placed at the bottom of the 0.5mm thick galvanized steel frame and painted in black; and mild steel 4" X 2" thick V-shaped ribs and 4" X 2" cross section welded to a 0.5 mm V-shaped absorber and five Vs placed in a row and these 12 rows equidistant each other on the lining and side. To supply air in two solar heaters, a fan is used. At the inlet and outlet of the two air heaters, a 12.5 mm copper tube is mounted through which air can enter and exit the two solar heaters.

In the predefined case, a 1.5 m x 0.5 m wooden structure is made of 10 mm thick plywood panels and the top of the structure is covered with a 2 mm clear glass pane. For a 1mm thick W-shaped fin, 4 x 2 inch cross-section solar heater, weld a 0.5mm or larger mild steel part into a W and weld three Ws. Raw, these 12 rows are evenly spaced in the liner and laterally, and this absorber is placed at the bottom of another black-painted solar heater to improve heat transfer. A fan he used to supply air to the two solar heaters. Copper pipes with a thickness of 12.5 mm are attached to the inlet and outlet of the two air heaters, through which the air can enter and exit the two solar heaters. Plate 1 and Plate 2 show W Rib and V Rib arrangement.

3. Results and Discussion

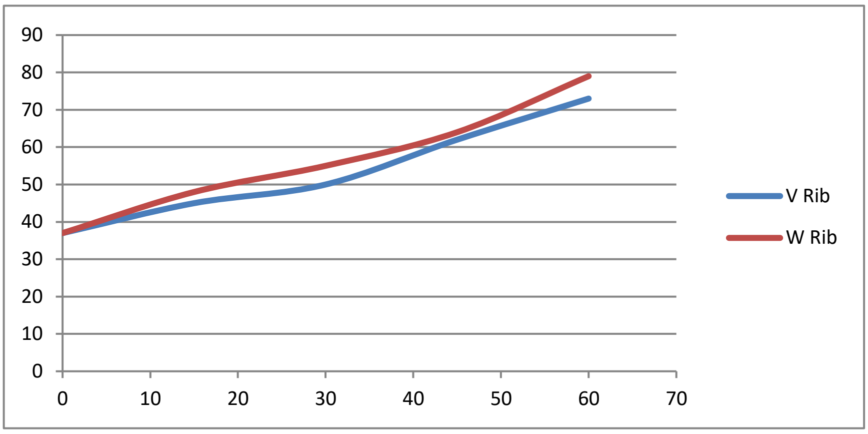

Fig 3 Temperature Variation w.r.t Time for Air Velocity of 2.6 m/s

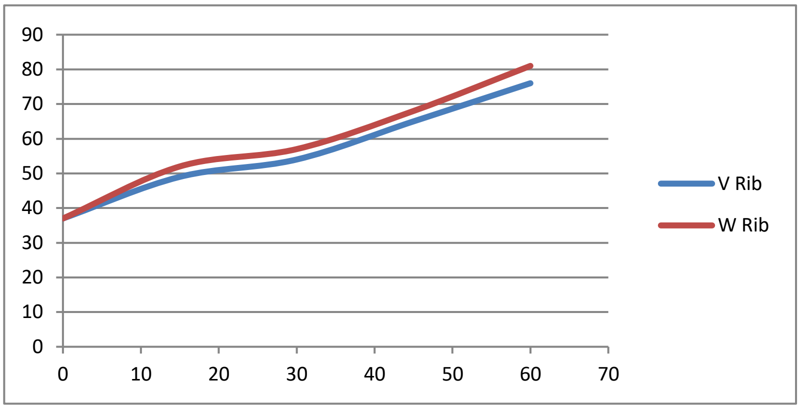

Fig 4 Temperature Variation w.r.t Time for Air Velocity of 2.1 m/s

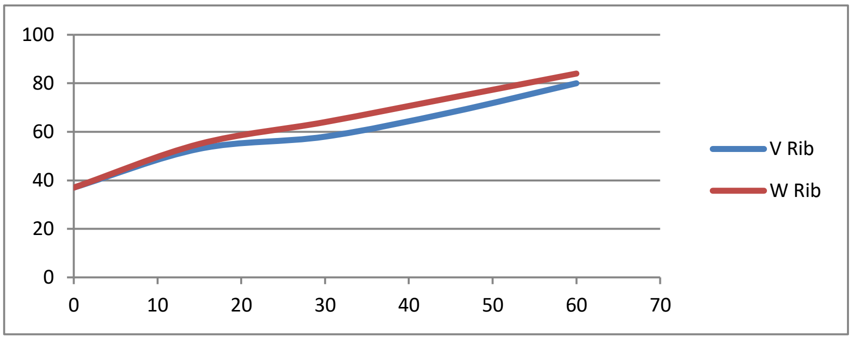

Fig 3 Temperature Variation w.r.t Time for Air Velocity of 1.2 m/s

Table 1 Result Table

High Speed									
V	Cp	Area	Density	Mass Flow Rate	V Rib	W Rib		V Rib	W Rib
m/s	kJ/kg-K	m^2	Kg/ m^3	Kg/ s	Qo	Qo	Qi	η	η
2.60	1.005	0.00012	1.20	0.00038	0.000	0.0000	0.68	0.00	0.00
2.60	1.005	0.00012	1.20	0.00038	0.003	0.0085	0.68	0.45	1.25
2.60	1.005	0.00012	1.20	0.00038	0.005	0.0120	0.68	0.74	1.76
2.60	1.005	0.00012	1.20	0.00038	0.010	0.0166	0.68	1.42	2.44
2.60	1.005	0.00012	1.20	0.00038	0.014	0.0216	0.68	2.04	3.18
Medium Speed									
2.1	1.005	0.00012	1.20	0.00031	0.000	0.0000	0.68	0.00	0.00
2.1	1.005	0.00012	1.20	0.00031	0.004	0.0065	0.68	0.55	0.96
2.1	1.005	0.00012	1.20	0.00031	0.005	0.0103	0.68	0.78	1.51
2.1	1.005	0.00012	1.20	0.00031	0.009	0.0153	0.68	1.28	2.24
2.1	1.005	0.00012	1.20	0.00031	0.012	0.0174	0.68	1.79	2.56
Low Speed									
1.2	1.005	0.00012	1.20	0.00018	0.000	0.0000	0.68	0.00	0.00
1.2	1.005	0.00012	1.20	0.00018	0.003	0.0032	0.68	0.42	0.47
1.2	1.005	0.00012	1.20	0.00018	0.004	0.0048	0.68	0.55	0.71
1.2	1.005	0.00012	1.20	0.00018	0.006	0.0066	0.68	0.81	0.97
1.2	1.005	0.00012	1.20	0.00018	0.008	0.0084	0.68	1.13	1.23

In the present work, two solar air heaters with V rib and W rib are compared on their thermal performance basis and the outcome is in case W Rib solar air heater, the higher temperature of air can be obtained mainly because the more obstruction in the flow increases the retention period for air so air can absorb more heat and one more interesting observation is that at high air velocity, air outlet temperature is low compared to air outlet temperature at low air velocity may be because of less turbulence in the flow, as in case of high air velocity, past stream of air is pushed forward. The thermal efficiency of both solar air heaters decreases with increase in air velocity due to drastic fall in mass flow rate of air.

4. Conclusion

The major outcome is that due to presence of more obstruction in the flow better air outlet temperature can be obtained but at the cost of low thermal efficiency.

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