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Heat Transfer Enhancement Of Solar Air Heater At Different Shape Ribs Absorber Plate

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ABSTRACT

In this work effect of V, W and S -Shape ribs absorber plate on heat transfer enhancement of solar air heater has been discussed. Three different types of absorber plate have been used. The absorber plates have V, W and S -shape ribs. It is observed that the highest thermal efficiency is found out to be for black colour plate with continuous multiple S –shape ribs at all the exit wind velocity. All absorber plates have metallic black color painted. It is determined that the maximum heat transfer was at V-Shape, W-Shape plate with continuous multiple S- shaped absorber plate at all the exit wind velocity because the path of air has increased as compare to V Shape and W Shape absorber plate. Increased path depends on geometry was equally spaced and air flowing from inlet to outlet in between ribs of plate channel. The efficiency of V-Shape, W-Shape ribs absorber plate solar air heaters is low because of low heat transfer coefficient between the absorber plate and the flowing air. Solar air heaters are used at low to medium temperature application like industrial application, space heating, crop drying and other. A direct performance comparison of the V-Shape, W-Shape ribs absorber plate and continuous multiple S-shape ribs absorber plate solar air heater shows that the thermal efficiency of the continuous multiple S-shaped ribs absorber plate solar air heater is 25% higher than the V-Shaped and W-Shape ribs absorber plate solar air heater; highest thermal performance advantage is at the lowest flow rate. The collector efficiency in a solar air heater without and with using embossed absorbing plate has been investigated experimentally analyzed that depends on different parameter like inclination angle, radiation and velocity of air etc.

Keywords: Solar Air Heater, Different shaped ribs, S-Shape Ribs, Thermal Efficiency, Mass Flow Rate

1.INTRODUCTION

A non-polluting fuel reservoir is made available by the free and constant availability of sunlight. The best and most efficient way to use solar energy is to use solar collectors to turn it into thermal energy for heating purposes. Due to its minimal material and value consumption, the sun-based air warmer has a crucial position among sun-based warming plants. The warm strength of sunlight-based air radiators has been reported to be typically inadequate when compared to sun-oriented water warmers, which is deduced from their habitually poor capacity for heat exchange between the retentive plate and air flowing inside the channel. Therefore, to make the solar-powered air warmers financially viable, the heat-exchange efficiency must be improved. There are a few key methods for improving the heat transfer rate between the permeable plate and air. Due of its intrinsic simplicity, solar air heaters are inexpensive and frequently used assortment items. The most common applications for solar-powered air radiators include range warming, flavoring wood, hardening commercial products, and effectively curing/drying solid/dirt construction components. The main tactic entails extending the area of heat exchange by using wrinkly or developed surfaces referred to as blades that do not affect the constant convective heat exchange [1]. The second step involves creating turbulence at the heat-exchanging surface to increase convective heat exchange. The improvement of the thermo-hydrodynamic efficiency of many mechanical applications, such as warm power plants, warm exchangers, aerating and cooling components, refrigerators, synthetic handling plants, automobile radiators, and sun-oriented air warmers, is widely related to this idea. A device called a sunlight-based solar duct raises the temperature of the air with the use of heat that is extracted from solar energy [2]. This may be done by applying simulated unpleasantness to the retentive plate's underside. Numerous researchers have tried to design a roughness portion that can improve convective heat exchange with the smallest possible increase in rubbing losses. In the past several years, it has been common practice to expand the convective heat exchange of a rectangular duct with the aid of perplexes/ribs. These are inexpensive, have a simple design, need minimal maintenance, and are environmentally friendly. They therefore have practical uses for flavoring wood, drying agricultural products, warming enclosed spaces, curing mud/solid construction components, and curing mechanical components.

2.LITERATURE REVIEW

A variety of roughness geometries like ribs, protrusions, wire mesh and roughness have been investigated to exa mine the effect with respect to plane on the thermo-hydraulic performance of solar air heater. There are some detailed review of the roughness geometries used by researchers in the solar air heater have been presented in the recent past.

Khanlari et al. [1] uses computational and experimental analysis to examine the impact of putting a nano-enhanced absorber coating on the energetic and exergetic performance of an unglazed vertical solar air heating system. In the initial phase of the study, computational fluid dynamics was used to examine different vertical solar air heater topologies, such as hollow, baffled, and perforated baffled systems. The system with perforated baffles provided the best performance metrics, according to the numerically acquired findings. (2022)

Nidhul, **et al. [2]** used numerous types of ribs in SAH, which may be useful for future research. Heat transfer has been significantly improved at the expense of a pressure decrease that is insufficient to compensate for the advantages. Energetic performance analysis is carried out in addition to energy analysis to evaluate the many types of energy losses that occur in a SAH. The influence of ribs on SAH energy gain is also discussed. Energetic performance of V-ribs, multiple V-ribs, and multiple V-ribs with gaps was also performed to investigate the effect of multiple ribs and gaps on the energetic performance. The findings of the preceding study highlight the following key points: The primary flow separates and reattaches in the inter-rib zones because of ribs beneath the absorber plate. This reduces the thermal barrier to heat transfer by preventing the formation of a thermal boundary layer near the heated plate. The cross-flow formed by inclined ribs, its movement, and subsequent mixing with the primary flow stream adds turbulence and improves heat transfer.(2021)

Raju et al. [3] investigated that experiments were conducted on a double pass packed bed SAH with encapsulated PCM on its absorber plate capsules in two different geometries, square and circular in cross sections were used. Four absorber plates with capsules in inline and staggered grid arrangements were attached one by one to SAH and experimental analysis was carried out with mass flow rate of air changed in between 0.008643 and 0.01454 kg/s. It was found that intensity of solar radiation steadily increases before noon, reaching to its maximum at noon and decreases after the noon. Accordingly, absorber plate temperature and PCM temperature in capsules were recorded as higher compared to other temperatures in the experimental setup during charging period, that is, from 10:00 AM to 2:00 PM. • Efficiency of SAH was found to be increasing with increase in mass flow rate of air for all the arrangements. (2021)

Tarek Kh. et al. **[4]** suggested that SAH quality has been proven to be improved by artificial roughness in the shape of repeating ribs. Ribs interrupted the viscous sub-layer and created local wall turbulence without stopping the principal turbulent stream, resulting in an increase in the convective heat transfer coefficient between the air and heated surface as a result of fluid separation and reattachment. As a result, in this investigation, a SAH roughened with aluminum separation and reattachment. As a result, in this investigation, a SAH roughened with aluminum broken arc ribs was covered with a novel solar selective coating composed of 4% CNTs/CuOblack paint. (2020)

Jin et al. [5] The effect of staggered multiple S-shaped ribs was studied, and it was shown that the stagger distance significantly influences the increase of heat transfer by affecting the subsidiary vortex strength in the inter-rib area and redevelopment length at the leading end region. (2017)

Kumar et al. [6] A larger number of leading ends and secondary flow cells are formed as a result of manufacturing more than one v-rib, increasing the relative roughness width (W/w), which improves the nusselt number relative to the Reynolds number.

3.EXPERIMENTAL S ET-UP

The experimental set-up is a rectangular channel with forced convection flow having entrance, test and exit sections. The components of experimental set up consists blower, wooden rectangular duct, GI pipe, GI black colour absorber plate, GI blacked colour with Different shaped roughened absorber plate, GI blacked colour with S-shape roughness absorber plate, control valves, orifice plate, U-tube manometer and thermocouples. Double pass solar air heater has been designed and fabricated by 18mm thick plywood with 10mm insulation provided around a rectangular duct at outlet to minimize the heat losses. The comparison in the enhancement of heat transfer and thermal efficiency having three different type of G.I. absorber plate of 22 gauges to be used V-Shape, W-Shape ribs absorber plate and with S-Shape ribs absorber plate for experimental study. The flow system consists of three sections i.e. the entry section consists of (300×200mm), test section consists of (1670×200mm) and exit section is (300×200mm). Transparent glass cover sheets are (1950×200mm) is used as it allows shorter wavelength radiation to pass and restricts larger wavelength radiation to go back. In total 18 thermocouples were used out of which 12 thermocouples were provided over the test section for measuring the surface temperatures and 6 thermocouples were used to measure the in let and outlet temperature..The mass flow rate of air was measured by means of calibrated orifice meter connected with a U-tube manometer and we have to use another method to find the mass flow rate of air i.e . anemometer. In anemometer find the velocity of air and calculated the mass flow rate on the basis of velocity and other standard parameter of air. Control valves were provided to control the flow. An orifice plate was designed for flow measurement in the pipe having diameter 40 mm. Upper side of transparent glass used insulator to minimize the heat loss.

The duct is the main part of the experimental setup. The duct is fabricated from wooden planks of different cross-sections. The inner dimension of the duct is 1950mm× 180mm×60mm.

3.1 Experimental Procedure

Before start an experiment checked out all major components i.e. pyranometer, centrifugal blower, temperature indicator, control valve, inclined U-tube manometer and anemometer have been inspected for its functioning. The connection of thermocouple and leak proof joint is ensured along the whole duct, after that switch on all connections. Initially starts the blower around five minute for normalizes the effect of preheat of solar air heater. In this experiment used three speed of blower that is three velocities of air passes on the duct. After that air passing from blower by the help of GI pipe. In the GI pipe consist of flow control valve and orifice. Orifice normally used to calculate the difference of pressure and the difference of pressure head shown in the U tube manometer. The air passes through between transparent glass cover and absorber plate duct. In the absorber plate thermocouple wire are used to measure the surface temperature, inlet air temperature and exit air temperature by the help of tempera ture indicator display. During this process plate temperature along with pressure drop in orifice plate were also measured. And the entire temperature and pressure drop calculated on the basis of mass flow rate of air, in the setup three mass flow rates are used to calculate the value of temperature and pressure. An pictorial view of experimental set is shown in Fig. 3.1.

Fig. 3.1 Pictorial view of experimental setup

4.RES ULTS AND DISCUSS ION

4.1 Variation of thermal Efficiency with Reynolds number for V-Shape, W - Shape and S – Shape Ribs Solar

Air Heater

The variation of thermal efficiency with Reynolds number. for V-Shape, W - Shape and S - Shape Ribs Solar air heater is shown in Fig 4.1.

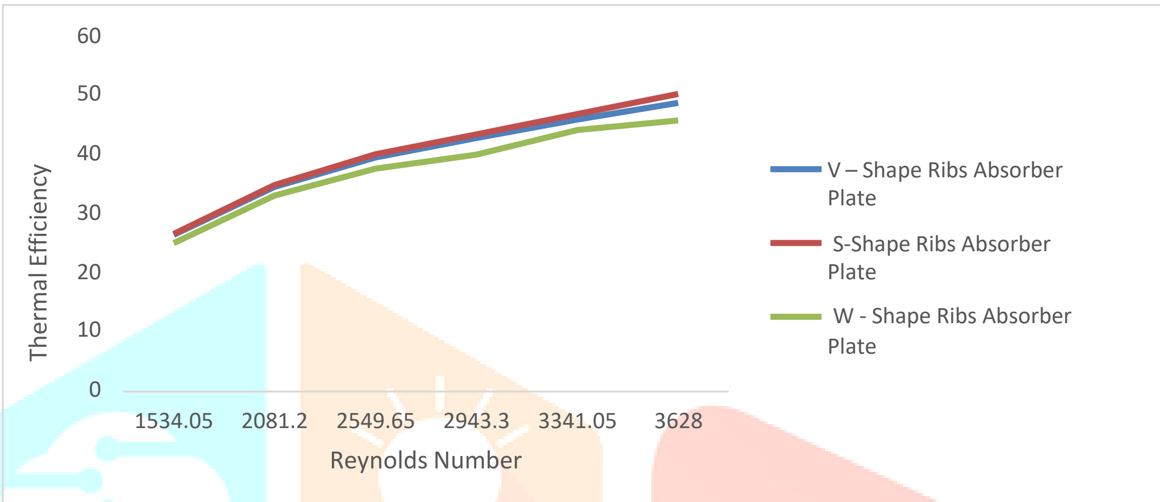

Fig 4.1 Variation of thermal efficiency with Reynolds number for V-Shape,W - Shape and S–Shaped Ribs of Solar Air Heater

The thermal efficiency of both plates improves with an increase in Reynolds number, as shown in Graph 4.1 The cause of this is an increase in turbulence when mass flow is increased. For S-shaped absorber plates, high thermal efficiency values are obtained. This may be caused by the working fluid's (air) high exit temperature, which may be due to the plate's roughened S-shape's enhanced turbulence.

4.2 Variation of Friction Factor with Reynolds Number for V-Shape, W-Shape and S - Shape Ribs plate Solar Air Heater

The variation in friction factor and Reynolds number at different mass flow rate for V-Shape, W - Shape and S-Shape Ribs Solar Air Heater are shown in Fig. 4.2.

The Friction factor decreases with increase in Reynolds number for all solar air heaters. Also, it is reported that Lower Friction factor is obtained for S - Shape Ribs solar air heater as compared to V shape and W shape ribs solar air heater. Further Lowest Friction factor is obtained apart from S–shape ribs absorber plate of solar air heater.

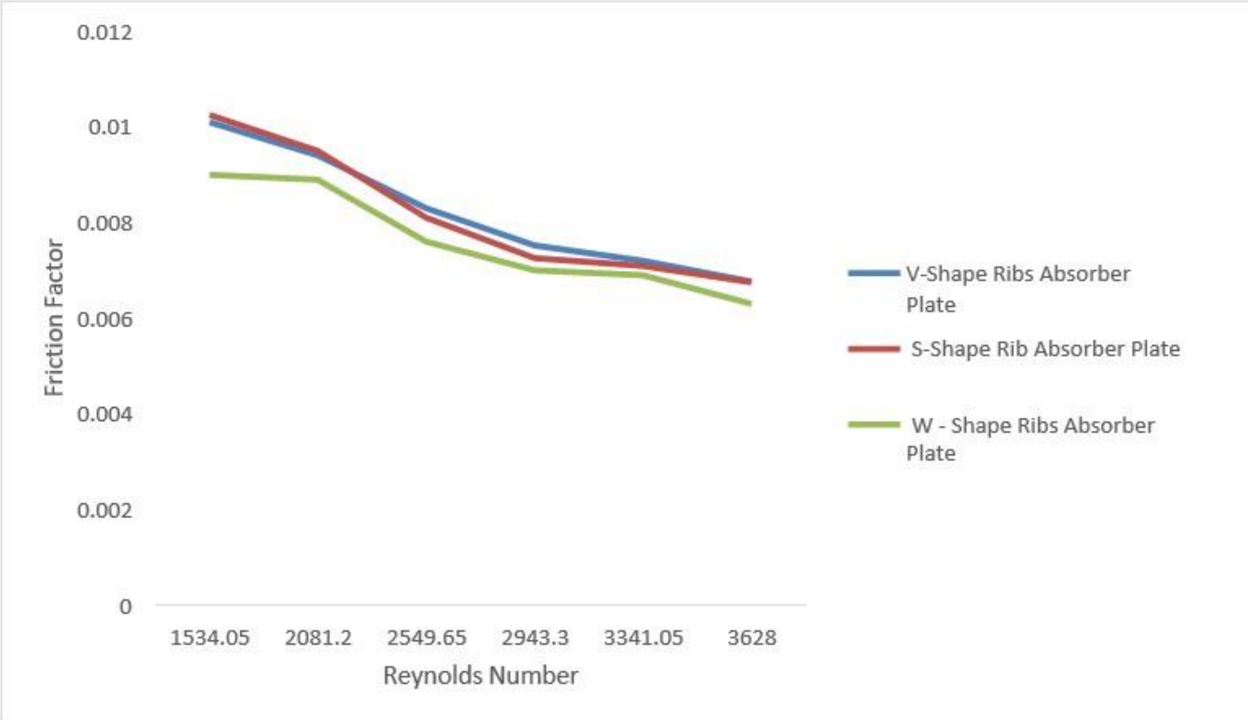

Fig. 4.2 Variation of Friction factor with Reynolds Number at Different Mass Flow Rate for V - Shape, W - Shape and S – Shape Ribs Solar Air Heater

4.3 Variation of Nusselt Number with Reynolds number for V-Shape, W - Shape and S - Shape Ribs Solar Air Heater

The variation of Nusselt number with Reynolds number V-Shape, W - Shape and S - Shape Ribs Solar Air Heater are shown in Fig. 4.3

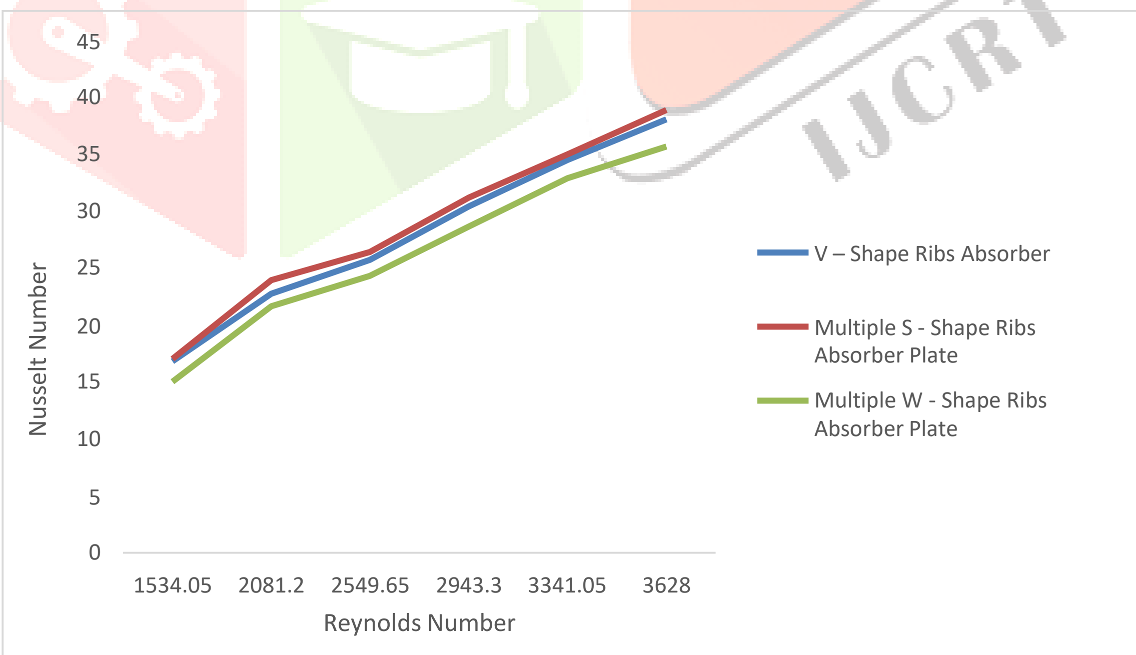

Fig. 4.3 Variation of Nusselt number with Reynolds number for V-Shape, W - Shape and S– Shape Ribs Solar Air Heater

For all absorber plates, Nusselts Number increase as Reynolds Number rises, as shown in Graph 4.3. Increased heat content and high working fluid temperature causes rise in Nusselts Number for three absorber plates. Additionally, greater values were achieved for the S-shape ribs absorber plate due to the working fluid's high temperature for the same. This result is a result of the S-shape ribs absorber plate's increased roughness, which stirs up the working fluid .

4.4 Variation of Heat Transfer Coefficient with Reynolds number for V-Shape,W - Shape and S–Shaped Ribs of Solar Air Heater

The variation of Heat transfer coefficient with Reynolds number for V-Shape, W - Shape and S - Shape Ribs Solar Air Heater are shown in Fig. 4.4

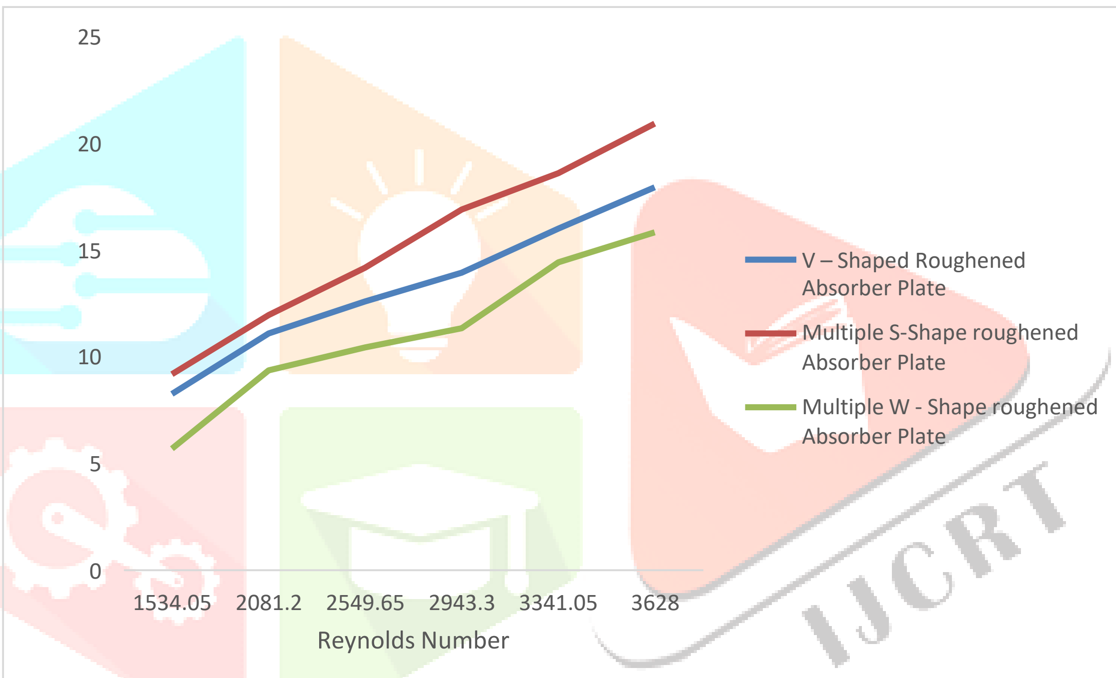

Fig. 4.4 Variation of Heat Transfer Coefficient with Reynolds number for V-Shape,W - Shape and S–Shaped Ribs of Solar Air Heater

For various absorber plates, Graph 4.4 demonstrates that the heat transfer coefficient increases as the Reynolds Number. For an increase in Reynolds number, the value of the heat transfer coefficient increases with increasing roughness on the absorber plate surface. In comparison to S-shape Ribs absorber plate with V -Shape and W - Shape absorber plate has a lower value of heat transfer coefficient.

4. CONCLUS ION

1. It has been found that the thermal efficiency of S-shape rib absorber plate is higher as compare to V - Shaped and W-Shape ribs absorber plate solar air heater.
2. 1.It has been observed that an enhanced Nusselt's number is obtained on an artificial roughness provided on under sides of absorber plate as compare to V-Shape and W-Shape plate..

3.The maximum value of Nusselt's number has been found on the S- shape absorber plate as compare to V-Shape & W - Shape ribs absorber plate solar air heater

4.The maximum value of thermal efficiency and Nusselt's number of S-shape ribs absorber plate is found to be 1.46 and 1.36 times respectively higher as compare to V & W - Shape ribs absorber plate solar air heater..

5.It has been also found that the absorption of heat by the S-shape roughened absorber plate is higher as compare to V & W - Shape ribs absorber plate solar air heater.

6.The thermal efficiency of the S-shape ribs absorber plate solar air heater is 25% higher than the V-Shape and W-Shape ribs plate, highest thermal efficiency is at the high mass flow rate

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