2nd International Conference on Current Research Trends in Engineering and Technology
© 2018 IJSRSET | Volume 4 | Issue 5 | Print ISSN: 2395-1990 | Online ISSN : 2394-4099
Themed Section: Engineering and Technology

Investigation on Thermal Performance of Solar Air Heater by using artificial roughness A Review

Prajapati Jignesh[1], Shah Pujak[2], Sheikh Aejaj[3], Vishal Jha[4], Mr. Jay I Patel[5]
[1-4]U.G. Student, Computer Engineering, Sigma Institute of Engineering, Bakrol, Gujarat, India
[5]Assistant Professor, Computer Engineering, Sigma Institute of Engineering, Bakrol, Gujarat, India

ABSTRACT

The term solar air heating is a technology in which the radiant energy emitted by the sun is captured in an absorber and is used for space heating and the device used is Solar Air Heater. The Performance of Solar Air Heater found to be low due to Low Heat Transfer Coefficient between Absorber Plate and Air. When Air Passes through Solar Air Heater Duct, Laminar Sub Layer is created on Absorber Plate, Which Reduce Heat Transfer between Absorber Plate and Air. Improvement in the thermal performance of a solar air heater can be done by enhancing the heat absorbing and transfer capacity of absorber plate. Providing an artificial roughness on a heat transferring surface (Absorber plate) is an effective heat transfer technique to enhance the rate of heat transfer to flow of air. So, the different types of artificial roughness viz. Horizontal, Zig-Zag and V-shape on Absorber Plate is used to break this Laminar Sub layer.

Keywords: Solar air heater, Absorber plate, Heat transfer efficiency, Artificial roughness

I. INTRODUCTION

Solar energy is a very large inexhaustible source of energy. The power from the sun intercepted by the earth is approximately 1.8×1011 MW which is many thousands of times larger than the present consumption on the earth of all commercial energy sources. The solar energy has compared to fossil fuels and nuclear power is environmentally clean source of energy and it is free and available in adequate quantities in almost all parts of the world.

Solar air heaters due to simplicity and low cost are most widely used collection devices and are generally used for collecting solar energy which absorbs the incoming solar radiations, converting it into thermal energy at absorbing plates and transferring heat to air flowing through the collector. They are used for several applications such as space heating, crop drying etc.

A solar air heater generally consists of an absorber plate with a parallel plate below forming a passage of high aspect ratio through which the air to be heated flows. As in the case of the flat-plate collector, a transparent cover system is provided above the absorber plate, while a sheet metal container filled with insulation is provided on the bottom and sides. The air flows between the cover and absorber plate as well as through the passage below the absorber plate.

The thermal efficiency of solar air heater is comparatively poor due to the low heat transfer coefficient between the absorber plates and flowing air. To make solar air heater more economical their thermal efficiency need to be improved by increasing their heat transfer coefficient.

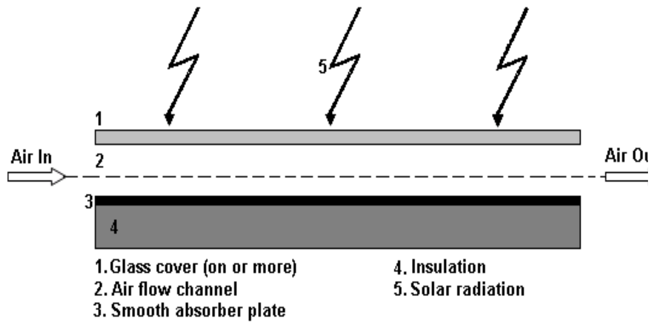

Figure 1: Flat Plate Solar Air Heater[1].

II. LITERATURE REVIEW

Lanjewar A.M. et al [2] had investigated heat transfer in rectangular duct using repeated ribs in W-continuous pattern. The W- pattern ribs have been tested for both pointing upstream and down stream directions to the flow. The parameters used were Reynolds number range 2300-14000, relative roughness height (e/ Dh) = 0.03375, relative roughness pitch (p/e) 10, rib angle of attack (α) = 45°, thickness of plate 1 mm, channel aspect ratio (W/H) 8, test length 1500 mm, hydraulic diameter 44.44 mm. and find the W- shaped ribs pointing downstream have better performance than W – shaped ribs pointing up stream to the flow. The Stanton number is enhanced 2.39 times for W- down and 2.21times for W- up ribs respectively compared to smooth plate.

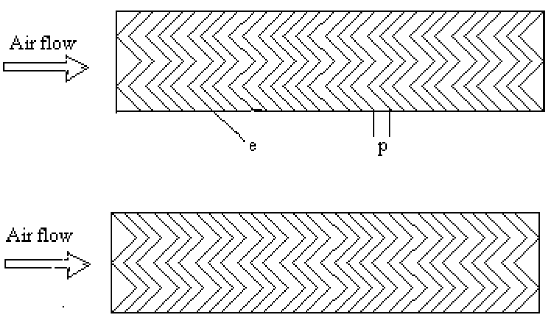

Figure 2: Roughness geometry Of W- Up Ribs [2].

Aharwal et al [3] had investigated Heat transfer and friction characteristics of solar air heater ducts having integral inclined discrete ribs on absorber plate. The maximum heat transfer enhancement occurs at the relative gap position of 0.25 with the relative gap width of 1.0 for the relative roughness pitch of 8.0, angle of attack of 600 and relative roughness height of 0.037.The maximum value of friction factor occurs for discrete transverse ribs with relative roughness pitch of 8.0.

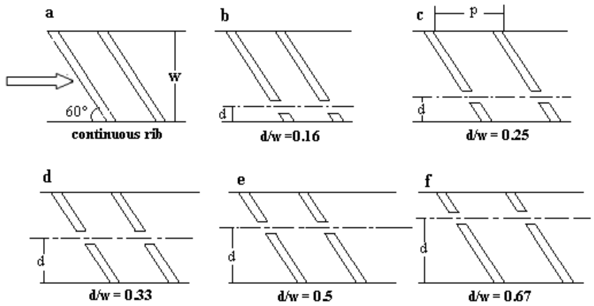

Figure 3: Roughness geometry Transverse Ribs [3].

Bopche and Tandale [4] has used artificial roughness in the form of specially prepared inverted U-shaped turbulators on the absorber surface of an air heater duct. As compared to the smooth duct, the turbulator roughened duct enhances the heat transfer and friction factor by 2.82 and 3.72 times, respectively. at low Reynolds number too (Re < 5000) where ribs are inefficient. At Reynolds number, Re = 3800, the maximum enhancement in Nusselt number and friction factor are of the order of 2.388 and 2.50, respectively.

Arvind kumar et al [5] has carried out an experimental investigation to study the heat transfer and friction characteristics in solar air heater by using discrete W-shaped roughness on one broad wall of solar air heater with an aspect ratio of 8:1. The parameters used were Reynolds number (Re) range from 3000-15000, relative roughness height (e/Dh) in the range of 0.0168-0.0338, relative roughness pitch (p/e) 10 and the angle of attack (α) in the range of 30 o – 75 o. the maximum enhancement of nusselt number and friction factor has been found to be 2.16 and 2.75 times that of smooth duct for an angle of attack of 60^{o}.

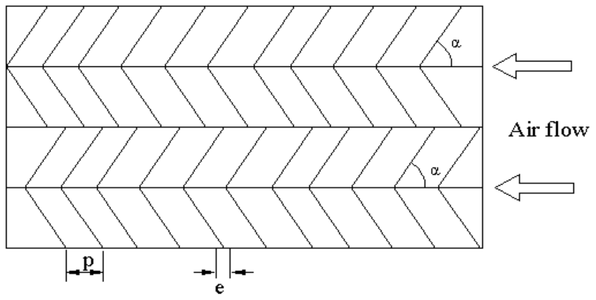

Figure 4: Roughness geometry Of W- Shape [5].

Bhagoria [6] had done an experimental study carried out heat transfer and friction factor data rib geometry. Experiment based on the range of relative roughness height (e/D) of 0.015-0.033, Reynolds number (Re) range of 3000-18000 and relative roughness pitch (p/e) of 12.12 to 60.17 and wedge angle was $8\text{-}15^{0}$. It has been observed that the maximum heat transfer occurs for a relative roughness pitch of about 7.57. The maximum enhancement of heat transfer at wedge angle was about 10^{0}, and also enhancement in Nusselt number up to 2.4 times while the friction factor increases up to 5.3 times as compared to smooth duct.

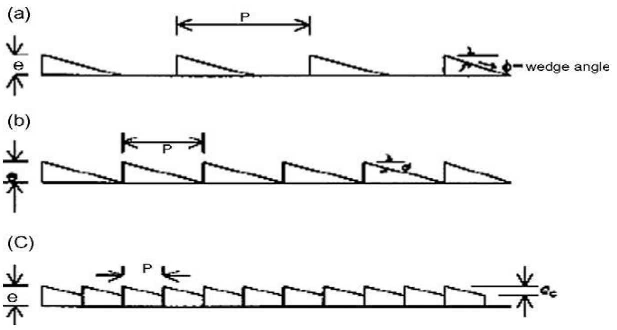

Figure 5: Wedge shaped ribs [6].

Eiamsa-ard and Promvonge [7] had investigated turbulence model effects, computations based on a finite volume method, are carried out by utilizing four turbulence models: the standard k–ε, the Renormalized Group (RNG) k–ε, the standard k–ω, and the shear stress transport (SST) k–ω turbulence models. It is found that the grooved channel provides a considerable increase in heat transfer at about 158% over the smooth channel and a maximum gain of 1.33 on thermal performance factor is obtained for the case of B/H=0.75.

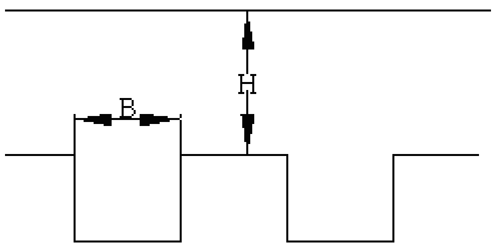

Figure 6: Schematic diagram of Grid arrangement for grooved channel flow [7].

Saini and Saini [8] had investigated solar air heater having artificial roughness in the form of arc-shape parallel wire. The effect of system parameters such as relative roughness height (e/d) and arc angle (a/90) have been studied on Nusselt number (Nu) and friction factor (f) with Reynolds number (Re) varied from 2000 to 17000. The maximum enhancement in Nusselt number has been obtained as 3.80 times corresponding the relative arc angle (a/90) of 0.3333 at relative roughness height of 0.0422. However, the increment in friction factor corresponding to these parameters has been observed 1.75 times only.

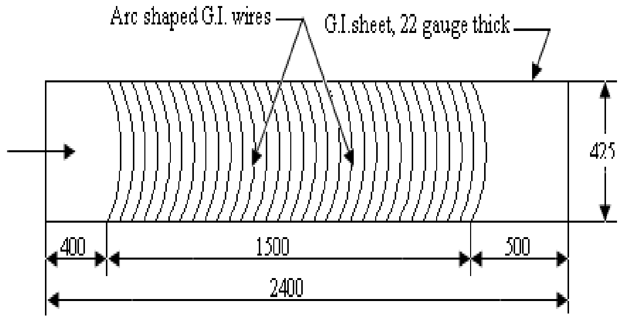

Figure 7: Arc shaped roughness on Absorber plate [8].

Alok Chaube et al [9] had used nine different rib-shapes of roughness geometry like Rectangular rib (2X3 mm, 4X3 mm, and 5X3 mm), Square rib (3X3 mm), Chamfered rib (Chamfer angle 110, 130, and 150), Semicircular rib (radius r=3 mm), Circular rib (diameter d=3 mm) have been analyzed for similar duct parameters. They selected Shear stress transport k-ώ turbulence model comparing the predictions of different turbulence models with experimental results available in the literature. The highest heat transfer is achieved with chamfered ribs but the best performance index is found with rectangular rib of size 3X5 mm. It is observed that the 2D analysis model itself yields results, which are closer to the experimental ones as compared to 3D models. The turbulence intensity is found maximum at peak of the local heat transfer coefficient in the inter-rib regions.

Saini and Verma [10] had used dimple-shape artificial roughness on the underside of the absorber plate. The maximum value of Nusselt number has been found corresponds to relative roughness height (e/D) of 0.0379 and relative pitch (p/e) of 10. While minimum value of friction factor has been found correspond to relative roughness height (e/D) of 0.0289 and relative pitch (p/e) of 10.

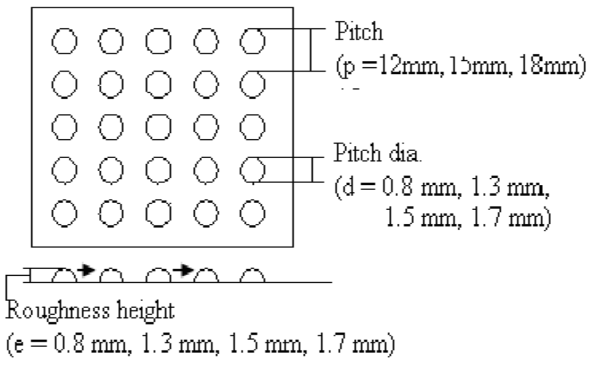

Figure 8: Schematic diagram of dimple-shape geometry [10].

Verma and Prasad [11] had carried out an outdoor experimental investigation for thermo hydraulic optimization of the roughness and flow parameters for Reynolds number (Re) range of 5000– 20,000, relative roughness pitch (p/e) range of 10–40 and relative roughness height (e/D) range of 0.01–0.03. The optimal value of roughness Reynolds number was found to be 24 and corresponding to this value, optimal thermo hydraulic performance was reported to be 71%. Heat transfer enhancement factor was found to vary between 1.25 and 2.08 for the range of parameters investigated. Correlations for heat transfer and friction factor were developed.

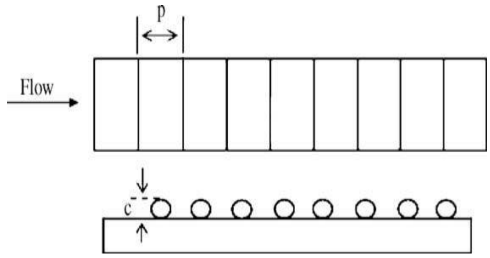

Figure 9: Transverse continuous ribs [11].

Karwa [12] had experimentally investigated the effect of repeated rectangular cross-section ribs on heat transfer and friction factor for duct aspect ratio (W/H) range of 7.19–7.75, relative roughness pitch (p/e) value of 10, relative roughness height (e/D) range of 0.0467–0.050, Reynolds number (Re) range of 2800–15,000 as shown in Fig. It was explained that vortices originating from the roughness elements beyond the laminar sub-layer were responsible for heat removal as well as increase in friction factor. The enhancement in the Stanton number was reported to be 65–90% while friction factor was found to be 2.68–2.94 times over smooth duct.

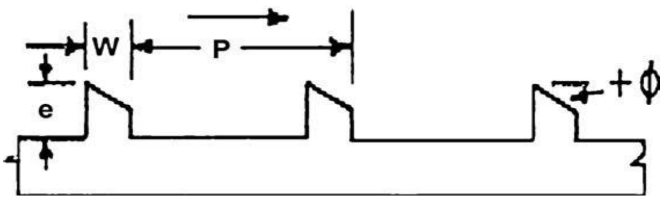

Figure 10: Chamfered ribs [12].

Gupta [13] had investigated the effect of relative roughness height, angle of attack and Reynolds number on heat transfer and friction factor in rectangular duct having circular wire ribs on the absorber plate. It was found that the heat transfer coefficient in roughened duct could be improved by a factor up to 1.8 and the friction factor had been found to increase by a factor up to 2.7 times of smooth duct. The maximum heat transfer coefficient and friction factor were found at an angle of attack of 60°and 70° respectively in the range of parameters investigated. The thermo-hydraulic performance of roughened surfaces had been found best corresponding relative roughness height e/D of 0.033 and the Reynolds number corresponding to the best thermo-hydraulic performance were around 14,000 in the range of parameters investigated.

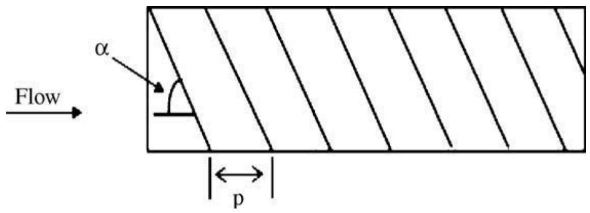

Figure 11: Inclined continuous ribs [13].

Momin [14] had experimentally investigated the effect of geometrical parameters of V-shaped ribs on heat-transfer and fluid flow characteristics in rectangular duct of solar air heater. The investigation covered Reynolds number range of 2500–18,000, relative roughness height of 0.02–0.034 and angle of attack of flow (a) of 30–90 for a fixed relative pitch of 10. For this geometry it was observed that the rate of increase of Nusselt number with an increase in Reynolds number is lower than the rate of increase of friction factor. The maximum enhancement of Nusselt number and friction factor as result of providing artificial roughness had been found as 2.30 and 2.83 times to smooth surface respectively for an angle of attack of 60°. It was also found that for relative roughness height of 0.034 and angle of attack of 60°, the V-shaped ribs enhance the value of Nusselt number by 1.14 and 2.30 times over inclined ribs and smooth plate respectively. It was concluded that V-shaped ribs gave better heat transfer performance than the inclined ribs for similar operating conditions.

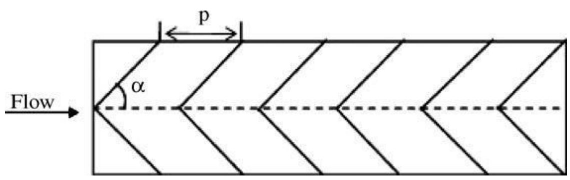

Figure 12: V-shape ribs [14].

Sahu and Bhagori [15] had investigated the effect of 90°broken ribs, on thermal performance of a solar air heater for fixed roughness height (e) value of 1.5 mm, Relative roughness height (e/D) value of 0.0338, duct aspect ratio (W/H) value of 8, pitch (p) in the range of 10– 30 mm and Reynolds number (Re) range of 3000–12,000. It was found out that the maximum Nusselt number attained for roughness pitch of 20 and decreased with an increase in roughness pitch. Roughened absorber plates increased the heat transfer coefficient by 1.25–1.4 times as compared to smooth rectangular duct under similar operating conditions at higher Reynolds number. Based on experimentation it was concluded that the maximum thermal efficiency of roughened solar air heater was to be of the order of (51–83.5%) depending upon the flow conditions.

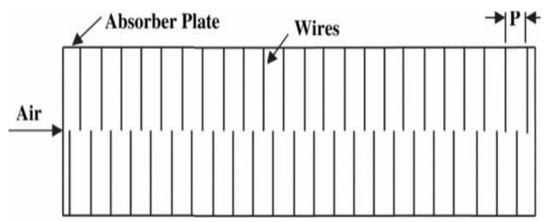

Figure 13: Transverse broken ribs [15].

III. CONCLUSION

It can be concluded from the literature review that various types of artificial roughness of different shapes and sizes such as V-shape, zig-zag shape, W-shape etc. has been investigated on the absorber plate of solar air heater and found that considerable enhancement in the heat transfer coefficient can be achieved with some increment of friction also the laminar sub layer breaks due to the use of artificial roughness and the flow becomes turbulent.

IV. REFERENCES

1. Gizem Maraba "An experimental study on enhancement of heat transfer in a solar air heater collector by using porous medium" October 2012.
2. A.M. Lanjewar, J.L. Bhagoria and R.M. Sarviya, "Heat transfer enhancement in solar air heater." Indian Journal of Science and Technology, vol.3,no.8, pp.908-910, Aug 2010.
3. K.R. Aharwal, Bhupendra K. Gandhi, J.S Saini, "Heat transfer and friction characteristics of solar air heater ducts having integral inclined discrete ribs on absorber plate." International Journal of Heat and Mass Transfer, vol.52, pp.5970–5977, 2009.
4. Santosh B. Bopche, Madhukar S. Tandale, "Experimental investigations on heat transfer and frictional characteristics of a turbulator roughened solar air heater duct" International Journal of Heat and Mass Transfer ,vol.52, pp.2834–2848, 2009.
5. Arvind Kumar, J.L. Bhagoria, R.M Sarviya., "Heat transfer and friction correlations for artificially roughened solar air heater duct with discrete Wshaped ribs." Energy Conversion and Management, vol.50, pp.2106–2117, 2009.
6. J.L. Bhagoria , J.S. Saini , S.C. Solanki. Heat transfer coefficient and friction factor correlations for rectangular solar air heater duct having transverse wedge shaped rib roughness on the absorber plate. Renewable Energy 25 (2002) 341–369.
7. Smith Eiamsa-ard., Pongjet.Promvonge, "Numerical study on heat transfer of turbulent channel flow over periodic grooves." International Communications in Heat and Mass Transfer,vol.35, pp.844-852, 2008.
8. S.K.Saini, R.P.Saini, "Development of correlations for Nusselt number and friction factor for solar air heater with roughened duct having arc-shaped wire as artificial roughness." Solar Energy, vol.82, pp.1118–1130, 2008.
9. Alok Chaube, P.K Sahoo., S.C. Solanki, "Analysis of heat transfer augmentation and flow characteristics due to rib roughness over absorber plate of a solar air heater." Renewable Energy, vol.31, pp.317–331, 2006.
10. R.P. Saini, Jitendra Verma, "Heat transfer and friction factor correlations for a duct having dimple-shape artificial roughness for solar air heaters." Energy, vol.33, pp.1277– 1287, 2008.
11. Verma SK, Prasad BN. Investigation for the optimal thermohydraulic performance of artificially roughened solar air heaters. Renew Energy. 2000; 20:19–36.
12. Karwa R, Solanki SC, Saini JS. Thermo-hydraulic performance of solar air heaters having integral chamfered rib roughness on absorber plates. Energy 2001; 26: 161–76.
13. Gupta D, Solanki SC, Saini JS. Thermo hydraulic performance of solar air heaters with roughened absorber plates. Solar Energy 1997;61:33–42.
14. Momin AME, Saini JS, Solanki SC. Heat transfer and friction in solar air heater duct with v- shaped rib roughness on absorber plate. Int J Heat Mass Transfer.2002;45:3383–96.
15. Sahu MM, Bhagoria JL. Augmentation of heat transfer coefficient by using 90 broken transverse ribs on absorber plate of solar air heater. Renew Energy. 2005;30: 2057–63.