ISSN: 2319-8753

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 5, May 2014

Investigation on Thermal Performance of Solar Air Heater by Using Artificial Roughness – A Review

M.M.Sahu[1], J.L.Bhagoria[2]

Research Scholar, Department of mechanical engineering, M.A.N.I.T., Bhopal (MP) 462051,India [1]

Professor, Department of mechanical engineering, M.A.N.I.T., Bhopal (MP) 462051,India [2]

Abstract: In the present paper an attempt has been made to review on thermal performance of solar air heater by using different roughness on absorber plate. The convective heat transfer coefficient of solar air heater is low due to the presence of viscous sub layer between the air and absorber plate. This can be improved by providing artificial roughness on the heat transferring surface. The thermal performance of solar air heater by providing artificial roughness on absorb plate by various investigators have been reviewed and presented.

Key words: Artificial Roughness, Heat Transfer Coefficient, Absorber Plate, Solar air heater

I. INTRODUCTION

Solar air heaters 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 fluid(air) flowing through the collector. Solar air heaters due to simplicity and low cost are most widely used collection devises. They are used for several applications such as space heating, crop drying etc.[1] 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 [2]. The heat transfer coefficient of solar air heater can be enhanced by breaking the laminar sub layer formed on the vicinity of absorber plates. The use of artificial roughness on the surface of absorber plate is an effective technique to enhance the heat transfer between absorber plate and air flowing over it. The application of artificial roughness in the form of fine wires and ribs of different shapes has been recommended to enhance the heat transfer coefficient by several investigators [3]. The use of artificial roughness would also result in an increase in friction losses and hence greater power is required for pumping air through the duct. In order to keep the friction losses at a low level, the turbulence must be created only in the region very close to the surface. A number of investigations have been carried out on the heat transfer characteristics and friction of the absorber plate with different types of roughness element on it.

II. VARIOUS ROUGHNESS USED BY INVESTIGATORS

Saini and Saini [4] investigate 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.

ISSN: 2319-8753

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 5, May 2014

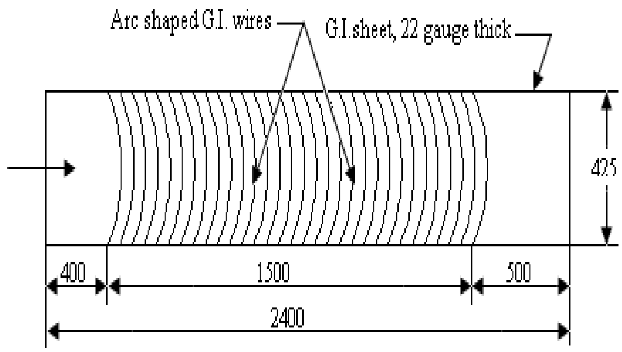

Fig. 1 Arc shaped roughness on Absorber plate investigated by Saini and Saini [4]

Karmare and Tikekar[5]investigated optimum thermo hydraulic performance of metal rib grits roughness. The rate of increase of useful energy gain is relatively higher at low range of Reynolds number, whereas it is a bit lower at higher range of Reynolds number. But the rate of increase of power consumption is low for lower range of Reynolds number and increases relatively at high rate as Reynolds number increases. The thermal efficiency lies within ±8% with a standard deviation of ±6%.

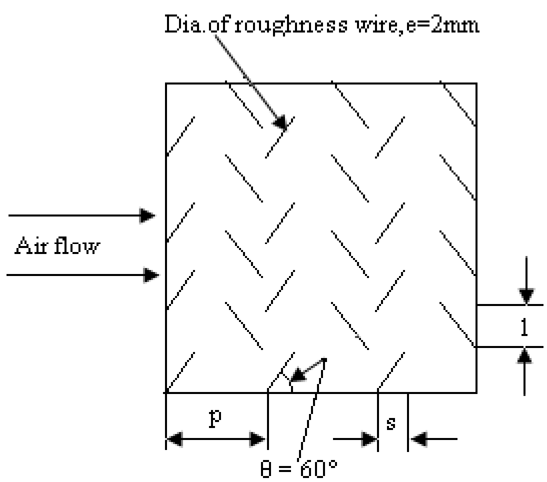

Fig.2 Layout of roughness surface investigated byKarmare and Tikekar [5]

Bopche and Tandale[6]using 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

ISSN: 2319-8753

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 5, May 2014

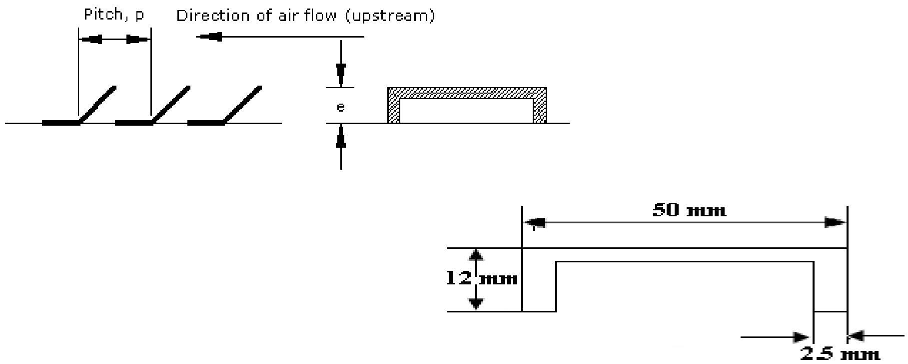

Fig. 3 Turbulator geometry investigated by Bopch andTandale [6]

Aharwal et al. [7] investigate 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 60^0 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.

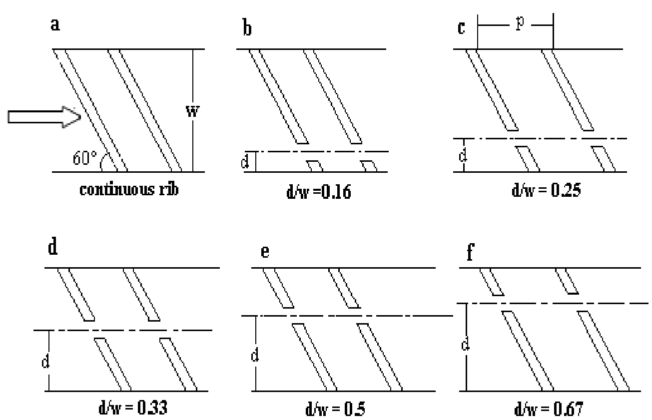

Fig. 4 Rib roughness geometry investigated by Aharwalet. al. [7]

Saini and Verma[8]usingdimple-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.

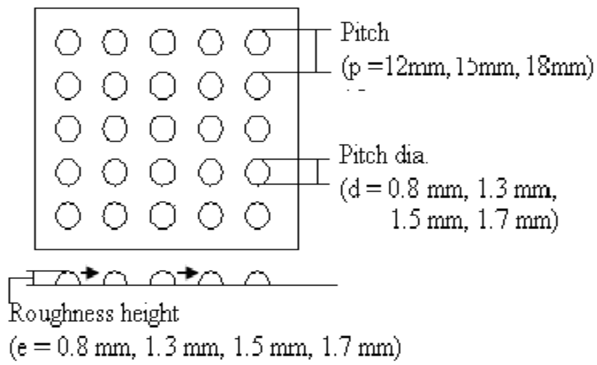

Fig. 5 Schematic diagram of dimple-shape geometry investigated by Saini and Verma [8]

AlokChaube et al[9]Using 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 11^0, 13^0, and 15^0), 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

Eiamsa-ard and Promvonge[10]investigate 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.

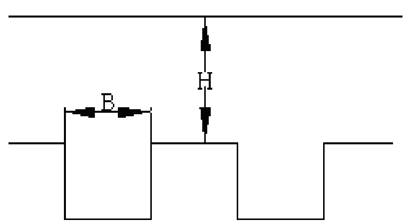

Fig.6 Grid arrangement for grooved channel flow investigated byEiamsa-ard and Promvonge [10]

Arvindkumaret. al.[11]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

ISSN: 2319-8753

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 5, May 2014

enhancement of nussult 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.

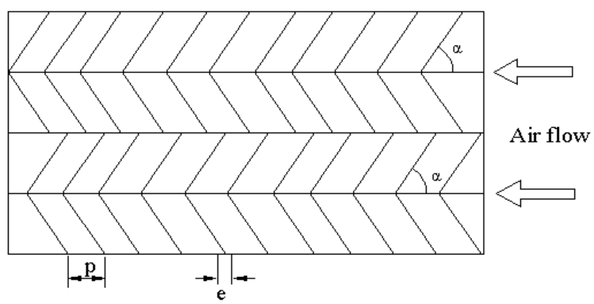

Fig. 7 Roughness geometry investigated by Arvindkumaret. al. [11]

Lanjewar A.M. et.al.[12]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 tream directions to the flow. The parameters used were Reynolds number range 2300-14000, relative roughness height (e/ D_h) = 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.

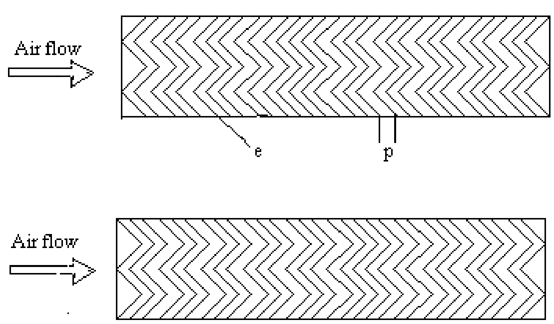

Fig. 8 Roughness geometry investigated by Lanjewar A.M. et.al [12]

III. CONCLUSION

It can be concluded from the present review that various type of artificial roughness of different shapes and sizes has been investigated and found that considerable enhancement in the heat transfer can be achieved with some increment of friction.

REFERENCES

[1] Abdul-Malik EbrahimMomin, J.S Saini., S.C Solanki, “Heat transfer and friction in solar air heater duct with V-shaped rib roughness on absorber plate.” International Journal of Heat and Mass Transfer,vol. 45, pp.3383-3396, 2002
[2] Varun, R.P.Saini, S.K Singal., “A review on roughness geometry used in solar air heaters.” Solar Energy ,vol.81, pp.1340–1350, 2007

ISSN: 2319-8753

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 5, May 2014

[3] 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, pp.341–369, 2002

[4]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.

[5]S.V.Karmare,A.N.Tikekar,"Experimental investigation of optimum thermo hydraulic performance of solar air heaters with metal rib grits roughness." Solar Energy, vol.83, pp.6–13, 2009.

[6] 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

[7] 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.

[8] R.P. Saini, JitendraVerma, "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.

[9] AlokChaube, 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] 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.

[11] Arvind Kumar, J.L. Bhagoria, R.M Sarviya., "Heat transfer and friction correlations for artificially roughened solar air heater duct with discrete W-shaped ribs." Energy Conversion and Management, vol.50, pp.2106–2117, 2009.

[12] 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.