CFD Investigation of Solar Air Heater by varying Rib Profiles-A Review

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Abstract— The heat is transferred between air and the absorber plate in a solar air heater. In general, the thermal performance of a solar air heater is low because of poor heat transfer between the absorber plate and air. It can probably be improved by enhancement of heat transfer from the absorber plate by the use of artificial roughness. This technique is gaining importance among the researchers since long time and a lot of research is still going on and has further scope. In this paper research outcomes of various researchers have been discussed. It is found through exploration of various studies on heat transfer enhancement in solar air heater absorber plate that heat transfer can be improved by providing artificial roughness on the absorber plate. Studies on various geometries of artificial roughness and roughness orientations have been investigated by the researchers. The results mainly obtained in the form of variations of Nusselt number and Friction factor with the flow of air in terms of Reynolds number. The review presented in this paper is aimed to provide research scope and findings in use of artificial roughness in solar air heater for better heat transfer.

Key words: Artificial Roughness, Solar Air Heater, Roughness Geometry, Nusselt Number, Thermo-Hydraulic Performance, Reynolds Number

I. INTRODUCTION

It is an effective technique to use artificial roughness in the form of repeated ribs on a surface to augment the heat transfer rate. Augmentation of convective heat transfer of a rectangular duct with the help of ribs is now common between engineers and scientists. This concept is widely applied in enhancing the thermo-hydraulic efficiency of various industrial applications such as solar air heaters, air conditioning components, refrigerators, chemical processing plants, automobile radiators and. Solar air heater is a device used to augment the temperature of air with the help of heat extracted from solar energy. These are cheap, have simple design, require less maintenance and are eco-friendly. As a result, they have major applications in seasoning of timber, drying of agricultural products, space heating, curing of clay/concrete building components and curing of industrial products.

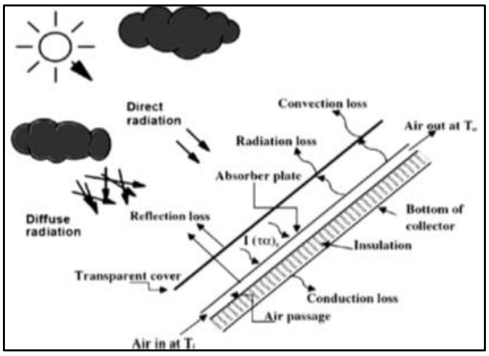

Fig. 1: Solar air heater constructional details

The shape of a solar air heater of conventional application is that of rectangular duct having an absorber plate at the top, a rear plate, insulated wall under the rear plate, a glass cover over the sun-radiation exposed surface, and a passage between the bottom plate and absorber for air to flow in. The detailed constructional details of a solar air heater are shown in fig. 1.

II. LITERATURE SURVEY

Saini and Saini [1] 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.

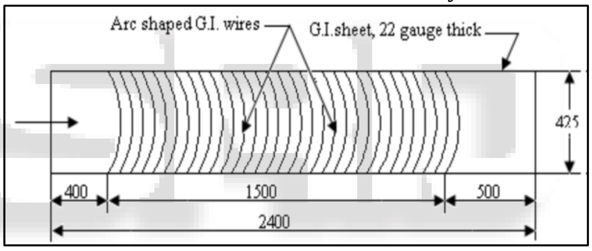

Fig. 1: Arc shaped roughness on Absorber plate investigated by Saini and Saini

Karmare and Tikekar[2]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%.

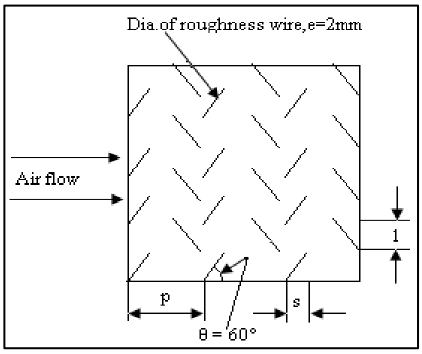

Fig. 2: Layout of roughness surface investigated byKarmare and Tikekar

Bopche and Tandale[3]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

Aharwal et al. [4] 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 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.

Saini and Verma [5] using 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.

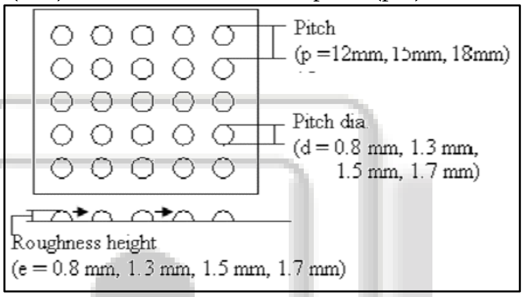

Fig. 3: Schematic diagram of dimple-shape geometry investigated by Saini and Verma

AlokChaube et al[6]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 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.

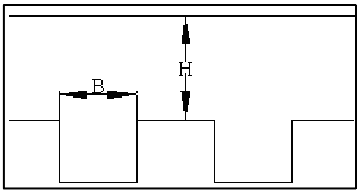

Fig. 4: Grid arrangement for grooved channel flow investigated by Eiamsa-ard and Promvonge

Eiamsa-ard and Promvonge [7] 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.

Arvindkumaret. al[8]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 ₀ – 75 ₀. the maximum 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 60₀.

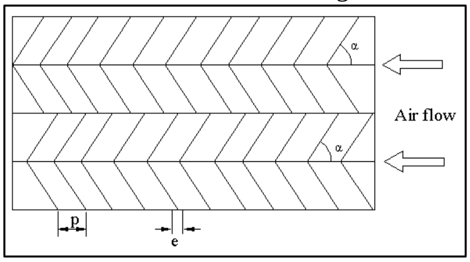

Fig. 5: Roughness geometry investigated by Arvindkumaret. al.

Lanjewar A.M. et.al.[9]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/ 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.

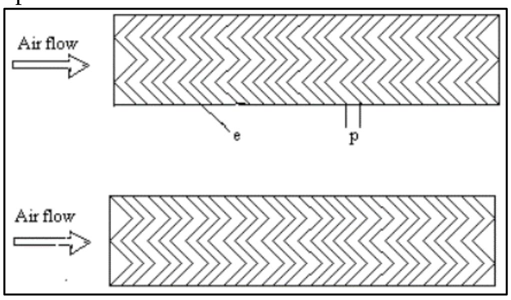

Fig. 6: Roughness geometry investigated by Lanjewar A.M. et.al

III. Conclusion

This paper on the review of solar air heater using artificial roughness is aimed to provide the information about the solar air heater, its performance and the artificial roughness. It has been reviewed from the previous researches that the conventional solar air heater performance is poor because of the poor heat transfer between the absorber plate and the air flowing over the plate. This is because of the formation of laminar sub layer above the absorber plate. The performance of the heater can be improved by establishing turbulence in the laminar sub layer region. This turbulence can be provided by the artificial roughness elements. The shape, size and orientation of the roughness elements play critical role in the effectiveness of the heat

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