Thermal Performance of Solar Air Heater by with Artificial Roughness-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.

Keywords- *Artificial roughness, Solar air heater, Roughness geometry, Nusselt number, thermo hydraulic performance, Reynolds number.*

I. INTRODUCTION

Inclination towards the Solar energy utilization is increasing rapidly not only due to the fast depletion of conventional energy sources but the environmental changes taking place globally are also alarming for the implementation of non-conventional energy sources. Since hot air is being used widely in residential and industrial purposes and a lot of conventional energy sources are employed in heating the air. The conventional sources of energy are using fossil fuels which are limited for use and also creating environmental problems of pollution globally. It is the non-conventional sources of energy such as solar energy which is not only available abundantly but also not affecting our environmentally adversely.

The solar energy is widely used in heating of air for residential and industrial purposes. Although, its usage is still very limited because of it's certain limitations such as low efficiency of solar air heaters. The solar air heater performance mainly depends upon the heat transfer rate from the absorber plate to the air. Since the air is a poor conductor of heat, the heat transfer rate is also poor from the absorber plate to the air in its simple form of arrangement. The falling solar radiations on the absorber plate of the solar air heater are absorbed by the absorber plate and the absorbed heat is transferred to the air surrounding the plate. Different researchers have modeled the heat transfer in heater.

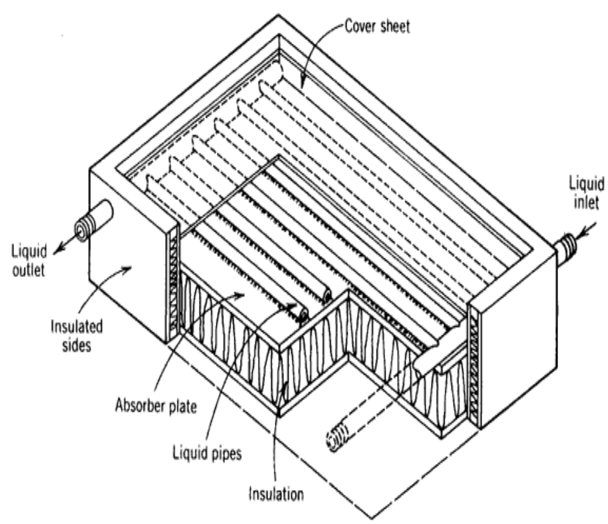


Figure 1:Flat Plate Liquid Heating Collector

The solar heater as shown in figure 1 is used for liquid heating. This type of heater has flat plate absorber with insulation to prevent the heat loss from the heater. Figure 2 is showing the flat plate collector for air heating. Atmospheric air is supplied under pressure though inlet and hot air is obtained from the other end of the heater.

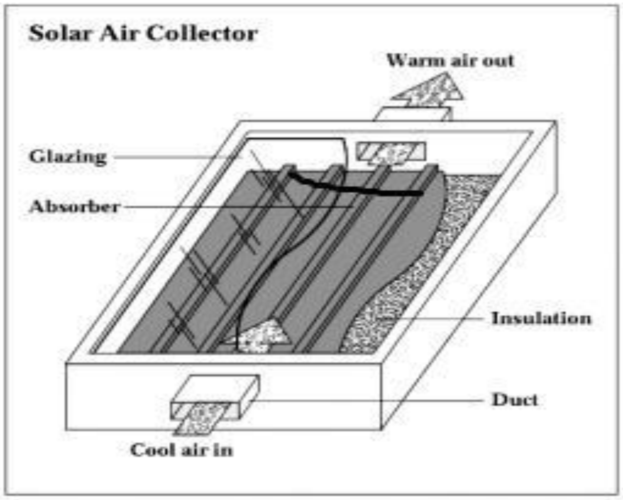


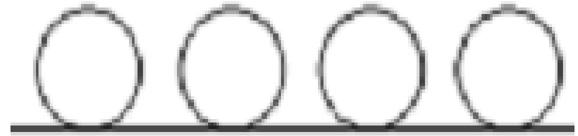
Figure 2:Flat Plate Air Heating Collector

The heat transfer rate from the absorber plate to the air can be improved by providing artificial roughness to the absorber plate. This technique has been used by various researchers and the results are compared by the smooth plate. In this paper it is focused to present different surface roughness geometries used in various researches and the geometry arrangements.

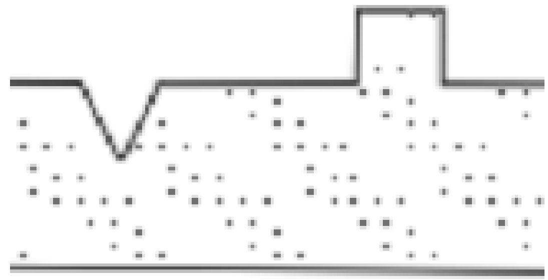
A. Artificial Roughness Technique

Artificial Roughness technique has been used by the researchers since long for the enhancement of heat transfer from the absorber plate of the solar air heater. In this technique the air flowing over the absorber plate is provided turbulence so as to improve heat transfer. The turbulence is provided by the artificial elements. The artificial roughness elements are kept over the plate surface where transfer of heat is taking place. The turbulence in air is created by these elements and depends upon the shape and size of the elements of roughness. Since the artificial roughness provides resistance to flow, power requirement for the flow also increases. It is therefore required to keep the power requirement as low as possible by maintaining surface resistance to a minimal value.

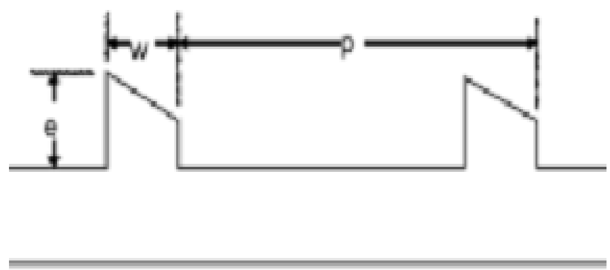
For the analysis of the performance of the solar air heater with artificial roughness, some parameters are used e. g Relative roughness pitch, Relative roughness height, Angle of attack and aspect ratio. Various roughness geometries have been used by the researchers for heat transfer analysis some of the geometries are V shaped, Square shaped, wire rib, transverse rib grooved, metal grit rib and chamfered rib as shown in figure3.



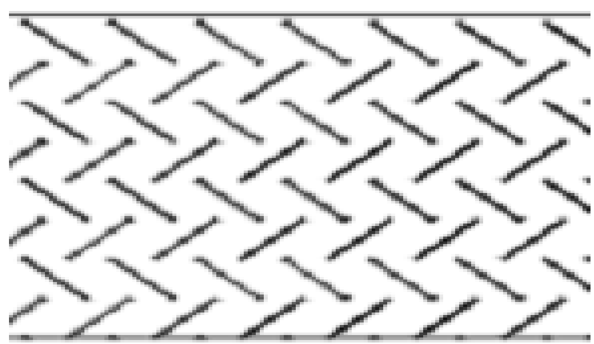
(a) Wire rib



(b) Transverse rib grooved



(c)Chamfered rib



(d)Metal grit rib

Figure 3: Different Roughness geometries

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.

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%.

Bopche and Tandale[6]using artificial roughness in the form of specially prepared inverted U-shaped tabulators 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

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 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

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.

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 usedwere 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 p

II. PERFORMANCE OF SOLAR AIR HEATER

The performance of solar air heater is the efficiency of the heater to absorb the solar radiations and transferring the heat absorbed to the air flowing over the absorber plate. The conventional solar air heaters have poor efficiency due to the lower heat transfer between the absorber plate and the air. This is primarily because of the formation of laminar sub layer above the absorber plate. The efficiency of the solar air heater can be improved if somehow this laminar sub layer could be broken.

III. CONCLUSIONS

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 transfer.

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