ISSN: 2321-8169
2883 - 2886

Comparative Study for Heat Transfer Enhancement and Friction Characteristic of Solar Air Heater having Artificial Roughness Geometry

Manish Parmar[1], Sukritindra Soni[2], Ashvin Suthar[3]

[1]M.E.Thermal Engineering Student, MIT, Piludara, Mehsana, Email Id: *manishmech123@yahoo.com*, [2, 3] Assistant Professor in Mechanical Engineering Department, MIT, Piludara, Mehsana, [2]email Id: *sukrit.soni@gmail.com*, [3]Email Id:*assuthar.me@spitcp.ac.in*

Abstract: Various active or passive methods have been introduced to save energy by increasing the heat transfer coefficients on absorber plate in Solar Air Heater. Rib/groove is one of the commonly used passive heat transfer enhancement techniques in solar air heater. Experimental investigation and Comparative study has been carried out to measure the combine effect of wavy-ribs & grooves Turbulators absorber plate in duct of double pass solar air heater. Also, a significant improvement has been observed in Nusselt Number for the experiment at Re 10000 to 20000. From this Experiment conclude that the Nusselt Number and Efficiency has been increased in double pass solar air heater as compared to the smooth (without turbulator) absorber plate in duct. The efficiency of DPSAH increased from 48% to 55%.

Key words*: - Solar energy, Solar air heater, Artificial roughness, collector efficiency, external recycle*

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1. Introduction

Solar air heaters are simple devices that utilize incident solar radiation to obtain clean energy for a wide usage. The solar air heater device intercepts solar radiation, converts this radiation to the heat in air and delivers the air for use. The main components of a solar air heater is an absorber plate, one or more channels for the flowing air, insulation for the bottom and lateral sides of the solar collector and one or more transparent covers. The use of a blower is optional for the air supply. Solar air heaters are the cheapest and extensively used solar energy collection devices employed to deliver heated air at low to moderate temperatures for space heating, drying agricultural products such as fruits, seeds and vegetables and some industrial applications.

Lots of work has been carried out to increase the efficiency and heat transfer rate of the double pass solar air heater. Such as different conductive material used as an absorber plate, porous media used in the DPSAH, Effect of different Insulation material, Fill different geometry inside the DPSAH, Artificial Roughness Geometry.

Artificial roughness is a passive heat transfer enhancement technique by which thermo hydraulic performance of a solar air heater can be improved .As the air flows through the duct of a air heater, laminar sub layer is formed over the absorber surface that obstructs heat transfer to the flowing air, there by adversely affecting the thermal performance of the solar air heater. In order to attain high heat transfer coefficient, it is enviable that flow at the heat transferring surface is made turbulent. However, energy for creating such turbulence comes from fan, which in turn increases the power requirement artificially roughened absorber plate, is considered to be good methodology to increases the heat transfer coefficient since it breaks laminar sub layer in order to reduce thermal resistance. But this also causes simultaneous increase in friction factor. Artificial roughness is provided in the form of ribs, dimple shape roughness, wire mesh, or baffles, delta winglets etc.

Abdul-Malik Ebrahim Momin et al.[1] investigated for the effect of geometrical parameters of V-shaped ribs on heat transfer and fluid flow characteristics of rectangular duct of solar air heater with absorber plate having V-shaped ribs on its underside. The range of parameters are Reynolds number (Re) range of 2500–18000, 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; this appears due to the fact that at relatively higher values of relative roughness height, the re-attachment of free shear layer might not occur and the rate of heat transfer enhancement will not be proportional to that of friction factor. The thermo-hydraulic performance parameter improves with increasing the angle of attack of flow and relative roughness height and the maxima occurs with an angle of attack of 60°.

J.L. Bhagoria et al. [2] performed an experiment to collect heat transfer and friction data for forced convection flow of air in solar air heater rectangular duct with one broad wall roughened by wedge shaped transverse integral ribs. Twenty wedge shaped ribs of varying geometries have been used for study. A maximum enhancement of heat transfer occurs at a wedge angle of about 10° while on either side of this wedge angle, Nusselt number decreases. The friction factor increases as the wedge angle increases.

Moummi et al.[3] theoretically and experimentally analyzed the energy of a solar air collector with rows of rectangular plate fins inserted perpendicular to the flow. Two types of absorber plates were used in the collector; black-painted aluminum sheets (nonselective absorber plate) and cooper

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sun plates (selective absorber plate). The results achieved were compared with experimental results of a solar air collector without fins. It was concluded that the rectangular fins increased the temperature of the absorber plate and enhanced the heat transfer.

Sahu et al.[4] experimentally investigated the heat transfer coefficient of a solar air heater with 90° broken transverse ribs on the absorber plate. For comparison of the results, four types of absorber plates were used; one smooth and three artificially roughened with roughness pitch of 10, 20 and 30mm. During the experiments, the roughened wall was heated while the other three walls were insulated. The pressure drop, Reynolds and Nusselt numbers, heat transfer coefficients and the efficiencies were calculated based on the experimental results obtained. The comparison of the smooth and roughened three collectors revealed that the plate having a roughness pitch of 20 mm provided the highest efficiency of 83.5% and the roughened absorber plates increased the heat transfer coefficient 1.25 - 1.4 times under similar operating conditions. The maximum enhancement of heat transfer coefficient occurred at a pitch approximately 20 mm.

Jaurker et al. [5] Investigated the heat transfer and friction characteristics of a rectangular shaped duct with a roughened absorber plate. The roughness was achieved by repeated rib-grooves. The absorber was a 3 mm thick aluminum plate. It was concluded that the existence of roughness increased the Nusselt number and friction factor up to 2.7 and 3.6 times, respectively. To obtain the maximum heat transfer, the relative roughness pitch value should be about 6.0. The Nusselt number and friction factor correlations developed were found to predict the experimental values with a deviation of 2.73 and 3.16% respectively.

2. Experimental Setup

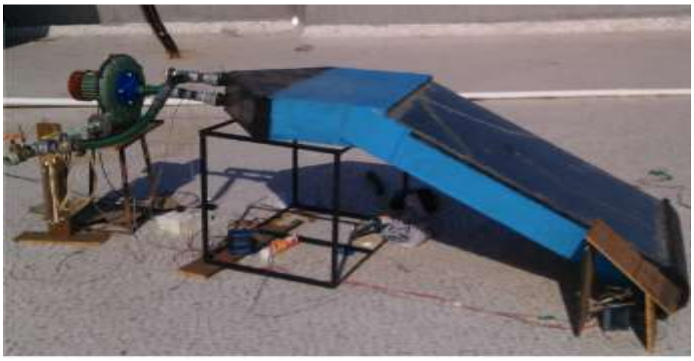

Figure2.1 Experimental Setup

An experimental setup has been fabricated with two different absorber plate smooth simple absorber plate and rib grooved roughned turbulor absorber plate. Whole side box of double pass solar air heater has been made up of wooden sheet of 15mm thickness. 5mm thick two glass cover has been used to receive the maximum solar radiation. Both the absorber plates have been manufactured from the galvanized iron sheet. An absorber plate has been blackened coated to absorber the maximum solar radiation during the day period. An inclination of 23° to the horizontal has been provided to utilize the receiving of maximum solar radiation. Separate duct has been provided for inlet and outlet of the air flow. The solar radiation has been measured with help of digital solari meter and an orifice meter has been provided to measure the flow of air in the outlet section with the help of pressure drop and in duct section with the help of inclined tube manometer. 1hp blower has been used to blow the air. All temperatures have been measured with the help of j-Type thermocouple and it indicates in the j-Type temperature indicator.

Figure 2.2 Rib-Grooved Roughned geometry absorber plate

In this experiment the resultant data has been predicted with different mass flow rate at different velocity such as 5 m/s for smooth simple absorber plate for a bright sunny day, then after that replace the absorber plate with rib-grooved roughned geometry type absorber plate. The detail of the 60°angle of attack triangular wavy ribs and groove is displayed in the fig.2.2.The pitch ratio(P/H) is 1.5, rib blockage ratio(b/H) is 1.2 at a single rib height of 5 mm, Compare the results of these both results and find out the Nu, Re, f, heat transfer co-efficient.

3. Result and Discussion

3.1 Validation of the smooth channel

The presents experimental results on heat transfer and friction characteristics in smooth channel are validated in terms of Nusselt (Nu) number and friction factor(f).The Nu and f obtained from the experimental results are validated with those from the correlations of dittus-boelter and blasius equation (6).

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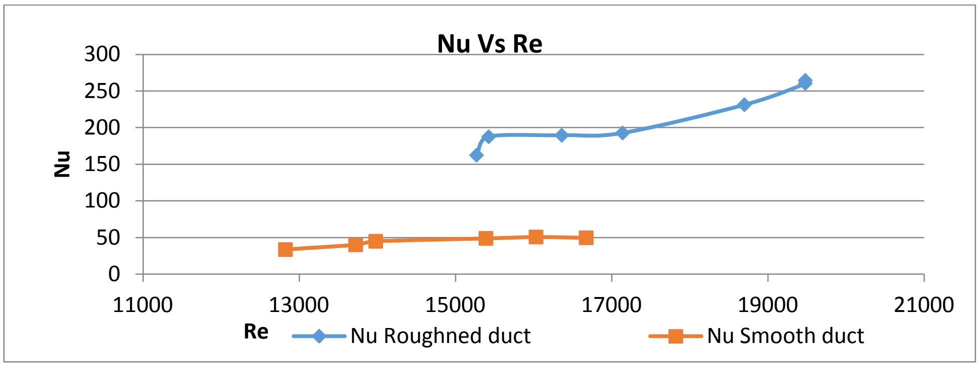


Figure 3.1 Effect of Re on Nusselt Number of smooth duct and roughned duct

Nusselt number of smooth duct and roughned duct has been calculated and compared in the above chart Figure 3.1. From the above chart it has been observed that the Nu of smooth absorber plate and of rib grooved roughned geometry DPSAH is gradually increase with increase in Reynold numbers or mass flow rate of the air. The value of maximum Nu is 264 and lowest value of Nu of DPSAH is 33.

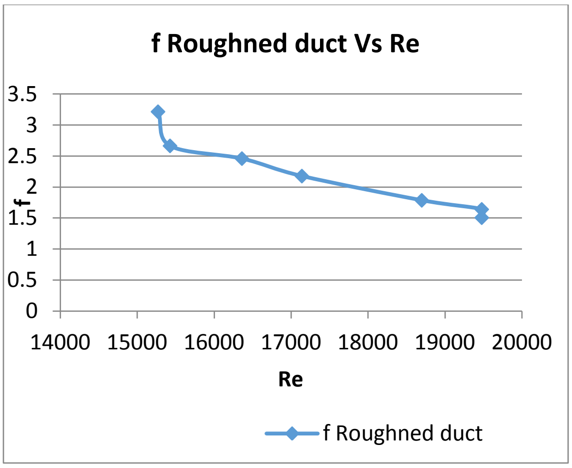
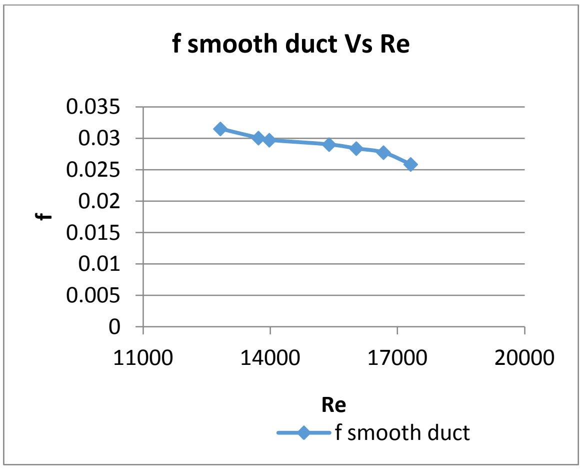


Figure 3.2 (a) Effect of Re on Friction factor for roughned Duct



(b) Effect of Re on Friction factor for smooth duct

Friction factor is affected by Reynolds number. The maximum friction factor has been gained in this experiment in DPSAH with rib-grooved roughned absorber plate. Figure 3.2 shows the comarision of friction factor with respected to Re. it shows the effect of Re increasing gradually the friction factor has been reduced from 3.2 to 1.5 with range of Reynolds number 14000 to 20000 in rib-grooved roughned geometry absorber plate, then in smooth absorber type friction factor reduced from 0.05 to 0.025.

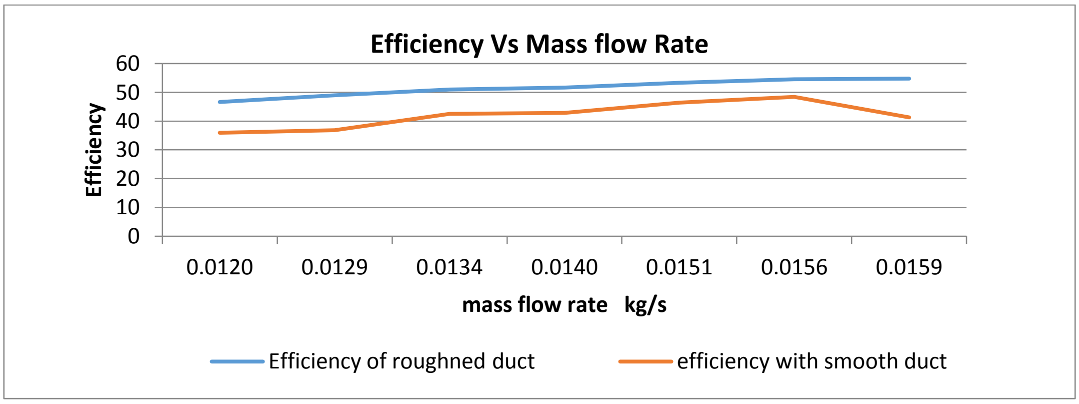


Figure 3.3 Effect of mass flow rate on the efficiency of the DPSAH

Efficiency of the solar air heater is the main approach of this study is to enhance the heat transfer co-efficient and efficiency of the double pass solar air heater. From this figure it has been observed that the efficiency of the DPSAH increasing with the use of rib-grooved roughned geometry in place of smooth absorber plate from 30%-48% to 45%-58%.

Conclusion

From the above experimental comparative study it has been conclude that the combined rib-groove roughned geometry gives the more efficiency as compared to the smooth absorber plate used in the DPSAH. The increment in efficiency has been observed up to 10%. Significant improvement in Nu has been observed and friction factor has been drastically increasing in rib-grooved roughned geometry used as absorber plate in DPSAH.

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