Heat Transfer Enhancement in Solar Air Heater: A Review

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Abstract: ***Investigators have shown that by providing the obstruction in the flow of air through the duct enhances the heat transfer of solar air heater. This enhancement is accompanied by considerable rise in pumping power. In view of the fact the investigator needs to carefully examine the method of providing obstruction in the flow. In this paper some methods of providing obstruction in the flow have been formulated on the basis of heat transfer enhancement and thermo hydraulic performance. The objective of this paper is to review the various methods used to enhance the heat transfer rate with little penalty of friction. Correlations developed by various researchers with the help of experimental results are discussed in this paper. These correlations are used to predict the thermo hydraulic performance of solar air heaters.***

Keywords: Solar air heater, heat transfer enhancement, thermo hydraulic performance

1. Introduction

Energy plays key role for economic and social development. Demand for energy has been rising rapidly with growing population, transportation and industrialization. Due to continuous use of fossil fuels, not only the energy starvation is felt at global level but another serious problem of environment degradation has also been resulted. The rapid depletion of conventional energy sources has necessitated search for alternative energy sources to meet the energy demand of immediate future and for generations to come. Of the many alternatives, solar energy stands out as the brightest long range promise towards meeting the continually increasing demand for energy. Solar energy is available freely, omnipresent and an indigenous source of energy provides a clean and pollution free atmosphere. The simplest and the most efficient way to utilize solar energy are to convert it into thermal energy for heating applications by using solar collectors. Solar air heaters, because of their inherent simplicity are cheap and most widely used collector devices. Solar air heaters are being used for many applications at low and moderate temperatures. Some of these are crop drying, timber seasoning, space heating, cooking etc. The thermal efficiency of solar air heater has been found to be low due low thermal capacity of air and because of low convective heat transfer coefficient between absorber plate and flowing air in the duct. Attempts has been made to enhance the heat transfer rate by use of extending surface in form of fins, by providing artificial roughness in the duct, , by providing transverse rib in the direction of flow and by introducing baffled duct.

Turbulence is created by obstruction in the viscous sub layer to obtain heat transfer enhancement. Several methods have been tested so far to enhance heat transfer with consumption of pumping power. This paper is the review of work done by various researchers on solar air heater to enhance its performance.

2. Methods of Performance Enhancement

A. By using artificial Roughness

CFD Based Performance Analysis of Artificially Roughened Solar Air Heater by Arun Kumar Yadav. In this paper author has performed a CFD analysis of a solar air heater with an artificial friction which increases the turbulence and heat Reynolds number increases because of it heat transfer rate enhances.

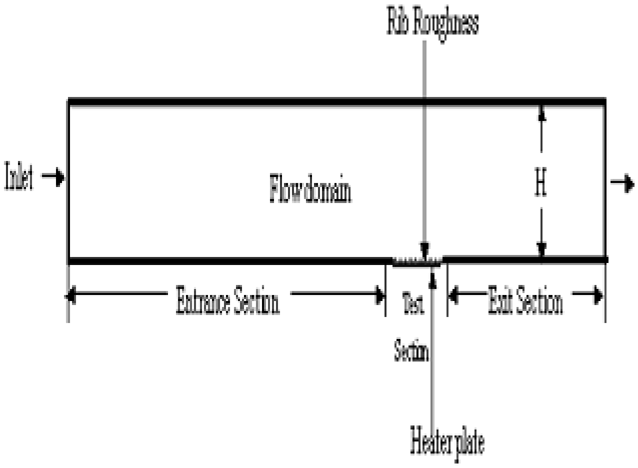

Figure: 2D representation of experimental setup for SAH with artificial roughness

After doing CFD analysis Results are presented in form of graphs, representing the average Nusselt number at different Reynolds numbers, and in form of temperature and velocity contours at particular sections for a fixed Reynolds number.

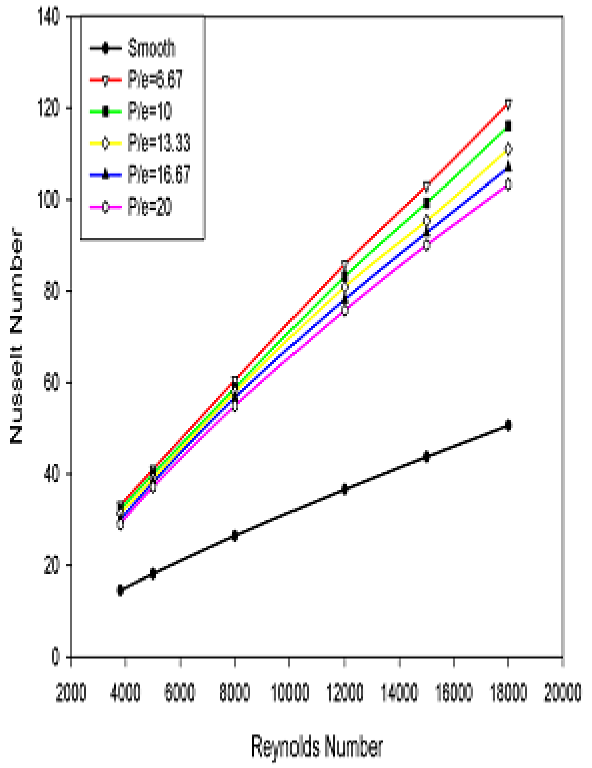

Figure: Effect of Reynolds number on average nusselt number for SAH with artificial roughness

It can be seen that the enhancement in heat transfer of the roughened duct with respect to the smooth duct also increases with an increase in Reynolds number. It can also be seen that Nusselt number values decrease with the increase in relative roughness pitch (P/e) for fixed value of relative roughness height (e/D). This is due to the fact that with the increase in relative roughness pitch, number of reattachment points over the absorber plate reduces. The roughened duct with relative roughness pitch of 6.67 provides the highest Nusselt number (Nu=121) at a Reynolds number of 18000. The roughened duct with relative roughness pitch (P/e) of 20 provides the lowest Nusselt number (Nu=29) at a Reynolds number of 3800. The maximum enhancement of average Nusselt number is found to be 2.31 times that of smooth duct for relative roughness pitch of 6.67 at a Reynolds number of 18000.

Friction factor decreases with the increasing values of the Reynolds number in all cases as expected because of the suppression of laminar sub-layer for fully developed turbulent flow in the duct. It can also be seen that friction factor values decreases with the increase in relative roughness pitch (P/e) for fixed value of roughness height, attributed to less interruptions in the flow path. The maximum and minimum value of friction factor occurs at relative roughness pitch (P/e) of 6.67 and 20 respectively for the range of parameters investigated. It is also observed that the maximum enhancement of average friction factor is found to be 3.14times that of smooth duct for relative roughness pitch of 6.67 at a Reynolds number of 3800.

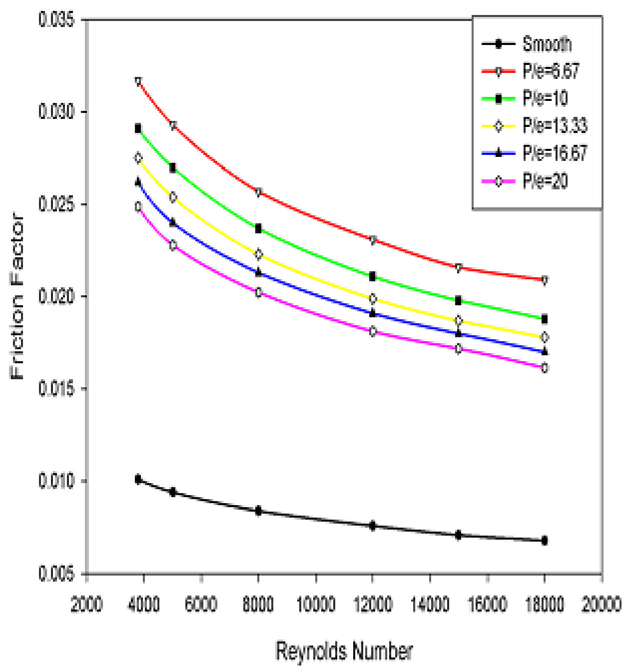

Figure: Effect of Reynolds number on average friction factor for SAH with artificial roughness

B. By using transverse rectangular ribs

CFD based analysis of heat transfer enhancement in solar air heater provided with transverse rectangular ribs by A. Boulemtafes-Boukadoum. In this paper the author has classified the solar air heater in three types;

Type I with air flowing between absorber plate and cover glazing;
Type II with air flowing between absorber plate and back panel;
Type III with two air channels above and below the absorber plate.

And used type I arrangement for CFD analysis and to enhancement the heat transfer transverse ribs are mounted to obstruct the flow. The obstacle generates the secondary flow or recirculation, which results in two separation zones on both sides of obstacle. The generated vortices are responsible of the turbulence and thus increase the heat transfer and pressure losses. Secondary fluid circulation promotes a better convective heat transfer. However it is desirable that turbulence takes place only in near wall region that is to say within laminar sub-layer, where the heat transfers takes place to minimize friction loss.

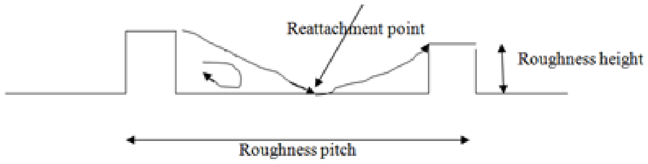

Figure: flow separation and reattachment over a rib

To study the heat transfer enhancement author has chosen a rectangular section channel with type-I solar air heater. The top surface is glazing and bottom one is the heated absorber. This surface is provided with rectangular ribs. Air is flowing between two surfaces in forced convection.

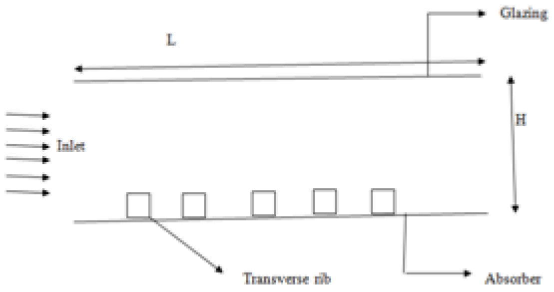

Figure: 2D representation of experimental setup for SAH with transverse rib

In this paper author has performed the CFD analysis of Type- I solar air heater and result is plotted on a graph Staton number verses Reynolds number.

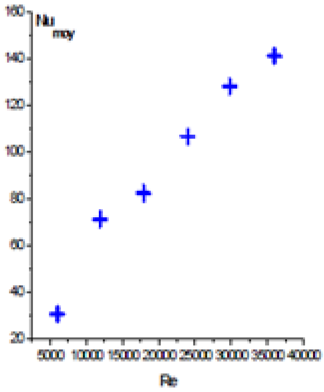

Figure: Effect of Reynolds number on Nusselt number for SAH with transverse ribs

This graph represents the Nusselt number mean evolution according Reynolds number for transverse ribs. Nu increases in an almost linear way with Re. This result was foreseeable because at low Reynolds numbers (laminar flow), Nusselt number for all surface types is barely constant, because of the resistance of the viscous sub-layer to heat transfer. The use of artificial roughness has for effect to break this resistance, and thus increase the heat transfer. However, a high value of Nu doesn’t guarantee a good thermal efficiency. Because when the Reynolds number increases, then generated vortex causes also losses of pressure.

The friction factor decreases with the increase in the Reynolds number. We can also observe that the values of the factor of friction remain moderate in all the range of Reynolds numbers.

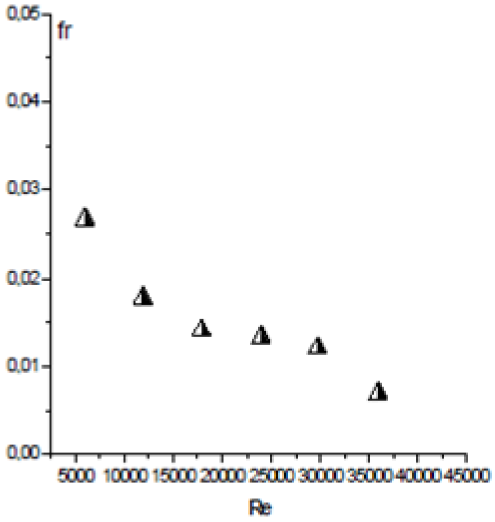

Figure: Effect of Reynolds number on friction factor for SAH with transverse ribs

C. By using baffled duct

Performance Study of Solar Air Heater with Baffled Duct by B.K. Maheshwari in this paper author has performed experimental analysis of solar air heater with baffled duct.

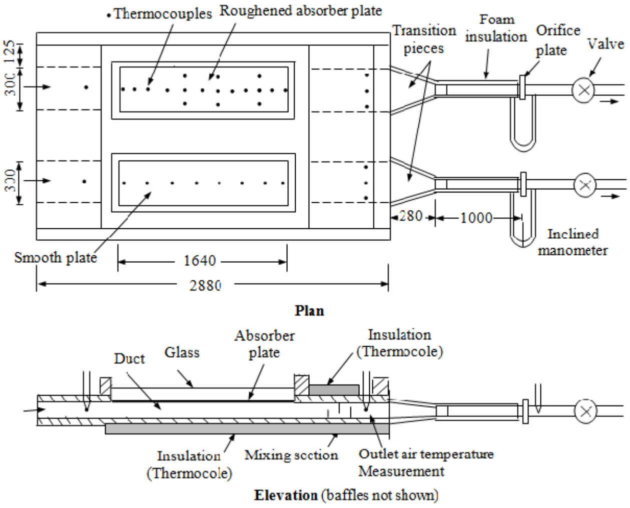

Figure: Experimental setup of solar air heater with baffled duct

It are consists of two parallel ducts (each 300 mm in width) with entrance, test and exit sections, a blower, control valves, and provision for temperature, flow and pressure drop measurements.

The results of above experiments are as follows;

G (kg/sm2)

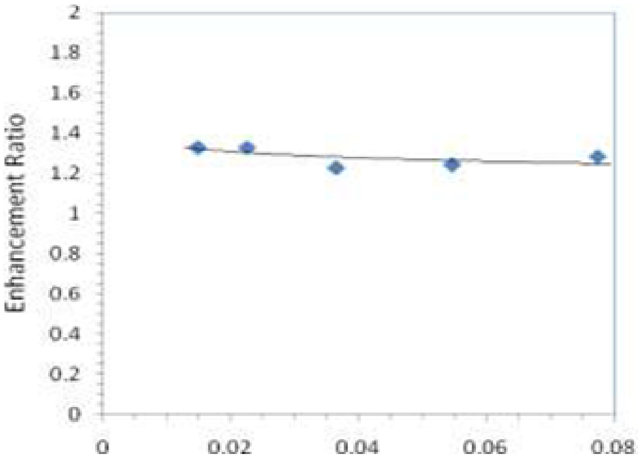

Figure: Thermal efficiency versus the flow rate per unit area of absorber plate for SAH with baffled duct

The enhancement ratio, ratio of thermal efficiencies of solar air heaters with perforated baffles and smooth duct is plotted against the air mass flow rate per unit area of the absorber plate. A thermal performance advantage of the order of 22-33% over the smooth duct solar air heater can be seen, which can be attributed to the heat transfer enhancement due to the baffles. The highest advantage is at the lowest flow rate of the study. The thermal efficiency of the baffled duct solar air is 40-84%; increasing with the flow rate because an increase in the flow velocity results in the increase in the heat transfer coefficient.

G (kg/sm2)

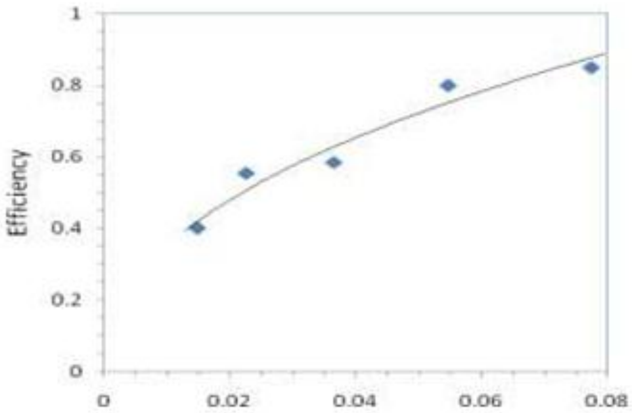

Figure: Thermal efficiency of baffled duct solar air heater

The pumping power requirement has been found to be quite insignificant and, hence, the perforated baffled duct solar air heaters are thermo-hydraulically advantageous and can be employed for applications involving mass flow rate per unit area of the absorber plate of 0.014-0.07 kgs-1m-2.

3. Conclusion

As we are creating turbulence in the form of to the air flow through the duct the heat transfer rate increases from artificial roughness, rectangular ribs.

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