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Effect of Various Artificial Roughnesses on Solar Air Heater Performance

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Abstract—*Many researchers have been conducting various experiments to improve heat transfer rate for solar air heater. Heat transfer rate can be increased by providing various artificial roughnesses to collector plate. By providing the various types of roughness like dimple, v shaped rib roughness on absorber plate inclined as well as the transverse rib on absorber plate. By using heat transfer coefficient the roughness number is fiend out and to decide that the actual now many heat transfer rate is increase. In this paper a review of different heat transfer enhancement techniques have been summarized.*

Keywords— *Nusselt number, Inclined and transverse ribs, V shaped rib, Roughness, Solar air heater, Friction factor, Efficiency*.

NOMENCLATURE

Nu- Nusselt number of smooth duct (Dimensionless)
P- Pitch (m)
h- heat transfer coefficient($wm^{-2}k^{-1}$)
Pr- Prandtl number (Dimensionless)
Re- Reynolds number (Dimensionless)
Cd- Coefficient discharge of orifice meter
f- friction factor (Dimensionless)
k- thermal conductivity
m- mass flow rate (Kgs^{-1})
Nu- Nusselt number of roughness duct
Ac- Area of absorber plate (m^2)
Cp- Specific heat of air ($JKg^{-1}K^{-1}$)
V- Velocity of duct (ms^{-1})
W- Width of duct (m)
SE- Stantum number
e- Height of roughness element (m)
L- Length of collector (m)
Greek Symbol:
ΔP- Pressure drop in test length (pa)
ρ- Density of air (Kgm^{-3})
α- Angle of attack of flow

I. INTRODUCTION

History of human, major development has been to increased to consumption of energy. The rapidly increasing the industrialization used more energy. The non-conventional energy is better option for the conversional source like solar, wind, etc.

Some investigations are investigated heat transfer rate in smooth and roughened the many useful information is available in today. For the flowing air the artificial roughness is better option for increasing the heat transfer rate. For purpose of the artificial roughness the wires, rib, dimple are used. The major component to utilized solar energy is solar air heater. It has several application in space heating and other area normally the rate of heat transfer is low in flat plate cause of low heat transfer coefficient between absorber plate and the following air for the thermal performance several method is used like us of fines packed bed is duct.

In recent work the many investigator investigate various type of geometry for artificial roughness. The recently the three side artificially roughness solar air heater is invalidated to enhance heat transfer rate also the booster mirror also used in one side to increased heat transfer. The roughness is provided for the purpose of the created.

A. Effect of the Combination of Incline and Transverse Ribs on the Solar Air Heater

Varuna, R.P. Sainib, S.K. Singalb,

Perform the experiment on the thermal performance of the solar air heater having roughness element of the combination the inclined and transverse rib on absorber plate

For the different roughness and operating parameter has been evaluated to represent the performance of the solar air heater is as shown in fig .the smooth collector performance also has been shown The three line are also drown for three value of p/e and one for the smooth absorber plate .obtained result also shown rough collector with absorber plate having relative roughness pitch p/e of give best performance

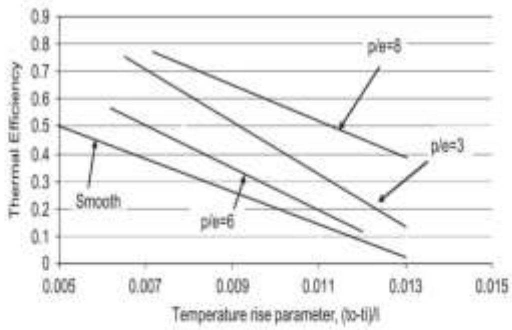

Fig. 1. Effect of the relative roughness pith on the thermal performance

The experimental value for the thermal efficiency for the roughened duct are represent as

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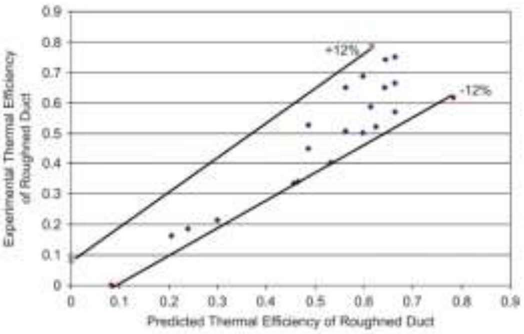

Fig. 2. Experimental verse predicted thermal efficiency roughness duct

The deviation are also accepted + -12%

The co-relation of Nusselt Number and friction factor

By obtaining the experimental value the relation is obtain as. The Nusselt is a function of Reynolds Number for the combination of the rib geometry. The power law relation between Nusselt Number and Reynolds number is an can show

Nu=B0*Re^1.213

Plot of Nu vs Re

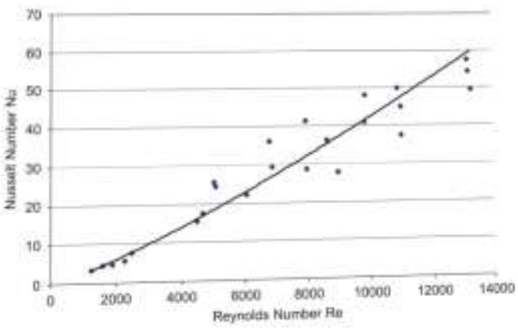

Fig. 3. Plot of the Nusselt number with Reynolds number

Bo is fact function of other influencing parameter. The other parameter is relative roughness pitch p/e value of (Nu/Re) has been plotted against relative roughness pitch (p/e)

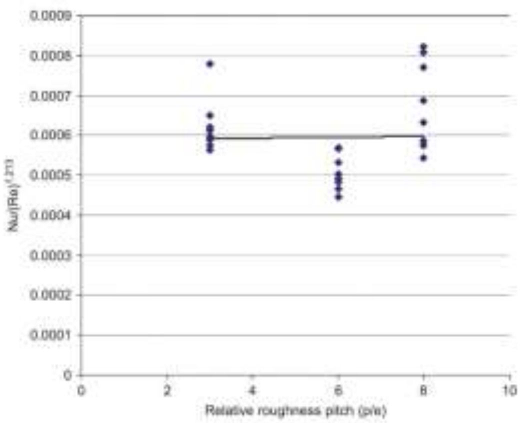

Fig. 4. Plot of Nu/Re 1.23 with Relative roughness pitch p/e

The following co-relation for Nusselt number

Nu/Re^1.213=0.0006*(p/e)^0.0104

A similar method has been used to developed the friction factor function fig show a plot of friction factor function of Reynold number for entire data for combination rib geometer.

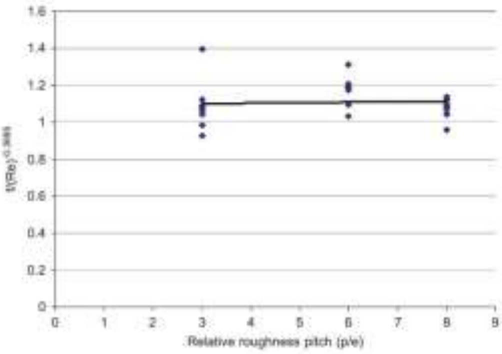

Fig. 5. Plot of f/Re^-0.3685 with relative roughness pitch

The relation between friction factor and Reynolds number is as

f=Co*Re

The following co-relation between friction factor is obtain as

f/Re^-0.3685=1.0858*(p/e)^0.0114

f=1.0858*(p/e)^0.0114*Re^-0.3685

The result obtain by the combination of the inclined and transver rib is solar air heater is also better than smooth absorbed plate.

B. Effect of V-Shaped Rib Roughness on the Absorber Plate for Heat Transfer and Friction Factor.

Abdul-Malik Ebrahim Momin a,*, J.S. Saini b, S.C. Solanki b perform the experiment and obtain the some value for the 45 and 60 degree v-shaped rib also have higher ribbed for heat transfer and pressure drop than corresponding angle

After completing the whole arrangement of the v shaped rib. The some experimental value was obtain the comparison of the value and those predicted by correlation for Nusselt number and friction factor of smooth duct proposed by modified diffuse bolter correlation for Nusselt number abd by modified Blasius correlation for Nusselt number range applied friction factor.

The modified diffuse Boelter co-relation is applicable for 2500<1.24*10^5 and minimum Reynolds number is our case is 2500.

For Nusselt number for smooth duct

Nu=0.023*Re^0.8*Pr^0.4*(2Rav/De)^-0.2

Where 2Rav/De=(1.156+H/W-1) (H/W) For rectangular angular factor,

Fs=0.085*(Re)^0.25

The following graph show the comparisons of experimental value and predicted values of friction factor for smooth duct is

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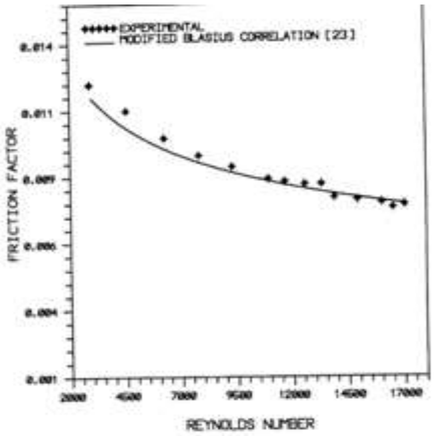

Fig. 6. Comparison of experimental values and predicted values of friction factor for smooth duct.

Effect of Reynolds Number

Generally the Nusselt number is inversely proportion to friction factor. The below show effect of Reynolds number on Nusselt number on for relative roughness height of 0.02 and for given angle of attack of flow

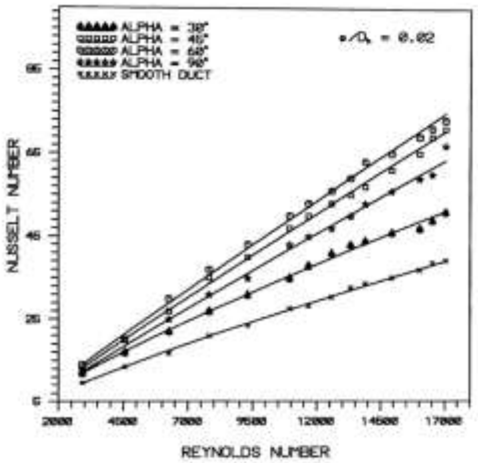

Fig. 7. Effect of Reynolds number on Nusselt number for relative roughness height of 0.02 and for given angle of attack of flow

Below graph also show effect of angle of attack of flow on Nusselt number for relative roughness height of 0.02 and for given Reynolds number.

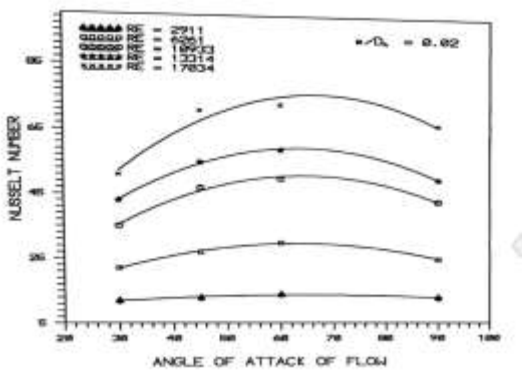

Fig. 8. Effect of angle of attack of flow on Nusselt number for relative roughness height of 0.02 and for given Reynolds number.

1) Nusselt number is directly proportional to Reynolds number and inversely proportional to friction factor obtain for smooth absorber plates.
2) Rate of heat transfer enhancement not proportional to friction factor.
3) When angle of attack of flow increase the thermo-hydraulic performance increase.

C. Effect of the Dimple-Shape Artificial Roughness on Solar Air Heaters

R. P. Saini, Jitendra Verma are perform the experiment on dimple shape artificial roughness on the solar air heater. They get correlation.

Correlations for Nusselt number and friction factor

As that the Nusselt number and friction factor are strong functions of flow and roughness parameters, namely flow Reynolds number (Re) and the roughness dimensions ofrelative pitch (p/e) and relative roughness height (e/D). The functional relationships for Nusselt number and friction factor can therefore be written as

$$Nu = fn^*(p/e, e/D, Re)$$

Fig 9 show the comparison of the experimental values of Nusselt and Reynolds number for roughened solar air heater. those predicted by correlations proposed by Modified Dittus–Boelter correlation for Nusselt number and Reynolds number It can be seen from these figures that the values obtained experimentally are comparable.

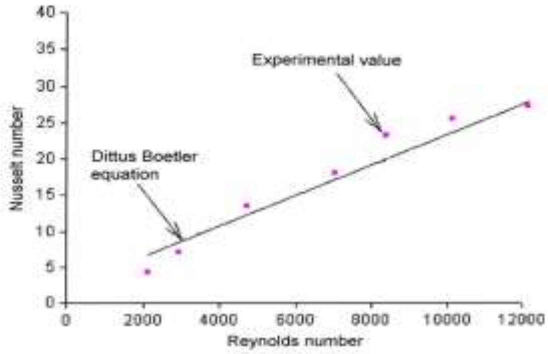

Fig. 9. Comparison of experimental and predicted values of Nusselt number.

Fig 10 shows the comparison between the experimental values of Nusselt number and those of predicted by the correlation developed for Nusselt number

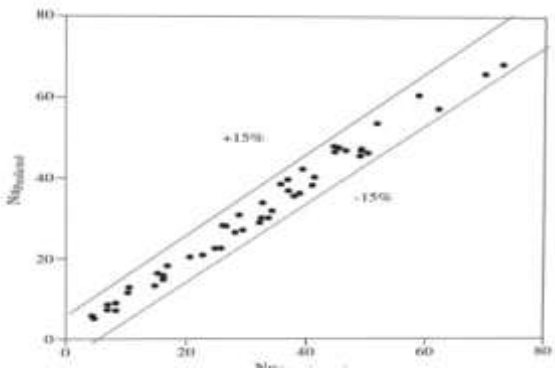

Fig. 10. Comparison of predicted values of Nusselt number with experimental values.

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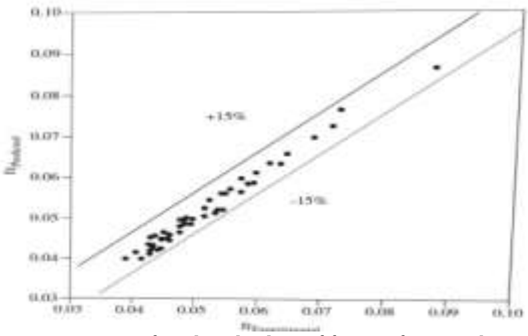


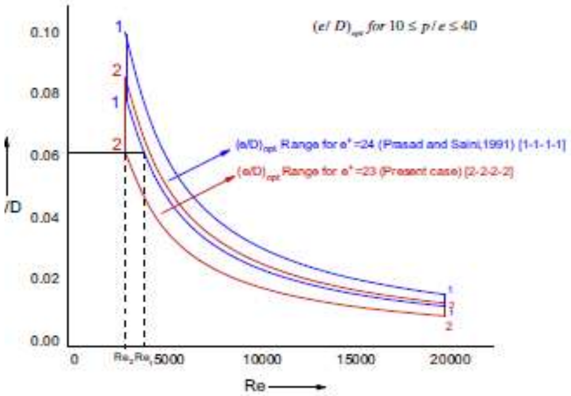
Fig. 11. Comparison of predicted values of friction factor with experimental values

Fig. 11 shows a comparison of experimental values and the values of friction factor obtained from the developed correlation. The average absolute percentage deviations between the experimental and predicted values have been found to be 7.58 and 4.68 for Nusselt number and friction factor, respectively.

D. Effect of the Three Side Artificial Roughness on Solar Air Heater.

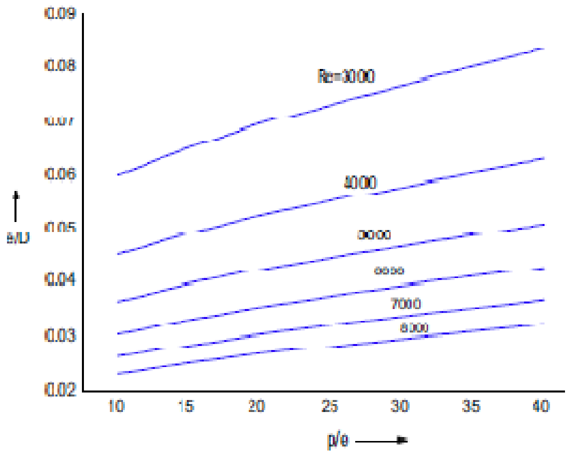
B.N. Prasad, Ashwini Kumar, K.D.P. Singh

They perform the experiment on three side artificial roughness on solar air heater the get better heat transfer rate than other one. Shows the optimal range of the values of relative roughness height, (e/D)opt for 10,<= p/e<= 40, at varying values of flow Reynolds number from 3000 to 20,000, for the present case and that of Prasad and Saini (1991), which shows that the range of optimal values of (e/D)opt, for the present is below that of Prasad and Saini (1991), and decreases with increasing values of flow Reynolds number.

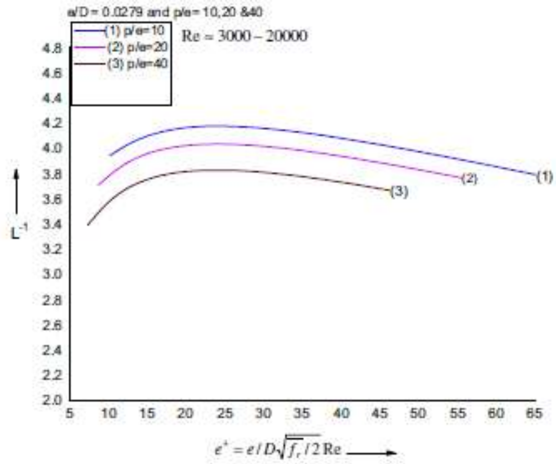


Optimal range of e/D.

Below figure show the variation of the Optimal thermohydraulic performance curve for three sides artificially roughened solar air heater.



Below the figure also show the effect of e+ on L^-1 for varying values of p/e.



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After completed of the experiment they get some important result as for the same values of roughness parameters and mass flow rate, three sides roughened solar air heaters will be qualitatively under optimal thermo hydraulic performance condition, better than those of one side roughened solar air heaters.

II. CONCLUSIONS

1) Optimal thermo hydraulic performance of three sides artificially roughened solar air heater of high aspect ratio has been analyzed.
2) Such solar air heaters have wider range of option for selecting the values of roughness and flow parameters than those of one side artificially roughened solar air heaters for optimal thermo hydraulic performance.
3) Such solar air heaters are both quantitatively and qualitatively better than one side artificially roughened solar air heaters under optimal thermo hydraulic performance conditions.
4) In general, Nusselt number increases whereas the friction factor decreases with an increase of Reynolds number. The values of Nusselt number and friction factor are substantially

higher as compared to those obtained for smooth absorber plates. This is due to distinct change in the fluid flow characteristics as a result of roughness that causes flow separations, reattachments and the generation of secondary flows.

5) 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

6) It was found that for relative roughness height of 0.034 and for angle of attack of 60_, the V-shaped ribs enhance the values of Nusselt number by 1.14 and 2.30 times over inclined ribs and smooth plate case at Reynolds number of 17034. It means that the V-shaped ribs have definite advantage over the inclined ribs for similar operating conditions.

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