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EFFECT OF DIFFERENT PARAMETERS ON THE PERFORMANCE OF RIB ROUGHNESS SOLAR DUCT

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Abstract - *The main objective of the present work is to study Effect of Relative roughness height (e/D), Relative roughness pitch (P/e), duct height (H) etc. on Effective as well thermal efficiency of roughened and smooth solar air heater.From the study it was found With increasing the duct height form 0.030 to 0.045 m there is decrement in the thermal performance of solar air heater. i.e. thermal performance is higher for the duct value of 0.030 m. With varying the value of duct length (L) form 1.5 to 2.0 m there is increment in the thermal performance of solar air heater. i.e. thermal performance is higher for the SAH having, duct length value of 2.0 m.*

***Key Words*:** V-shape roughness, Relative roughness height (e/D), Relative roughness pitch (P/e), duct height (H)

1. INTRODUCTION AND LITRATURE SURVEY ON APPLICATION OF ROUGHNESS

Solar collector is a simple system or device which works similar to a heat exchanger which, converts the solar energy which falls on its absorber plate into thermal energy and after that this thermal energy is used to raise the temperature of the fluid (air or water) flowing inside the collector. As per the requirements and temperature ranges the working fluid and its shape and designs may be changed [1--3]. Fig.1.

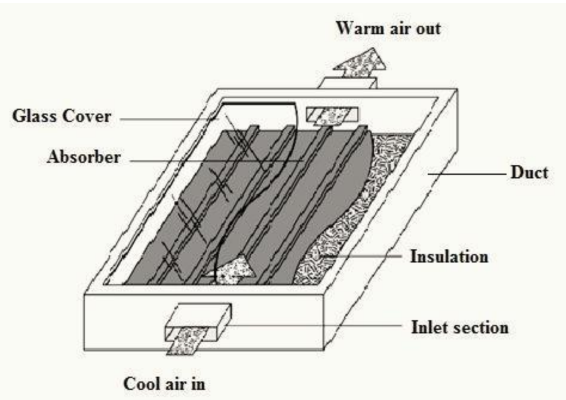

Fig.1. Pictorial view of solar air heater

Firstly Kays [4] suggested that Heat exchanger performance can be enhanced by using small diameter protrusion wires vertical to flow direction on surface of plate may help to break laminar sub-layer.

Sahu and Bhagoria [5] conducted an experiment to know the effect of transverse- broken ribs on heat transfer and friction factor of solar air heater. They found that the transverse broken ribs roughened absorber plates improved the heat transfer coefficient by 1.25–1.4 times as compared to smooth rectangular duct under the same operating conditions. Fig. 2. Shows the geometry of transverse-broken rib roughness.

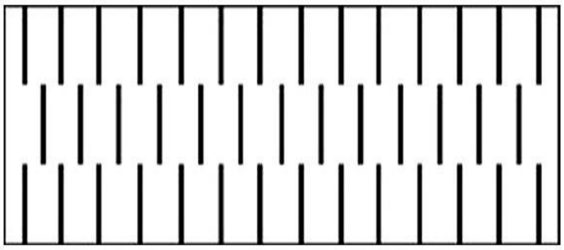

Fig. 2. Geometry of transverse-broken ribs.

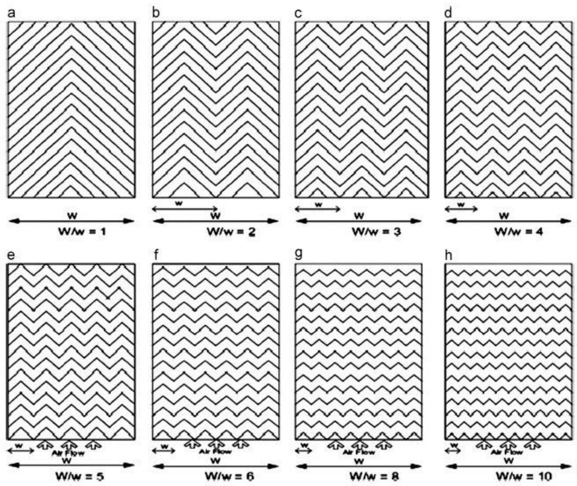

Fig.3. Multiple V- roughness geometry.

Hans et al. [6] investigated heat transfer and friction characteristics of multiple v-ribs roughened rectangular duct.A maximum enhancement of Nusselt number and friction

factor due to v-shaped ribs as artificial roughness has been found 6 and 5 times, respectively, over the smooth solar air heater duct for the range of experimental parameters. Fig.3. shows the multiple V- roughness geometry.
Karmare and Tikekar [7] carried out there experimental investigation by metal grit ribs roughness elements geomatry on the absorber plate as shown in Fig.4.

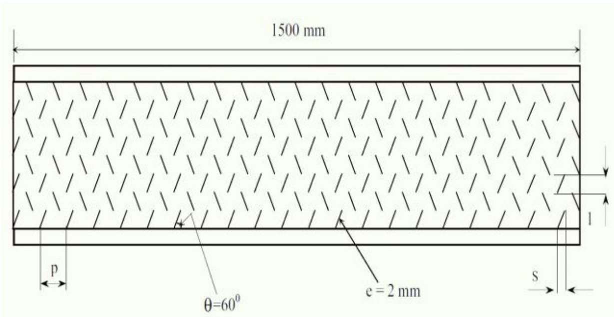

Fig.4. Metal grit ribs geometry.

Effect of discrete W-shape, (shown in Fig.5) on the performance of solar air heater duct is explored by Kumar et al. [8].

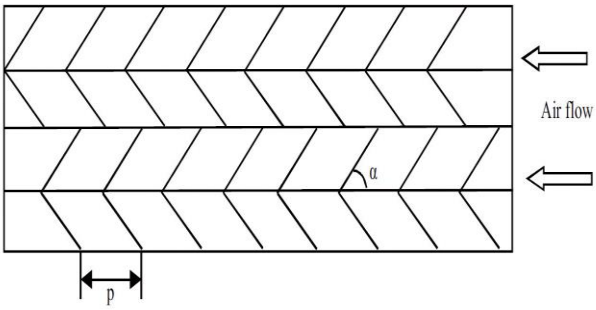

Fig.5. W-shape rib geometry

Effect of circular wire ribs in arc shape roughness geometry has been investigated by [9]. The roughness geometry arranged on absorber plate as shown in Fig.6. They investigate the thermal and thermohydraulic performance of this on the performance of solar air heater duct.

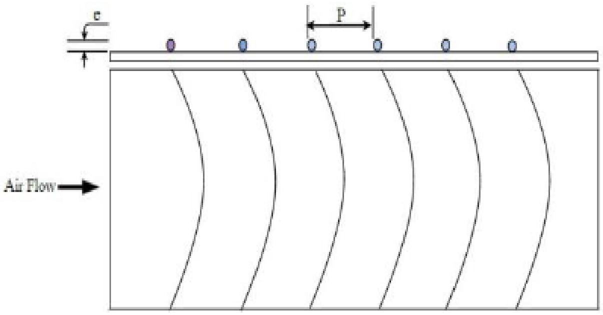

Fig.6. Arc shape roughness geometry.

2. AIMS OF PRESENT WORK

Present work has been done to predict the performance by varying the relative roughness height (e/D), relative roughness pitch (P/e), Reynolds number (Re), Mass velocity of air (G), and effect of Insolation (I) collectively on V-shaped wire Rib roughness solar air heater as shown in Fig 7 .

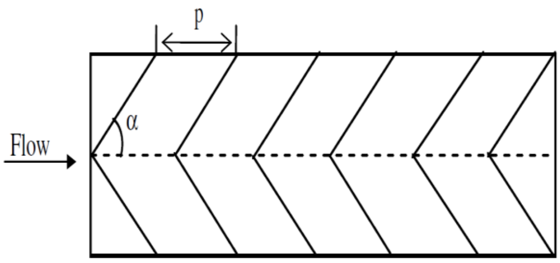

Fig.7. Geometry of V-shaped rib roughness.

3. MODELLING

The effective efficiency takes in account the fan work (Wp) by minus the equivalent thermal energy from useful heat gain (Qu) by air heater to obtain net thermal energy gain. The effective efficiency [10] is evaluated as ratio of thermal energy gain of solar air heater to the falling incident solar radiation on the absorber plate.

$$\eta_{eff} = \frac{Q_u - \left[\frac{Wp}{C}\right]}{I \times A_c} \qquad 1$$

The rate of useful thermal energy gain Q_u and Mechanical power (P) spent has been obtained by:

$$Qu = [I(\tau\alpha) - U_l(T_{pm} - T_a)/2]A_c F_R \qquad 2$$

The heat removal factor (F_R), of the solar air heater, which is calculated as;

$$F_R = \frac{mC_p}{A_c U_l}\left[1 - \exp\left[\frac{F'U_l A_c}{mC_p}\right]\right] \qquad 3$$

F′ is the collector efficiency factor which is calculated as;

$$F' = \frac{h}{h + U_l} \qquad 4$$

The thermal performance of solar air heater is calculated as [8]

$$\eta_{th} = \frac{Q_u}{IA_c} \qquad 5$$

Mechanical power (W_P) is calculated as:

$$W_P = VA_c \Delta P \quad (6)$$

The Value of pressure drop (ΔP) in the duct is calculated as:

$$\Delta P = \frac{2 f L V^2 \rho}{D} \quad (7)$$

The values of heat transfer coefficient, (h) and friction factor, (f) for smooth solar air heaters have been evaluated by [1-2, 12];

$$Nu_s = 0.024 \,\mathrm{Re}^{0.8}\, \mathrm{Pr}^{0.4} \quad (8)$$

Friction factor, (f_s) for smooth solar air heaters is calculated by;

$$f_s = 0.085 \,\mathrm{Re}^{-0.25} \quad (9)$$

Friction factor, (f) for v shaped rib roughened solar air heaters have been determined by the correlations developed by [11] which is given by;

$$f = 6.266.(\mathrm{Re})^{0.425} \left(e/D\right)^{0.565} \left(\alpha/60\right)^{-0.093} \exp[-0.719(\ln \alpha/60)^2] \quad (10)$$

The values of heat transfer coefficient, (h) for v shaped rib roughened solar air heaters have been determined by the correlations developed by [11] which is given by;

$$Nu_r = 0.067 \left(e/D\right)^{0.424} \left(\alpha/60\right)^{-0.077} .\exp[-0.782(\ln \alpha/60)^2] \mathrm{Re}^{0.888} \quad (11)$$

TABLE I. THE VALUES OF PARAMETERS CONSIDERED FOR THE PRESENT INVESTIGATION:

Parameters	Symbol	Value and Range	Unit
System parameters			
Collector length	L	1.5	m
Collector width	W	1.0	m
Height of Duct	H	0.030	m
Thickness of insulation		0.05	m
Thermal conductivity of insulation	Ki	0.037	W/m K
Number of glass covers	N	1	W/m K
Emissivity of absorber plate	ε_p	0.90	
Emissivity of glass cover	ε_g	0.85	
Transmittance-absorptance product	$\tau\alpha$	0.85	
Angle of attack	α	30-90	
Relative rib height	e/D	0.020-0.034	
Relative roughness pitch	P/e	10	
Overall heat loss coefficient	U_l	4-10	W/m^2 K
Operating parameters			
Fixed			
Ambient air temperature	T_a	301	K
Intensity of solar radiations	I	900-1200	W/m^2
Variable parameters			
Temperature rise parameter	$\Delta T/I$	0.0061-0.061	K/m^2 W
Reynolds number	Re	1600 - 20,000	

4. RESULT AND DISCUSSION

4.1. Effect of relative roughness height (e/D)

Effect of rib height (e) and relative roughness height (e/D) affects the performance of solar air heater. In roughened solar air heater it is desired that re-attachment of the shear layer occurred successfully or positively. In Fig.8. We can see the effect of rib height for different values of mass flow arte corresponding to m = 0.1951 (Re = 19970), m = 0.0650 (Re = 6654), m = 0.0217 (Re = 2216) .In lower range of mass flow rate there is significant enhancement in thermal efficiency as compare to higher Reynolds number.

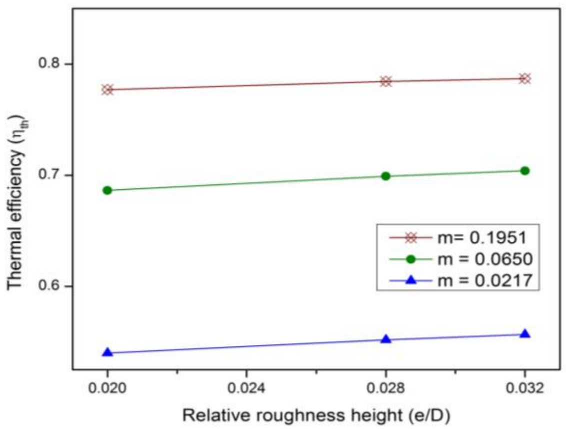

Fig.8. Effect of relative roughness height (e/D) on thermal performance for different values of mass flow rate.

4.2. Effect of relative angle of attack (α)

Effect of angle of attack (α) or orientation of rib with respect to flow on the absorber plate side, affects the performance of solar air heater. In roughened solar air heater it is desired that re-attachment of the shear layer and intensity of secondary flow should be more positively. In Fig.9. plots of the effect of angle of attack for different values of mass flow arte corresponding to m = 0.1951 (Re = 19970), m = 0.0650 (Re = 6654), m = 0.0217 (Re = 2216) .From Fig. it can be conclude that, In lower range of mass flow rate there is significant enhancement in thermal efficiency as compare to higher Reynolds number.

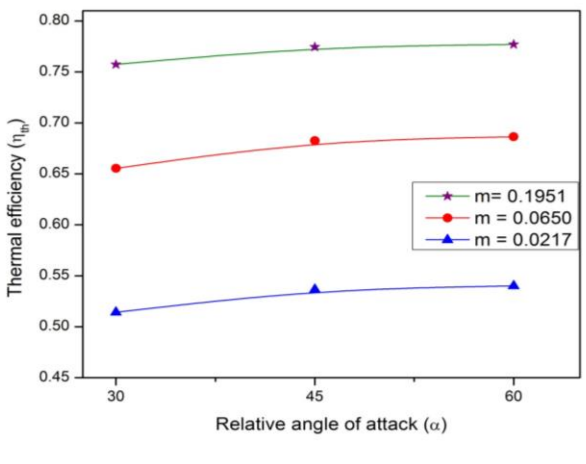

Fig.9. Effect of relative angle of attack (α) on thermal performance for different values of mass flow rate.

4.3. Effect of Duct Height (H)

Effect of duct height significantly affects the performance of the solar air heater. In Fig. 10 there are two different values of duct height are engaged, the fixed values are relative roughness height as e/D = 0.020, relative roughness pitch P/e = 10 and relative angle of attack α = 60° for I = 800 W/m^2, this values of geometrical parameter are selected due to we obtain the highest value of thermal and effective efficiency. From the Fig. it is clearly can be concluded, that Duct height having value of 0.030 m performs better than 0.045 m in terms of thermal efficiency.

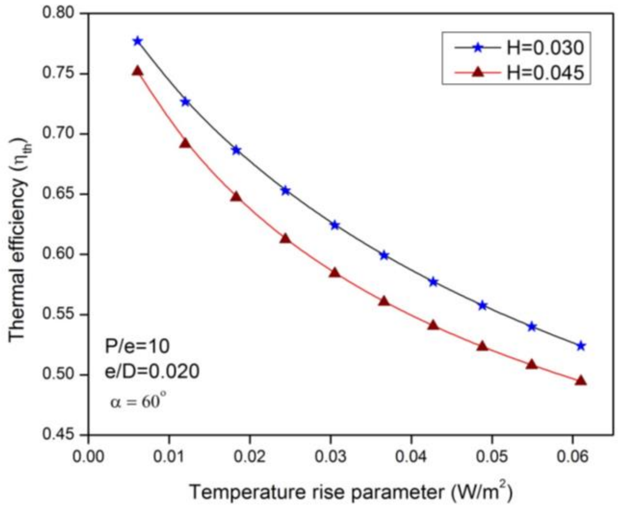

Fig.10 Effect of Duct height (H) on thermal efficiency as a function of temperature rise parameter at P/e =10, e/D = 0.020, α =60° and I = 800 W/m^2.

Fig.11 shows the graph between thermal efficiency with Reynolds number (Re) at different values of duct height (H), Duct height having value of 0.030 m consist of higher thermal performance over the duct value of 0.045 m for all the values of Reynolds number.

Thus it is concluded form our study that, Thermal performance increases with increase in Reynolds number but duct having lesser value also affects the performance significantly.

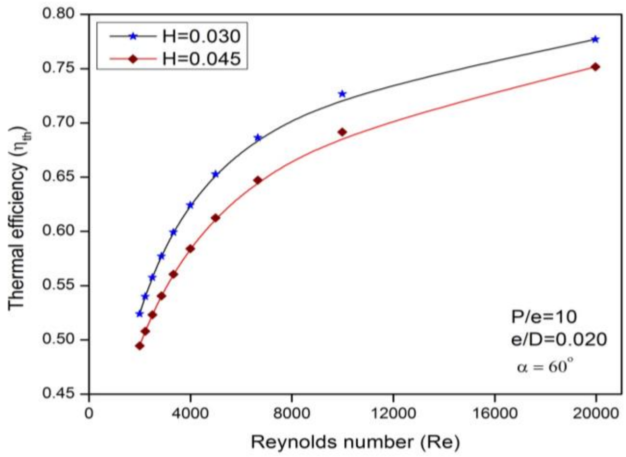

Fig.11. Effect of Duct height (H) on thermal efficiency as a function of Reynold number at P/e = 10, e/D = 0.020, α = 60° and I = 800 W/m^2.

4.4. Effect of Duct length (L)

Fig.12 shows the plots of thermal efficiency with temperature rise parameter as a function of duct length (L). Two different lengths of collector duct with 1.5 m and 2.0 m are taken for the present analysis. By increasing the length of duct , there is increase in surface area of the absorber plate so there is more incoming solar radiation through the glass cover hence the absorber plate temperature get more heat and outlet air temperature as compared to the smaller one hence the thermal performance increases for long SAH duct.

Furthermore the increase in the duct length also brings the more pressure drop hence more pumping power are required by blower fan , hence very long duct is avoidable where pumping power factor is considered or economically point of view.

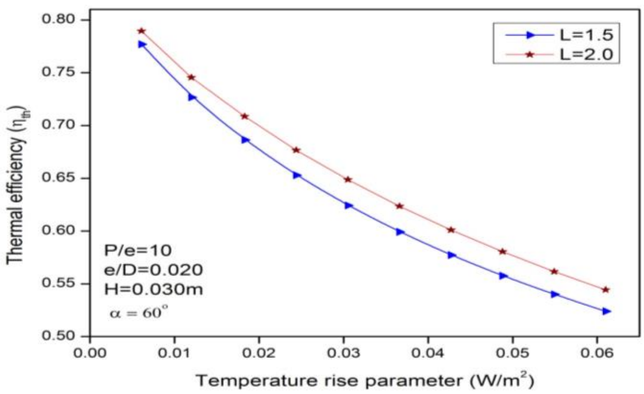

Fig.12. Effect of Duct length (L) on thermal efficiency as a function of temperature rise parameter at P/e = 10, e/D = 0.020, H = 0.030 m and I = 800 W/m².

Fig.13. Shows the graph between thermal efficiency with different values of Reynolds number (Re).The varying parameter is length of duct (L) the other fixed parameters which are used for calculations are shown in Fig . The duct length L = 2.0 perform better than the duct length L = 1.5 m .

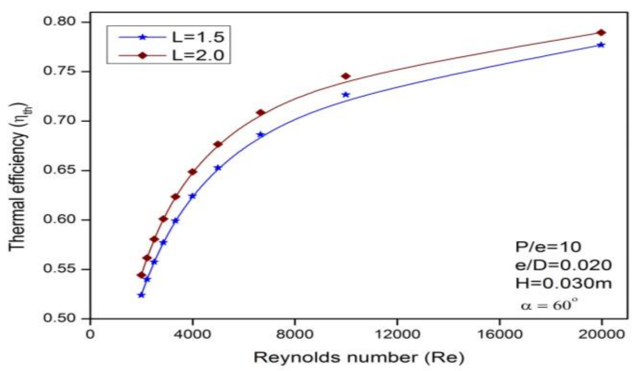

Fig.13. Plot of thermal efficiency as a function of temperature rise- parameter and length of duct (L) at P/e=10 , e/D=0.0220 and I= 800 W/m².

5. CONCLUSIONS

1. With increasing the duct height form 0.030 to 0.045 m there is decrement in the thermal performance of solar air heater. i.e. thermal performance is higher for the duct value of 0.030 m.

2. With varying the value of duct length (L) form 1.5 to 2.0 m there is increment in the thermal performance of solar air heater. i.e. thermal performance is higher for the SAH having, duct length value of 2.0 m.

3. The highest values of Thermal and effective efficiency is reported corresponding to the relative roughness height (e/D) and relative angle of attack value of 0.020 and 60° respectively, which is also reported by [11] by investigators, which validate the present work.

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