

5. Results And Discussion

The raw data collected have been processed to determined the value of thermal efficiency, heat transfer coefficient and friction factor. The result are discussed below.

5.1 Effect of Reynolds number on Nusselt number (Nu)

Figure 5 shows the variation of Reynolds number on Nusselt numbers for different wire screen matrices. Nusselt number increases with increase in Reynolds number for all the matrices. This is obvious as with the increase in the Reynolds number, the turbulence increases which increase the heat transfer coefficient and accordingly the Nusselt Number increases. It is also observed that the heat transfer coefficient enhancement is maximum for matrix M5 and minimum for matrix M3. The values of Nusselt number increases from 6.08 to 51.53 for increase in Reynolds number from 625.3 to 2619.9.

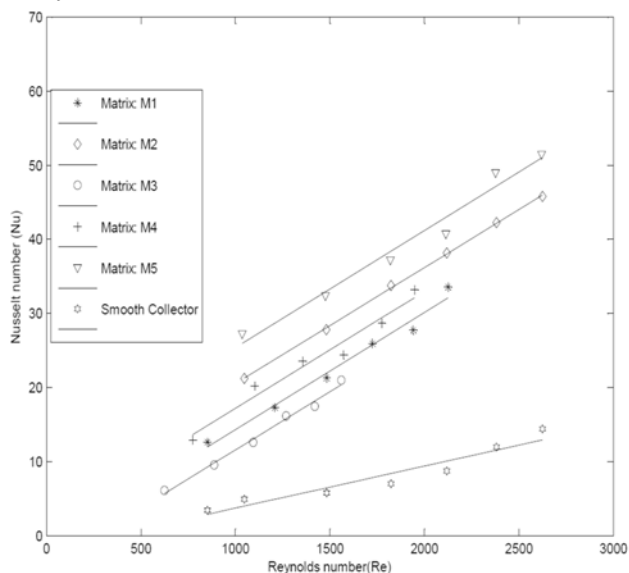


Fig.5. Effect of Reynolds number on Nu for different matrix

5.2. Effect of Reynolds number on Friction factor

Figure 6 shows the variation of friction factor with Reynolds number for different wire screen matrices. The friction factor is minimum for matrix M5 and maximum friction factor occurs for matrix M3 for the entire range of Reynolds number investigated. The friction factor for matrix M1, M2 and M4 is lies between the matrix M3 and M5, however the values of friction factor are always higher as compared to smooth collector. It is also observed that the value of friction factor reduces with the increase in Reynolds number. Friction factor is found to be

minimum for matrix M5 and maximum for matrix M3 out of the matrices investigated.

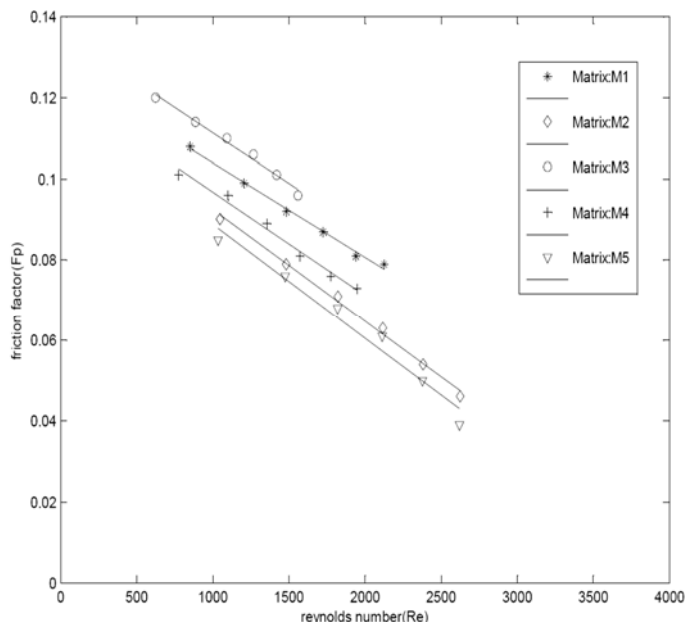


Fig.6. Effect of Reynolds number on friction factor for different matrix

5.3. Thermal performance of solar air heater

Performance plots are drawn in Fig. 7 and 8 for matrix M3 and M5 respectively following the procedure proposed by Reddy and Gupta (1980), where efficiency (η) is plotted against temperature rise parameter ($(t_o - t_i)/I$) each line in these plots has been drawn from first order least square fit of data points for a given set of bed parameters. Corresponding efficiency plots for data smooth collectors have also been shown in these figures.

From performance plots, it is observed that the efficiency of wire screen matrix packed air heater as well as smooth air heater increase with increase in mass flow rate and decrease with increase in temperature rise parameter ($(t_o - t_i)/I$). This is an expected behavior in view of the fact for a given incident solar radiation flux (I) and inlet temperature (t_i) when the flow rate of air through collector decrease the value of outlet temperature (t_o) increases. In other words when the flow rate of air increase the value of $(t_o - t_i)$ should decrease. Performance plots also indicate a substantial enhancement in thermal efficiency of packed bed collector over smooth collector for similar operating conditions.

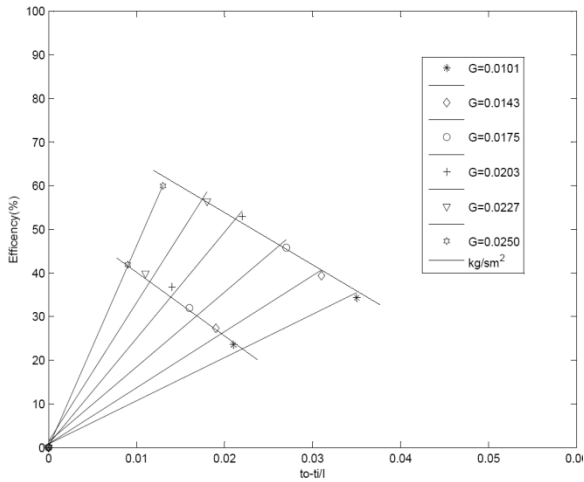


Fig. 7. Performance of packed bed air heater with matrix M3 and corresponding smooth air heater

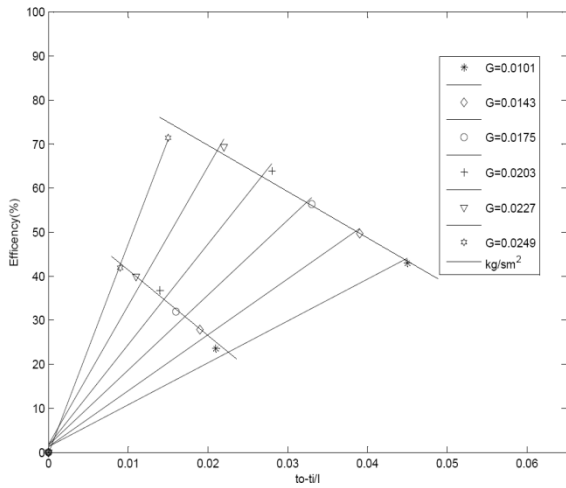


Fig. 8. Performance of packed bed air heater with matrix M5 and corresponding smooth air heater

Fig. 9 has been drawn to show the comparison of performance with different matrixes used for investigation.

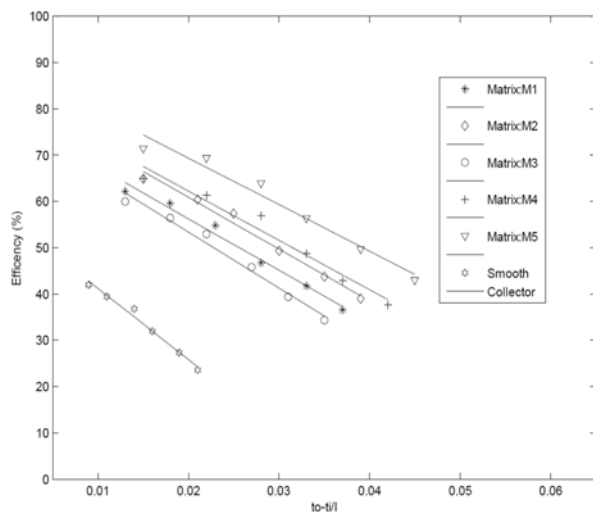


Fig. 9. Comparison of performance with different matrix and smooth air heater

Table 2 has been prepared to show the numerical values of efficiencies for packed bed air heater for different mass flow rates. Corresponding values of efficiency of air heater with wire screen matrix over smooth collector have been listed. These values correspond to extreme values of mass flow rate i.e. 0.0101 kg/s/m² to 0.0250 kg/s/m² with five set of matrices as a packing element.

For the purpose of comparison of performance of all five set of matrix, Fig. 12 has been prepared. The variation in performance seem due to varying geometrical and operating parameter. These effect can be analyzed based on the following discussion.

Table 2. Enhancement in collector efficiency

Matrix designation	G (kg/sm ²)	η_s	η	Enhancement (%)
M1	0.0101	23.58	36.57	55.08
	0.0249	41.94	63.21	50.71
M2	0.0101	23.58	38.98	65.30
	0.0249	41.94	67.89	61.87
M3	0.0101	23.58	34.29	45.41
	0.0248	41.89	59.94	41.15
M4	0.0101	23.58	37.57	59.32
	0.0250	41.92	65.02	55.10
M5	0.0101	23.58	43.01	82.40
	0.0250	41.92	71.39	70.03

5.3.1 Effect of mass flow rate

Effect of mass flow rate on temperature rise parameter for matrix packed solar air heater has been presented in Fig. 10 it is observed from the plot that there is a decrease in temperature rise parameter for increasing mass flow rate for all the matrix as well as smooth collector. The curves for all the matrices tend to converge at high mass flow rate and difference in their relative values decrease and become only marginal. Thermal efficiency corresponding to mass flow rate have been plotted in Fig. 11 These values for all the matrices and smooth collector increase with increase in mass flow rate. At lower mass flow the rate of increase in efficiency is higher, the rate decreasing with increase with mass flow rate. This behavior as seen in Fig. 10 and 11 can be attributed to the fact that as mass flow rate decreases, the collector operate at higher temperature which contributes to higher losses. Also the convective heat transfer coefficient

increases as the air mass flow rate decreases. This causes the efficiency to increase with increasing mass flow rate. The plot also indicates that the efficiency of packed bed air heater is significantly higher compared to smooth collector. It is worthwhile to note that although increasing the mass flow rate itself increases the efficiency and the effect is quite substantial but just increasing the mass flow rate cannot be used as a method of enhancement of efficiency because it is accompanied by fall-in output temperature, here lies, in contrast, the basic advantage of packing the bed, because providing the packing increases the

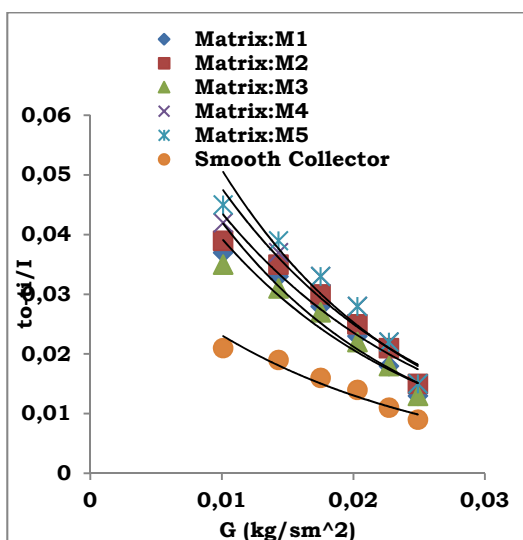


Fig.10. Variation of temperature rise parameter with mass flow rate for different matrices and smooth collector

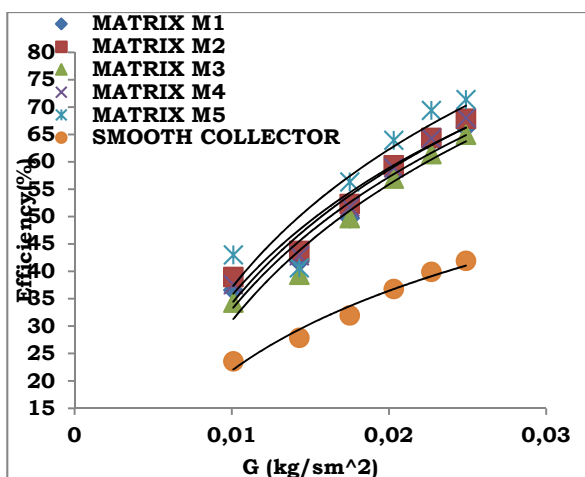


Fig.11. Variation of efficiency with mass flow rate for different matrices and smooth collector

efficiency as also increasing the output temperature a given mass flow rate at. The comparison of

enhancement given in Table 2 shows that the relative enhancement is much higher at relatively lower flow rates it is also interesting to note the efficiency plots tends the approach each other at higher flow rate indicating the similar behavior of all geometries of the matrix at very high flow rate.

6. Conclusions

The following are the main conclusions drawn from the present investigation:

1. It is observed that the heat transfer coefficient in packed bed solar air heater is improved appreciably as compared to conventional smooth solar collector.
2. Value heat transfer coefficient from matrix to air increases with increase in Reynolds number.
3. Friction factor is also found to increase appreciably as compared to conventional smooth collector. The value of friction factor decreases with increase in Reynolds number.
4. Thermal efficiency of solar air heater is found to improve appreciably in comparison to that of the conventional solar air heater as a result of packing the collector duct with wire screen matrixes. The improvement in thermal efficiency has been found to vary between 41.15 % and 82.40 % in the Reynolds number range of 600 to 3700.
5. Among the beds of wire screen matrixes with (wire diameter = 0.0585 mm, pitch = 3.17 mm, number of layer = 6, porosity = 0.945) has been found to yield maximum thermal efficiency for the range of operating parameter studied in the present work. The efficiency is seen not to depend only on porosity. The efficiency appears to depend on the geometry of the screen forming the matrix.
6. The maximum percentage enhancement for packed bed collector in comparison to the smooth solar air heater has been found to vary between 82.40 % and 71.03 % corresponding to temperature rise parameter values of 0.044 and 0.023 °C/W m².
7. The thermal efficiency of matrix packed collector increases with increase in mass flow rate because of increased heat transfer coefficient due to increased turbulence and the lower amount of thermal losses. In the range of lower mass flow rates, the rate of increase in efficiency is higher where as in the higher range of mass flow rate the rate of increase in efficiency is lower.
8. Performance of solar air heater is function of geometrical parameters of matrix. Porosity independently does not govern the performance.

Nomenclature

A	heat transfer area (m^2)	A_f	frontal area of duct (m^2)
A_c	collector plate area (m^2)	C_p	specific heat of air ($J.kg^{-1}.K^{-1}$)
D	depth of bed (m)	d_w	wire diameter of screen (m)
f_p	friction factor in packed bed	g	acceleration due to gravity ($m.s^{-2}$)
G	air mass flow rate per unit collector area ($kg.s.m^{-1}$)	G_o	mass velocity of air ($kg.s^{-1}.m^{-2}$)
hc	convective heat transfer coefficient ($W.m^{-2}.K^{-1}$)	I	solar radiation flux ($W.m^2$)
J	colburn j- factor)	L	length of collector duct (m)
m	mass flow rate of air ($kg.s^{-1}$)	Nu	Nusselt number
P	porosity	Pr	prandtl number
P_t	pitch in wire mess (m)	Δp	pressure difference (kPa)
Q_u	useful heat gain rate per unit collector area ($W.m^{-2}$)	r_h	hydraulic radius (m)
Re	Reynolds number	Re_p	packed bed Reynolds number
St	Stanton number	T_{me}	average mess temperature (K)
T_i, t_i	air inlet temperature (K)	T_f, t_f	average fluid temperature (K)
u	velocity of air in duct ($m.s^{-1}$)	η_s	efficiency of smooth air heater
η	collector thermal efficiency	ρ	density of air ($kg.m^{-3}$)
μ	dynamic viscosity of fluid ($Ns.m^{-2}$)		

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