AN EXPERIMENTAL INVESTIGATION OF PERFORMANCE ON PERFORATED SOLAR AIR HEATER

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ABSTRACT

An experimental investigation has been carried out to study the effect of heat transfer and friction characteristics of a smooth duct solar air heater having absorber plate with perforated baffles. In the present paper, the baffle height – to – duct height ratio (e/H) has been fixed at 0.495, which reduces flow passage blockage effect and simultaneously the baffle extend sufficiently deeper into the buffer zone. The baffle pitch – to – height ratio (p/e) is 7.06 and the flow Reynolds number study ranges from 3000-12000. Using the mathematical model, the performance plot for the baffled duct air heater has been presented, and the effect of the variation of ambient parameters on the predicted thermal efficiency has been studied.

Keywords : - *Perforated baffle, Solar air heater.*

1. INTRODUCTION:

The thermal performance of the solar collector is determined in part by obtaining values of incident insolation, ambient temperature and inlet fluid temperature. This requires experimentally measuring the rate of incident solar radiation on to the solar collector as well as the rate of energy addition to the transfer fluid as it passes through the collector all under steady state or quasi steady state condition. The test facility has been designed according to the guide line of ASHRAE standard 93-1986 for testing of solar collector operating in an open-loop mode which consists of 300 mm wide parallel ducts 69.

In present investigation a Butt-welded 1 mm dia Chromel Alumel bead (K-type) thermocouples having temperature range 0^o-1200^oC , calibrated against mercury thermometer of 0.1^oC least count, have been used for the temperature measurement.

2. EXPERIMENTAL CONDITIONS AND PROCEDURE:

All components of the experimental set up and the instrument have been checked for proper operation. The blower was then switched on and the joints of the setup were properly sealed to prevent leakage.

Micro-manometer and inclined U-tube manometer were properly leveled. Blower was switched on and the flow control valve was adjusted to give a predetermined rate of air flow through the test section. Before the covers were put off, it was ensured that all the thermocouples gave the same output.

All reading was noted under steady state condition, which was assumed to have been obtained when the plate and air outlet temperature did not deviate over a 10 minute period. The steady state for each run was obtained in about 1 hour and Reynolds number was fixed throughout the day in the following manner.

Table 1: Experimental Plan

Manometer fluid : Water Density : 1000kg/m^3

Inclined manometer reading : 23mm, 21mm, 90mm, 83mm, 203mm, 180mm, 360mm, 320mm

Day 1	Day 2	Day 3	Day 4	Day 5	Day 6
Nov.-13	Nov.-14	Nov.-15	Nov.-16	Nov.-17	Nov.-18
β=42.70%	β=42.70%	β=51.98%	β=51.98%	β=60.69%	β=60.69%
Re=3000 and Re=6000	Re=9000 and Re=12000	Re=3000 and Re=6000	Re=9000 and Re=12000	Re=3000 and Re=6000	Re=9000 and Re=12000

Table 2: Experimental conditions and dimensions of baffle and duct

Reynolds number, Re	3034 – 12003
Duct depth, H	38.4 mm
Width of duct, W	300 mm
Hydraulic Diameter, D	68.16 mm
Duct aspect ratio, W/H	7.81
Test section length, L	1640 mm
Test section length to hydraulic diameter ratio, L/D	24.06
Thickness of baffle, δ	0.643 mm
Baffle height, e	19 mm
Spacing between baffles (pitch), p	134.1 mm
Baffle height-to-duct height ratio, e/H	0.495
Baffle thickness-to-height ratio, δ/e	0.034
Baffle pitch-to-height ratio, p/e	7.06
Open area ratio of perforated baffle, β	Type I β = 42.70%
	Type II β = 51.98%
	Type III β = 60.69%

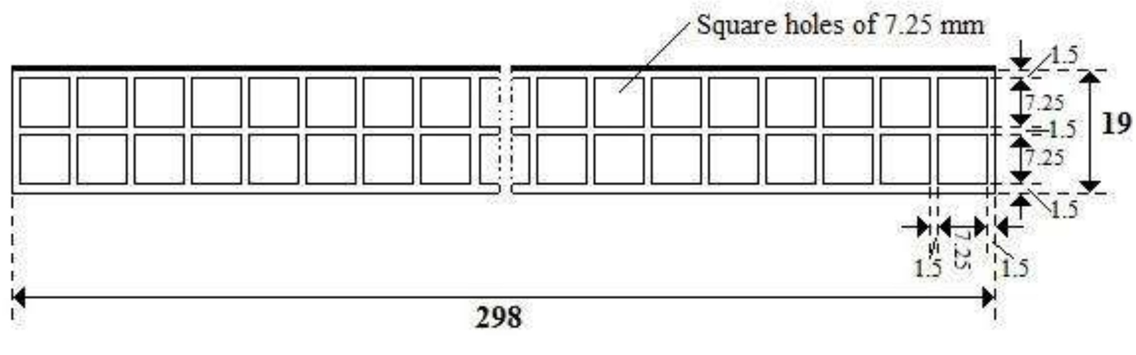

Fig -1: Details and dimensions of square perforated baffles of open area ratio β=60.69%.

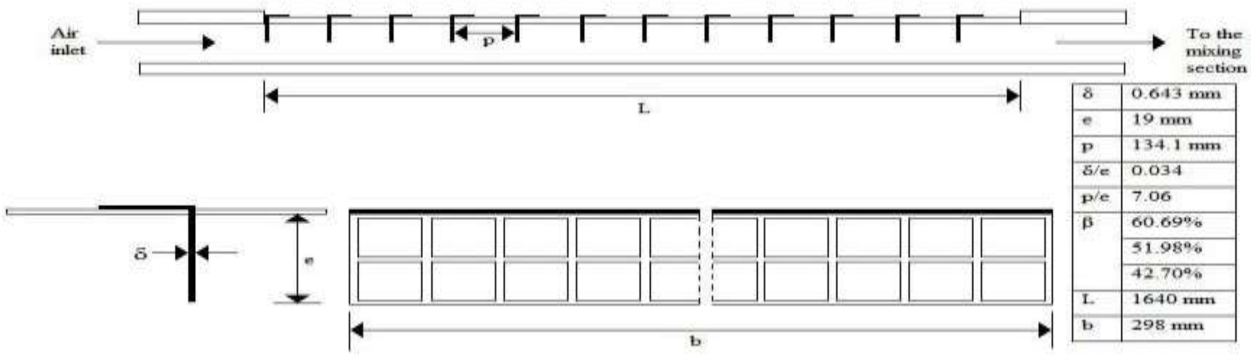

Fig-2: Various parameters of baffle.

3. DATA REDUCTION

Mass flow rate of air has been determined from pressure drop measurement across the orifice plate using the following relationship:

$$m = C_d A_o \sqrt{\{2 p_a (\Delta p)_o / RT_o\}}$$

The heat transfer coefficient for the heated test section was calculated from:

$$h = Q_u / \{A(T_{pm} - T_{fm})\}$$

Where the heat transfer rate Q_u , to the air is given by

$$Q_u = mC_p (T_o - T_i)$$

"A" is the heat transfer area of the plate without ribs. The electric heating gives a condition of constant heat-flux boundary condition and plate temperature varies in the direction of the air flow. In all the calculations, a mean plate temperature designed as T_{pm} has been calculated as weighted mean value of the plate temperature data obtained experimentally. T_{fm} is the average fluid temperature $= (T_o - T_i) / 2$.

The heat transfer coefficient has been used to determine the Nusselt number using the equation

$$N_u = hD_h / k$$

Where $Dh = (4WH) / \{2(W + H)\}$ is the hydraulic diameter.

$$S_t = N_u / (\mathrm{Re}\,\mathrm{Pr})$$

The Reynolds number was determined from the value of the mass flow rate, m, using the equation:

$$\mathrm{Re} = MD_h / \mu$$

Where $M = (\dot{m} / WH)$ is the mass flow rate per unit area of air through the collector duct.

The friction factor was determined from the measured values of pressure drop, δ_p ,

Across the test section length, L_f , of $1.2m$ (between the two points at about $400mm$ and $1600mm$ from the inlet of the test section) and the mass flow rate the equation:

$$f = 2(\delta_p) gD_h / (4L_f V^2)$$

The thermo-physical properties of the air have been taken at the corresponding mean temperature $T_m = T_{fm}$ or T_{mpg}. The following relations of thermos-physical properties, obtained by correlating data from NBS (U.S.), have been used:

$$c_p = 1006(T_m / 293)^{0.0115}$$

$$k = 0.02577(T_m / 293)^{0.86}$$

$$\mu = 1.81 \times 10^{-5} (T_m / 293)^{0.735}$$

$$\rho = 1.204(293 / T_m$$

$$Pr = \mu c_p / k$$

4. RESULT:

4.1 Variation of Nusselt Number with Reynolds Number

The Comparative plot of Nusselt number v/s Reynolds number has been shown in Fig.-3 for smooth and baffled duct of different perforations (i.e., β= 60.69%, 51.98%, and 43.70%).

Nusselt number increases with increase in Reynolds number for both smooth and baffled plate. It is observed that the rate of increase of Nusselt number is higher for baffled plate than the smooth plate. The enhancement in Nusselt number for baffled plate of open area ratio β=42.70% is found highest and is order of 1.36-2.09 times more than smooth plate. It is to be noted that value of Nusselt number is directly related to change in heat transfer coefficient. And eventually we get better heat transfer coefficient for baffled plates as compared to the smooth plate.

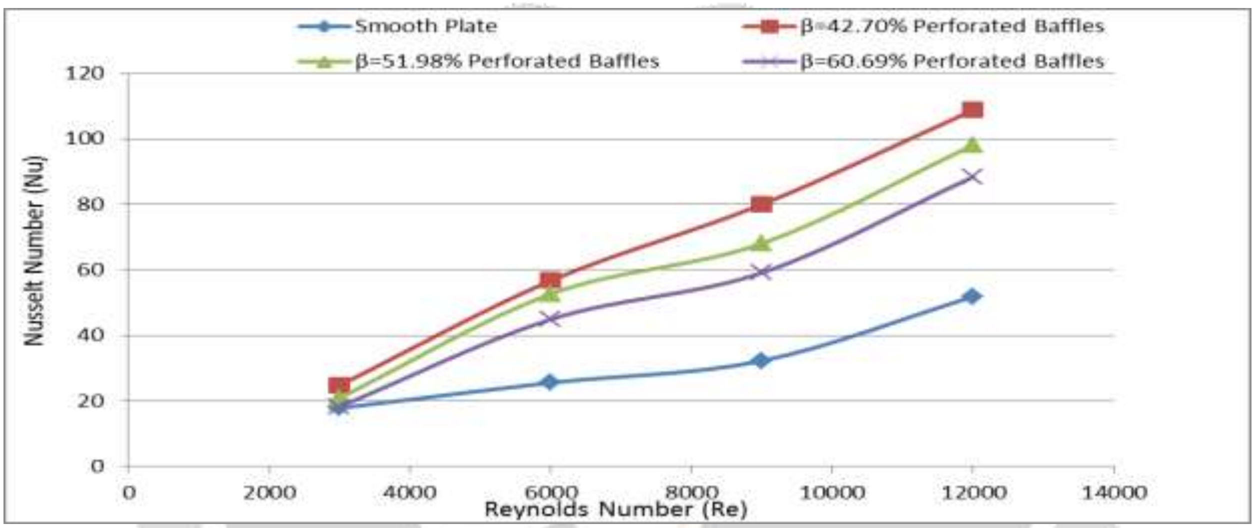

Fig -3: Variation of Nusselt Number with Reynolds Number.

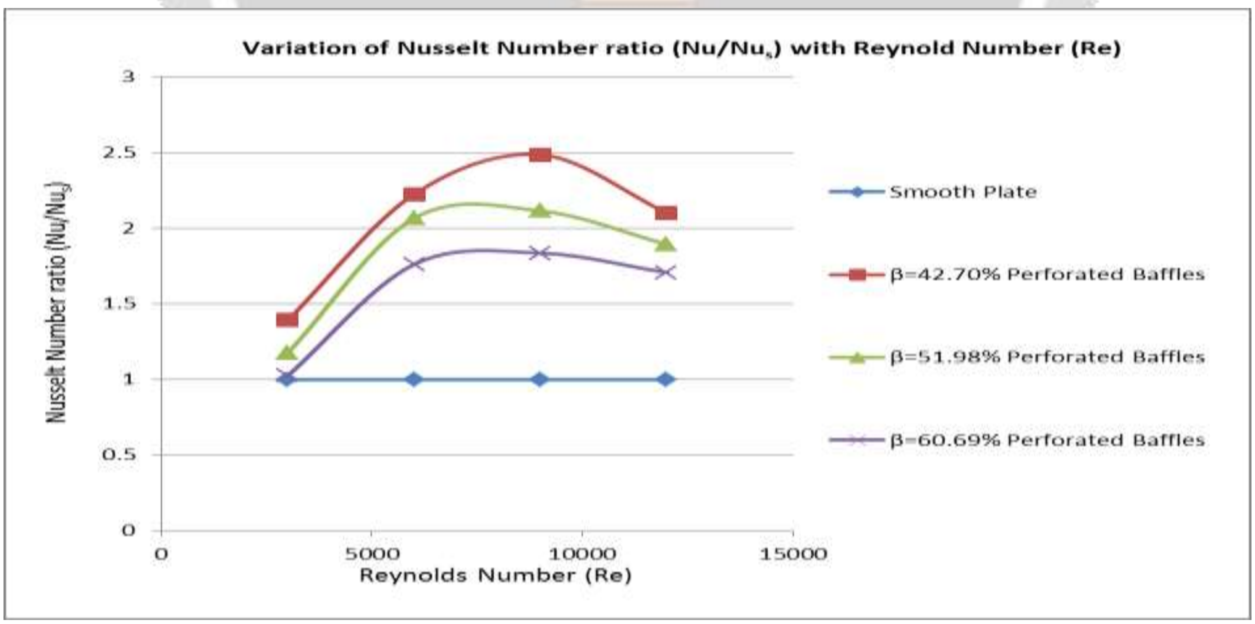

Fig -4: Plot of Nusselt number ratio versus the Reynolds number

4.2 Variation of Friction Factor with Reynolds Number

As shown in Fig-5 variation of friction factor has been found in good agreement with theoretical value given by Moody's Chart [5] for the given relative roughness height e/D.

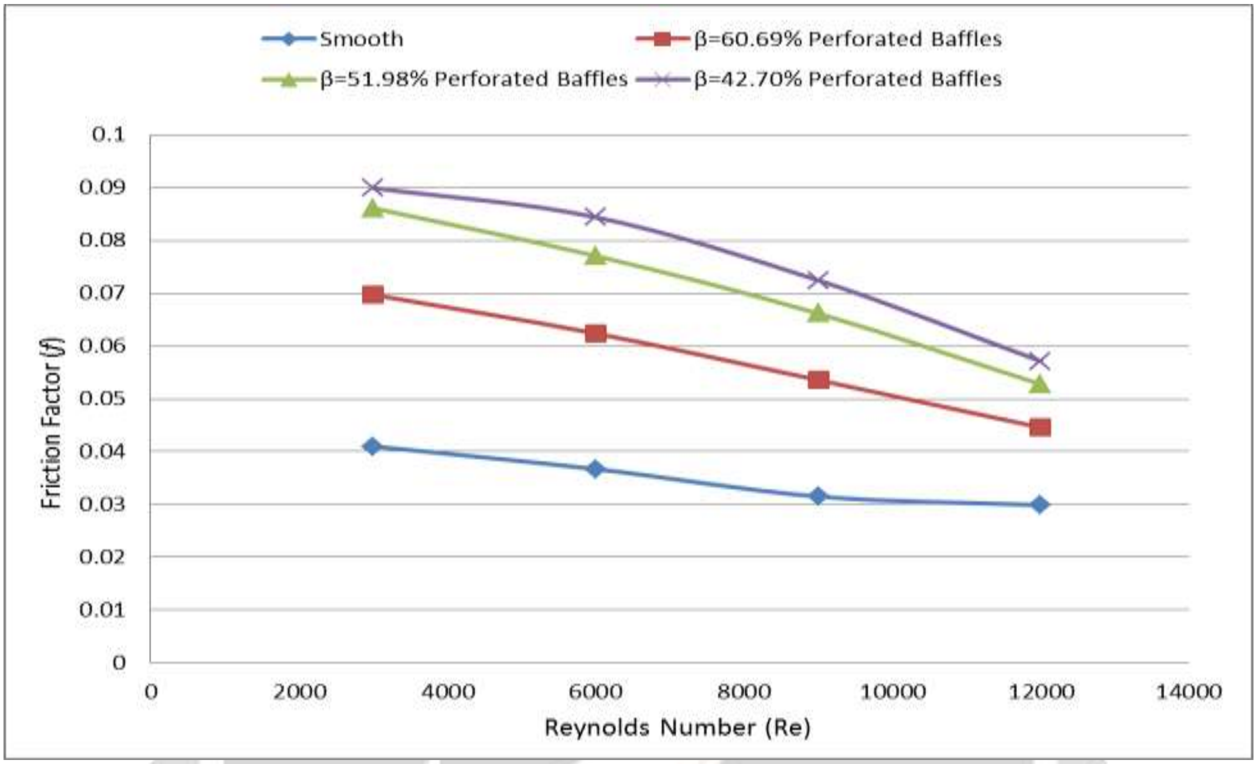

Fig -5: Variation of Friction factor with Reynolds Number

In the present experimentation study there was an enhancement of 1.36-2.09 times in Nusselt number while friction factor increased 1.91-2.19 times for the baffle of open area ratio β=42.70%.

It is found in the study that friction factor increment for other two baffles of open area ratio β=51.98% and 60.69% are 1.77-2.10 and 1.49-1.7 respectively.

4. CONCLUSIONS:

Nusselt number enhancement by use of square perforated baffles of different open area ratios was found to be in the range of 1.36 to 2.09 times to the corresponding values of smooth plate for the Reynolds Number 3034 to 12003. Increment in Friction factor (power penalty) was found 1.91-2.19, 1.77-2.10 1.49-1.7 for the baffle of open area ratio β=42.70%, β=51.98% and 60.69% respectively to the corresponding values of smooth plate for the Reynolds Number 3034 to 12003.

Nusselt number increases whereas friction factor decreases with increase of Reynolds number. Values of friction factor and Nusselt number were highest for perforated baffle of open area ratio β=42.70% and was lowest for perforated baffle of open area ratio β=60.69% but . This is due to change in flow characteristics because of baffles that cause flow separation, reattachments and generation of secondary flow.

5. REFERENCES

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