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Experimental Investigation of Heat Transfer and Friction Factor on A Roughened Solar Air Heater

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ABSTRACT: - *An experimental study has been carried out for the enhancement of heat transfer in a solar air heater duct fitted with artificially roughened absorber plate with discrete arc shape wire as roughness element. The roughness parameters relative roughness pitch (P/e), relative roughness height (e/D_h) and arc angle (α) were kept constant. The variation in Nusselt number (Nu) and friction factor (f) has been observed in relation to Reynolds number (Re) range 3000-15000. The maximum increase in Nusselt number and friction factor was 2.49 and 2.79 times that of smooth plate.*

Keywords: - Roughness, Geometry, Reynolds, Nusselt, manometer.

INTRODUCTION

Solar air heater (SAH), is simple in design and construction. They are widely used as collection device having application such as space heating and crop drying. 1] Flat plate collector have low thermal efficiency. To increase the performance of SAH the absorber plate is artificially roughened on the underside. The artificial roughness is an effective method to enhance the performance of SAH. There are several methods by which absorber plate is roughened i.e. pasting wire on surface, making grooved dimple roughness, making protrusions, machining surface etc. Wired rib is simple, fast and economical method to create artificial roughness. There are several parameters that needs to be considered for rib roughness e.g. rib height (e), relative roughness pitch (P/e), relative roughness height (e/D_h), relative staggered pitch etc.

LITERATURE SURVEY

Han et al. [2] reported inclined rib to have better heat transfer than smooth turbine blade. Prasad and Saini [3] investigated effect of relative roughness pitch (p/e), and relative roughness height (e/D_h) in heat transfer and friction factor. Gupta et al. [4] Investigated effect of angle of attack, relative roughness height and Reynolds number on heat transfer and friction factor. Verma and Prasad [5] determined the effects of similar parameters for circular wire ribs and reported thermohydraulic performance to be 71%. Saini et al. [6] Investigated arc shaped rib roughness with arc angle 30,40,50 and 60˚. They reported maximum heat transfer at arc angle 30˚. Singh et al. [7] investigated multiple arc roughness geometry to estimate Nusselt number and friction factor for varying arc angle, relative roughness pitch, relative roughness height and relative roughness width along with Reynolds number. They reported that maximum value of Nu is obtained at relative roughness pitch of 8, relative roughness height of 0.045, arc angle α/90 as 0.0667 and Reynolds number 22300. In view of above geometric configuration it can be concluded that by altering arc geometry an increase in Nusselt number can be obtained.

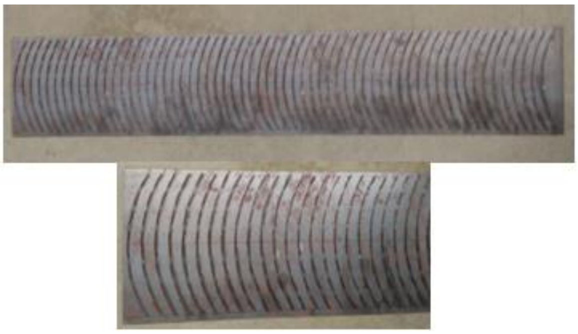

Fig. 1 Photograph of plate having discrete roughness

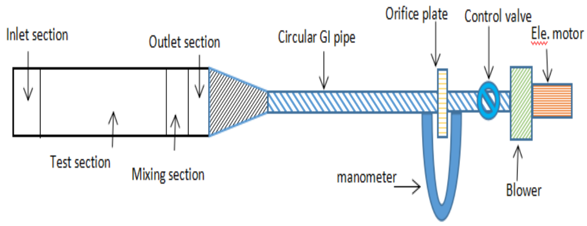

Fig. 2 Schematic of experimental set-up

Table 1 Roughness parameters

S. No.	Name of parameter	Value
1	Diameter Of wire (E)	2mm
2	Relative Roughness Pitch (P/E)	10
3	Relative Roughness Height (E/Dh)	0.045
4	Range of Reynolds Number (Re)	3000-15000
5	Angle of Attack Of Arc	30˚
6	Number of Gaps	3
7	Relative Gap Width (G/E)	4

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ROUGHNESS GEOMETRY AND RANGE OF PARAMETERS

To investigate the effect of roughness an indoor open loop test facility is designed as per ASHRAE [8]. In present experimental investigation of artificially roughened SAH discrete arc geometry is considered for investigation. Plate photograph having discrete arc geometry is shown in Fig. 1. The roughness parameters for investigation are shown in Table 1. Copper wires of circulation cross section have been used to create rib roughness.

EXPERIMENTAL SETUP

The experimental setup is shown in Fig. 2. It consists of rectangular test section, converging section, circular pipe having orifice plate to measure pressure drop, blower and electric motor. A variac is used to control voltage and current. Ammeter and voltmeter are used to measure current and voltage respectively. Thermocouple wires are fitted at inlet, outlet and over the plate to measure inlet, outlet and plate temperature. An electronic data logging device is used to determine temperature at real time. A U-tube manometer is used to measure pressure drop across the orifice plate. Pressure drop along the plate is measured with an electronic pressure metre.

RESULTS

Validity test: Friction factor and Nusselt number determined from the experiment performed on a smooth duct were compared with those obtained from modified Dittus Boelter equation for Nusselt number and modified Blasius equation for friction factor.

Modified Blasius equation
$f_s=0.085Re^{-0.25}$ (1)

Modified Dittus Boelter equation
$Nur=0.023xRe^{0.8}xPr^{0.4}$ (2)

Where f_s is friction factor for smooth duct, Re is Reynolds number, Nu_s is Nusselt number for smooth duct.

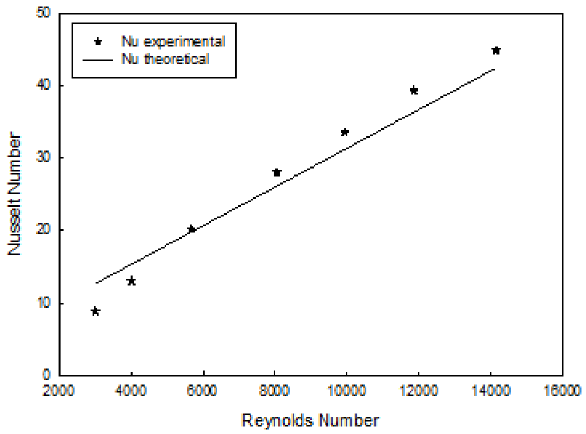

Fig. 3 Comparison of experimental and theoretical values of Nusselt number

Comparison of experimental and predicted values of Nusselt number and friction factor is shown in Fig. 3 and Fig. 4 respectively. It is observed that the values of friction factor and Nusselt number for smooth plate obtained by experiments agree reasonably good with the values predicted by eqn. (1) and eqn. (2) respectively. As experimental values of Nusselt number and friction factor are in reasonably close to predicted values, the validity of experiment is ensured. Variation of Nusselt number and friction factor for different Reynolds number for roughened plate is shown in Fig. 3 and Fig. 4. Figures show that discrete arc roughness has higher Nusselt number and friction factor than smooth plate. This is due to breaking of laminar sub layer by rib roughness.

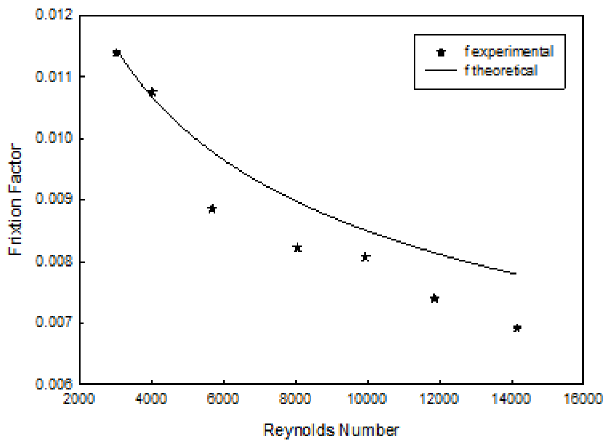

Fig. 4 Comparison of experimental and theoretical values of friction factor

CONCLUSIONS

Rib roughness results in more pressure drop and higher friction factor. The enhancement in Nusselt number varies from 13.53 to 58.53 for artificially roughened plate and in friction factor it is 0.0345 to 0.0244 in range of Reynolds number stated.

REFERENCES

[1]. Lanjewar Atul, Bhagoria JL, Serviya RM. Heat transfer and friction in solar air heater duct with W-shaped roughness on absorber plate 2011;36:4531-4541.
[2]. Han JC, Zhang YM. High performance heat transfer ducts with parallel, broken and V shaped broken ribs. Int J Heat Mass Transfer 1992; 35(2): 513-23.
[3]. Prasad BN, Saini JS, Effect of artificial roughness on heat transfer and friction factor in a solar air heater, Solar Energy 1998; 41(6): 555-560.
[4]. Gupta D, Solanki SC, Saini JS, Heat and fluid flow in rectangular solar air heater ducts having transverse rib roughness on absorber plates. Solar Energy 1993; 51: 31-37.

[5]. Verma SK, Prasad BN, Investigation for optimal thermohydraulic performance of artificially roughened solar air heaters 2000;20:19-36.
[6]. Saini SK and Saini RP, Development of correlations for Nusselt number and friction factor for solar air heater with roughened duct having arc shaped wire as artificial roughness. Solar Energy 2008; 82: 1118-11130.
[7]. Singh AP, Varun, Siddhartha, Heat transfer and friction factor correlations for multiple arc shape roughness element on the absorber plate used in solar air heaters Exp Thermal Fluid Sc. 2014;54:117-126.
[8]. ASHRAE standard 93-97, Method of testing to determine the thermal performance of solar collector. 1991.