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Thermal analysis of three sides artificially roughened solar air heaters

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Abstract

Artificial roughness have been provided under side of the absorber plate for improve in the friction factor, heat transfer and pumping power as compared to smooth one. Analysis and experimental investigation for fully developed turbulent flow of artificially roughened solar air heaters have been established to have a better performance as compared to smooth one under the similar operating conditions [1, 2]. Three sides glass covers with three sides artificially roughened solar air heater has been analyzed and investigated [3, 4], which result in enhancement of friction factor and heat transfer than existing one side artificially roughened ones. Three sides glass covers with three sides artificially roughened and existing one side artificially roughened collectors have been analyzed and optimized for maximum friction factor and heat transfer and minimum pumping power [5-7]. This paper represents an experimental investigation for the thermal analysis of three sides glass covers with three sides artificially roughened solar air heaters under actual outdoor conditions and compare well with smooth ones, also having three sides glass covers.

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Keywords: Friction factor, Heat transfer coefficient, Flow Reynolds number, Relative roughness height, Relative roughness pitch.

1. Introduction

Friction factor and heat transfer for tubes, artificially roughened collectors and annuli have been studied earlier by [8-11]. For enhancement of thermal performance, various solar air heaters have been developed and designed by the researchers over the years.

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For solar air heaters it has been concluded that the low range of heat transfer coefficient between the absorber plate and flowing air, which increase the absorber plate temperature and resulting higher value of heat losses and lower value of thermal efficiency. Inclination of 60^0 to artificial roughness using continuous ribs on the absorber plate, which results at higher relative roughness and low flow rate yields a better performance [12]. Transverse ribs have been used to enhance heat transfer coefficient [13]. Wire mesh roughness, wedge shape ribs, V-shape ribs, arc shape roughness, dimple shape roughness, combined inclined and transverse ribs, multi V-rib roughness, w-shaped ribs [14-22], are the works on investigations and analysis, have been found qualitatively and quantitatively enhancement of heat transfer coefficient. By providing artificial roughness it has been concluded that there is an improvement of heat transfer coefficient, which results increase in pumping power, pressure drop and also higher value of thermal performance. This paper represents the experimental investigation for three sides glass covers with three sides roughened collectors under the actual outdoor conditions at different range of roughness and flow parameters and also compare well with smooth ones having three sides glass covers.

Nomenclature

A_C	collector area, m^2	k	thermal conductivity of air, W/m K
B	solar air heater duct height, *m*	$\dot{m}$	mass flow rate of air, kg/s
Cp	specific heat of air at constant pressure, J/kg K	Nu	Nusselt number
D	hydraulic diameter of solar air heater duct, *m*	$\overline{Nu_r}$	average Nusselt number
e	roughness height, *m*	Nu_S	Nusselt number for smooth duct
e^+	roughness Reynolds number[4], $e^+ = {}^e/_D \sqrt{\frac{f_r}{2}}\, Re$	Nu_F	Heat transfer enhancement factor
e/D	relative roughness height	p	pitch of roughness element, *m*
f	friction factor	p/e	relative roughness pitch
f_S	friction factor for smooth duct	Re	flow Reynolds number
f_r	friction factor for four sided rough duct	T_0	outlet temperature of air, ^{0}C
$\bar{f_r}$	average friction factor	T_i	inlet temperature of air, ^{0}C
f_F	friction enhancement factor	$\bar{T}_P$	average plate temperature, ^{0}C
f_F	friction enhancement factor	$\bar{T}_f$	average air temperature, ^{0}C
H	convective heat transfer coefficient, W/m^2K	W	width of solar air heater duct, m
		SWG	standard wire gauge

2. Experimental study

Fig. 1 represents the two rectangular collectors of similar size, smooth one and three sides roughened collector, whereas, Fig. 1(a) represent the photograph of measuring instruments. Both the ducts are having three sides glass covers. The total length of the ducts consists of entry sections for flow stabilization and test sections. Mass flow rate was varied by controlling the blower speed by means of a 3-phase auto-variac. G.I. wires of 20, 22 and 24 SWG were used as artificial roughness in transverse direction for three sides artificially roughened collector. Flange-tap orifice-meters in both the ducts (roughened and smooth) used for measuring the flow rates. Multi-tube manometers were used to measure the pressure drop, while thermocouples measured the air and plate temperatures. A pyranometer was used for measuring the intensity of solar radiation. Top side absorber plate having artificial roughness shown in fig. 1(b), whereas, fig. 1(c) shows the side walls of the absorber plate with artificial roughness.