Experimental Thermal and Fluid Science 35 (2011) 986–995

Contents lists available at ScienceDirect

Experimental Thermal and Fluid Science

journal homepage: www.elsevier.com/locate/etfs

# Experimental study of augmented heat transfer and friction in solar air heater with different orientations of W-Rib roughness

A. Lanjewar *, J.L. Bhagoria, R.M. Sarviya

*Department of Mechanical Engineering, Faculty of Engineering, Maulana Azad National Institute of Technology, Bhopal 462 051, India*

ARTICLE INFO

*Article history:*
Received 30 August 2010
Received in revised form 4 December 2010
Accepted 31 January 2011
Available online 16 February 2011

*Keywords:*
Solar air heater
Heat transfer
Thermo-hydraulic performance
W-shape ribs

ABSTRACT

Artificial roughness in the form of ribs is a convenient method for enhancing thermal performance of solar air heaters. This paper presents the experimental investigation of heat transfer and friction factor characteristics of a rectangular duct roughened with W-shaped ribs arranged at an inclination with respect to the flow direction on its underside on one broad wall. W ribs have been tested both pointing in downstream W-down and upstream W-up to the flow. The range of parameters for this study has been decided on the basis of practical considerations of the system and operating conditions. The duct has a width to height ratio ($W/H$) of 8.0, relative roughness pitch ($p/e$) of 10, relative roughness height ($e/D_h$) of 0.03375 and angle of attack of flow ($\alpha$) of 30–75°. The air flow rate corresponds to Reynolds number between 2300–14,000. The heat transfer and friction factor results have been compared with those for smooth duct under similar flow and thermal boundary condition and thermo-hydraulic performance has been investigated. Thermo-hydraulic performance comparison for different angle of attack of flow shows that W-down arrangement with angle of attack of flow as 60° gives best thermo-hydraulic performance. In addition heat transfer and friction factor correlations have been developed.



## 1. Introduction

A solar collector absorbs incident solar radiation and converts it to useful heat for heating a collector fluid such as water or air. Solar air heaters being inherently simple are cheap and most widely used collection devices. These find several applications including space heating and crop drying. Efficiency of flat plate solar air heater is low because of low convective heat transfer coefficient between absorber plate and flowing air which in turn increases the absorber plate temperature, leading to higher heat losses to the environment. The low value of heat transfer coefficient is generally attributed to the presence of a viscous sub-layer, which can be broken by providing artificial roughness on the heat-transferring surface [1]. Efforts for enhancing heat transfer have been directed towards artificially destroying or disturbing this laminar sub-layer. Artificial roughness in the form of wires and in various arrangements have been used to create turbulence near the wall or to break the laminar sub-layer. But it also results in high frictional losses leading to more power requirement for fluid flow. Hence turbulence has to be created in a region very close to the heat-transferring surface to break the viscous sub-layer. Core fluid flow should not be unduly disturbed to limit the increase in friction losses. This is done by keeping the height of the roughness elements small in comparison to the duct dimensions [2]. Application of the artificial roughness in a solar air heater owes its origin to several investigations carried out for enhancement of cooling of turbine blades' passage. Several investigations have been carried out to study effect of artificial roughness on heat transfer and friction factor for two opposite roughened surfaces by Han [3], Han et al. [4–5], Wright et al. [6], Lau et al. [7–8], Taslim et al. [9], Han and Park [10], Han and Zhang [11] and Gao et al. [12] and correlations were developed by these investigators. Prasad and Saini [13], Gupta et al. [14], Karwa et al. [15], Bhagoria et al. [16], Momin et al. [17], Karwa [18] have carried out investigations on rib roughened absorber plates of solar air heaters which have only one roughened heated wall and three smooth walls. Correlations for heat transfer coefficient and friction factor have been developed for such systems. Prasad and Saini [13] used transverse small diameter wire as roughness element. Gupta et al. [14] investigated effect of relative roughness height, angle of attack on heat transfer and friction factor for inclined circular wire ribs. Karwa et al. [15] investigated effect of rib chamfer angle ($\Phi$), duct aspect ratio on heat transfer and friction factor using integral chamfered ribs. Bhagoria et al. [16] investigated wedge shaped transverse integral rib roughness. Momin et al. [17] investigated effect of geometrical parameters of V-shaped rib roughness. Maximum thermo-hydraulic performance occurred for angle of attack of 60°. Karwa [18] investigated effect of transverse, inclined, V continuous and V-discrete pattern ribs on heat transfer enhancement. V pattern ribs were tested for both pointing upstream and downstream to flow.

* Corresponding author.
*E-mail address:* lanjewar_atul@yahoo.com (A. Lanjewar).

0894-1777/$ - see front matter © 2011 Elsevier Inc. All rights reserved.
doi:10.1016/j.expthermflusci.2011.01.019