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Thermal characteristic in solar air heater fitted with plate baffles and heating corrugated surface

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Abstract

This paper presents a numerical investigation of heat transfer and friction factor characteristics in a solar air heater channel fitted with upper corrugated surface/wall and baffle series placed on a lower wall along the length of the channel. The corrugated surface/wall characterized by heating corrugated surface ratio (HCSR) varied from 0 to 0.5. The baffle series defined by blockage ratio (BR) fixed in 0.5. The fluid flow and heat transfer behaviors are presented for Reynolds numbers based on the hydraulic diameter of the channel ranging from 8000 to 20000. The computations are based on the finite volume method, and the SIMPLE algorithm has been implemented. The present results show that the heat transfer rate and friction factor increase with the raise of Reynolds number. The best thermal performance factor observed at HCSR=0.5 tends to 2.7 at highest Reynolds number.

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Keywords: corrugated surface, baffle, heat transfer, friction factor

1. Introduction

Many thermal applications need a raised performance such as heat exchangers, solar collectors and other engineering's installation. The feeble thermal efficiency of thermal applications due to the presence of laminar sub-layers decreases the thermal transfer execution. For decades, one method using in various thermal installations is

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baffles or ribs placing in the cooling channels or channel heat exchangers because this ribs restrict development hydrodynamic and thermal boundary layers and create turbulence near the wall leading to an increase in thermal transfer rate.

Nomenclature

b	Baffle Height, (m)
B	RBlockage ratio, (b/H)
D	Hydraulic diameter, (m)
f	Friction factor
h	Heat transfer coefficient, ($W\ m^2\ K^{-1}$)
H	Channel Height, (m)
hcs	Height of corrugated surface,(m)
HCSR	Heating corrugated surface ratio, (hcs/lcs)
G_K	Turbulent kinetic energy production
K	Turbulent kinetic energy, ($m^2\ s^{-2}$)
k_f	Thermal conductivity, $W\ m^{-1}\ K^{-1}$
lcs	Length of corrugated surface, (lcs=H),(m)
L	Channel Length, (m)

Greek letter

η	Thermal enhancement factor
ρ	Density, $kg\ m^{-3}$

Several experimental and numerical investigations have been carried out to study the effect of several geometrical parameters in solar air heater channels or different ribbed ducts on heat transfer and friction factor. In general, the geometry parameters used for design of baffled or ribbed channels are the attack and orientation angle, channel aspect ratio (AR), blockage ratio (BR), baffle pitch ratio (PR) and baffle arrangement.

The V baffle shape is presents in literature for generation of the vortex in channels. [1-5]. Singh et al. [6] used mathematical model for predicting the energetic efficiency of a solar air heater having the discrete V-down rib roughened absorber plate. They plotted the curves of optimum rib-roughness parameters. Lanjewar et al. [7] investigated experimentally the heat transfer and friction factor characteristics of solar air heater rectangular duct roughened with W-shaped ribs. They concluded that the Nusselt number increases whereas friction factor decreases. Promvonge et al. [8], Sriromreun et al. [9] they showed that the friction and enhancement factors dependent of the baffle height, pitch and Reynolds number. For investigate periodic laminar flow and heat transfers in channel, Sripattanapipat et al. [10] proposed diamond-shape baffles with different attack angles (5 to 35^0). They found that the order of heat transfer enhancement is about 200%–680% for using the diamond baffles. However, this augmentation of heat transfer is associated with enlarged friction loss ranging from 20 to 220 times above the smooth channel. Dutta et al. [11] noted in an experimental work that the thermal transfer rate depends on the position, the orientation and the geometry of the second baffle. Promvonge [12], Promvonge et al. [13] led to a combination between the attack angle, and V-shape baffle, they showed that this combination increases in thermal transfer rate and associated friction factor for different values of blockage ratio.

The surfaces roughness in baffled channels is present in several experimental and numerical studies. Eiamsa-ard et al [14] examine numerically to the turbulent forced convection in a two-dimensional channel with periodic transverse grooves on the lower channel wall. The computations based on a finite volume method. They used four turbulence models: the standard k−ε, the Renormalized Group (RNG) k−ε, the standard k−ω, and the shear stress transport (SST) k−ω turbulence models. They found that the RNG and the k−ε turbulence models generally provide better agreement with available measurements than others and concluded that the k−ε model is selected to use in prediction of this complex flow.

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