International Journal of Thermal Sciences 57 (2012) 163–171

Contents lists available at SciVerse ScienceDirect

International Journal of Thermal Sciences

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

Heat transfer enhancement in a channel with block(s) effect and utilizing Nano-fluid

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ARTICLE INFO

Article history:
Received 11 May 2011
Received in revised form
16 January 2012
Accepted 1 February 2012
Available online 6 March 2012

Keywords:
Numerical study
Forced convection
Partial block
Nano-fluid
Channel

ABSTRACT

In this study heat transfer and fluid flow analysis in a channel with blocks attached to bottom wall and utilizing Nano-fluid is numerically studied. The fluid temperature at the channel inlet (T_{in}) is taken less than that of the walls (T_w). The governing equations are numerically solved in the domain by the control volume approach based on the SIMPLE technique. A wide spectrum of numerical simulations has been done over a range of Reynolds number, Nano-fluid volume fraction and the block number. The influence of these parameters is investigated on the local and average Nusselt numbers. From this study, it is concluded that heat transfer in channels can enhance by addition of Nano-particles, and usage of block on hot walls. Simulations show that heat transfer in channels can enhance up to 60% due to the presence of nano-particles and the blocks in channels, but there exist a saturated number of blocks, beyond which, the average *Nu* do not increase. The present work can provide helpful guidelines to the manufactures of the compact heat exchangers.

1. Introduction

Forced convection in a channel is one of the most important subjects in many technological applications like high performance boilers, chemical catalytic reactors, solar collectors and power plants. Management of heat transfer for its enhancement or reduction in these systems is an essential task from an energy saving perspective [1–4].

Many researchers considered Nanotechnology as the most important driving moment for the major industrial revolution of this century. The low thermal conductivity of conventional fluids such as air, water, oil, and ethylene glycol mixture is considered as the primary obstacle to enhance the performance of heat exchangers. Addition of Nano-particles to the pure fluid, the so called “Nano-fluid”, can improve the thermal conductivity of the mixture. The Nano-fluids make larger thermal conductivity compared to the pure fluids [5].

Choi [6] is the first who used the term Nano-fluids to refer to the fluids with suspended Nano-particles. Several researches [7–9] have indicated that with low (1–5% by volume) Nano-particle concentrations, the thermal conductivity can be increased by about 20%. Xuan et al. [9] experimentally obtained thermal conductivity of copper–water Nano-fluid up to 7.5% of solid volume fraction. Several researches [10–15] have investigated heat transfer enhancement with nano-fluid.

Several studies were performed on natural convection using Nano-fluids in cavities. Khanafer et al. [5] investigated the heat transfer enhancement in a two-dimensional enclosure utilizing Nano-fluids for various pertinent parameters. Jou and Tzeng [16] used Nano-fluids to enhance natural convection heat transfer in a rectangular enclosure. They indicated that volume fraction of Nano-fluids causes an increase in the average heat transfer coefficient. Hwang et al. [17] investigated the buoyancy-driven heat transfer of water-based Al_2O_3 Nano-fluids in a rectangular cavity.

Some authors have studied numerical studies on forced convection using Nano-fluids. Xuan and Li [18] have experimentally investigated the heat transfer and flow field of copper–water Nano-fluid flowing through a tube. They have conducted their study for a range of *Re* (10,000–25,000) and ϕ (0.3–2%). Yang et al. [19] have investigated experimentally the convective heat transfer of graphite in oil Nano-fluid for laminar flow in a horizontal tube heat exchanger. Santra et al. [20] shows the heat transfer due to laminar flow of copper–water Nano-fluid through two-dimensional channel with constant temperature walls. They conclude that the rate of heat transfer increases with the increase in flow Reynolds number as well as the increase in solid volume fraction of the Nano-fluid.

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1290-0729/$ – see front matter
doi:10.1016/j.ijthermalsci.2012.02.001

Nomenclature

C_p	specific heat of fluid at constant pressure J/kg.K
H, L	height and length of the channel m
h	heat transfer coefficient W/m^{2}K
k	thermal conductivity W/mK
Nu	local Nusselt number
$\overline{Nu}$	average Nusselt number
p	pressure N/m^2
P	dimensionless pressure
Pr	Prandtl number μ C$_p$/k
Re_H	Reynolds number
S	total wall length of the bottom wall m
T	temperature K
T_W, T_C	temperature of the hot and cold wall K
u,v	velocity components m/s
U, V	dimensionless velocity components
W_1, W_2	width and height of blocks m
x, y	horizontal and vertical coordinates m
X, Y	dimensionless horizontal and vertical coordinates
X_i	ith block position m

Greek symbols

ρ	density kg/m^3
δ	the slope of the wall
μ	dynamic viscosity N s/m^2
ν	kinematic viscosity m^2/s
ϕ	volume fraction of Nano-particle
θ	dimensionless temperature

Subscripts

f	pure fluid (water in the present study)
in	input boundary
s	solid (copper in the present study)
nf	Nano-fluid

Block and fin installation in channel can be considered as control elements for increase or decrease of natural or forced convection heat transfer. Most of the studies on changing the flow pattern were performed using partitioning rectangular or square enclosures [21–24]. Varol et al. [25] investigated the effects of fin placement on the bottom wall of a triangular enclosures filled with porous media. Heidary et al. [26] have investigated free convection and entropy generation in an inclined square cavity filled with a porous medium. For forced convection Wang et al. [27] analyzed heat transfer to flow through a sinusoidally curved converging-diverging channel using a simple coordinate transformation method and the spline alternating-direction implicit method. Recently in a forced convection problem, we computed the heat transfer enhancement and hydrodynamics of the flow field in a wavy channel with nano-fluids [28]. In this study we investigated the effect of wave-amplitudes and wave-numbers on local

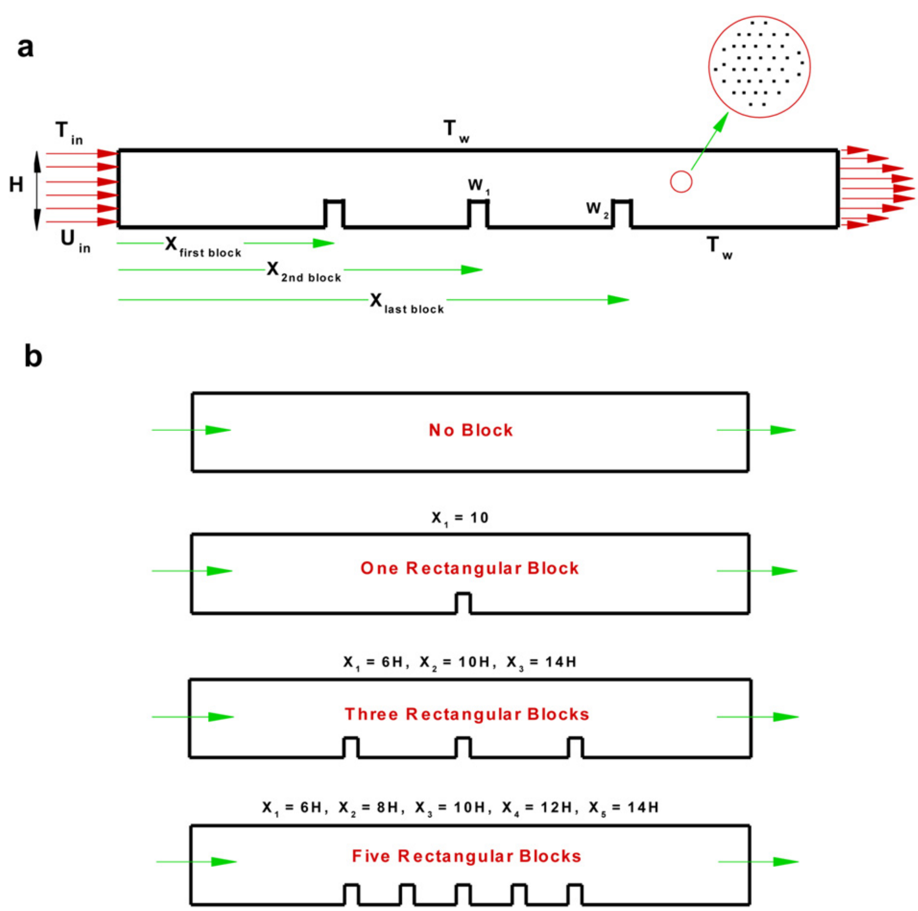

Fig. 1. (a) Schematic diagram of the duct studied in the present computation. (b) schematic diagram of the duct studied in the present computation for study of effect of block number.