International Journal of Heat and Mass Transfer 124 (2018) 980–989

Contents lists available at ScienceDirect

International Journal of Heat and Mass Transfer

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

Nanofluid turbulent convective flow in a circular duct with helical turbulators considering CuO nanoparticles

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ARTICLE INFO

Article history:
Received 21 February 2018
Received in revised form 4 April 2018
Accepted 4 April 2018

Keywords:
Nanofluid
Helical twisted tape
Numerical simulation
Turbulent flow
Forced convection

ABSTRACT

Nanofluid heat transfer augmentation in a heat exchanger equipped with helical twisted tape turbulator is simulated numerically via Finite volume method. Impacts of width ratio, Reynolds number and pitch ratio on nanofluid hydrothermal behavior were illustrated. Related formulas for Nusselt number and Darcy factor are provided according to obtained results. Outputs show that thermal boundary layer thickness decreases with augment of width ratio due to stronger secondary flow. Better nanofluid mixing can be obtained for lower values of pitch ratio.

1. Introduction

Heat exchanger is usual heat transfer equipment and its performance can be enhanced by means of active and passive techniques. Bondareva et al. [1] investigated heatline analysis for free convection of nanofluid in an open cavity. Sheikholeslami and Ghasemi [2] simulated the solidification of phase change material under the effect of thermal radiation. Sheikholeslami and Shehzad [3] utilized Non-equilibrium model for natural convection of nanofluid in a porous media. Nanofluid flow due to Lorentz forces in three dimensional enclosures has been simulated by Sheikholeslami and Ellahi [4]. They proved that velocity detracts with augment of Lorentz forces. Sheremet et al. [5] studied micropolar fluid flow in a wavy enclosure. They considered the unsteady free convection. Jafaryar et al. [6] investigated nanofluid turbulent flow due to using swirling flow device. They utilized finite volume method. Hayat et al. [7] demonstrates the water based nanofluid Marangoni convection in presence of radiative heat transfer. Sheikholeslami and Rokni [8] investigated different applications of magnetic nanofluid flow. Ramesh et al. [9] investigated dusty fluid flow over a stretching plate under the effect of magnetic field. Haq et al. [10] studied the CuO-water nanofluid heat transfer in a rhombus with heated square obstacle.

Promvonge et al. [11] employed V-finned twisted tapes in a duct to improve the hydrothermal treatment. Sheikholeslami and Shehzad [12] investigated nanofluid transportation in a porous media by means of new numerical method. Sheremet et al. [13] illustrated the convective motion of ferrofluid inside a rotating cavity. Bondareva et al. [14] simulated melting process in a cubical cavity in existence of magnetic field. Heat flux boundary condition has been utilized by Sheikholeslami and Shehzad [15] to show the ferrofluid flow in porous media. Sheikholeslami et al. [16] examined the nanoparticle transportation under the impact of thermal radiation. Zin et al. [17] studied transportation of silver nanoparticles to improve convective flow over a sheet in presence of Lorentz forces. Recently, several scientists published their publications about nanofluid heat transfer [18–35].

In this research, numerical simulation has been provided to find the influence of using helical twisted tape on nanofluid pressure drop and heat transfer augmentation. CuO-water is used as working fluid. Finite volume method is selected as simulation tool. Results are presented for various values of width ratio, Reynolds number, and pitch ratio.

2. Physical model

Figs. 1 and 2 depict the geometry of helical twisted tape and sample mesh which is utilized in this simulation. Inner and outer diameters are 5 and 20 mm, respectively. The length of the circular duct is 900 mm. The middle 300 mm is test section in which

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https://doi.org/10.1016/j.ijheatmasstransfer.2018.04.022
0017-9310/

Nomenclature

D	pipe diameter
f	darcy friction factor
BR	width ratio $(= 2b/D)$
L	length of pipe
b	width of the tape
Nu	Nusselt number
t	thickness of the fin
Pr	Prandtl number
P	Pressure
p	twisted pitch length
PR	Pitch ratio $(= 2y/D)$
T	fluid temperature
Re	Reynolds number

Greek symbols

α	Thermal diffusivity
μ	dynamic viscosity of nanofluid
ρ	density
ϕ	volume fraction of nanofluid

Subscripts

i	inner
o	outer
f	base fluid
s	particles
nf	nanofluid

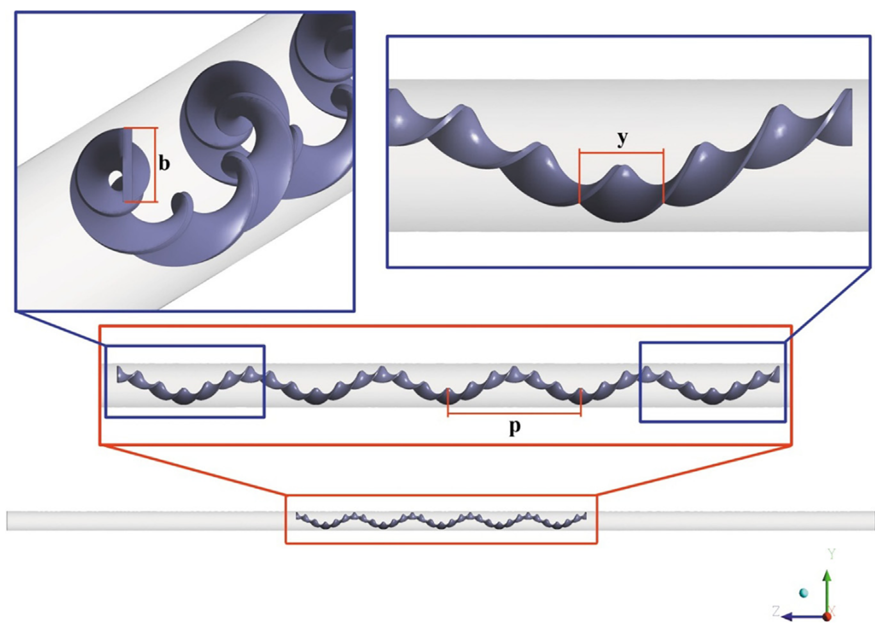

Fig. 1. Geometry of the problem.

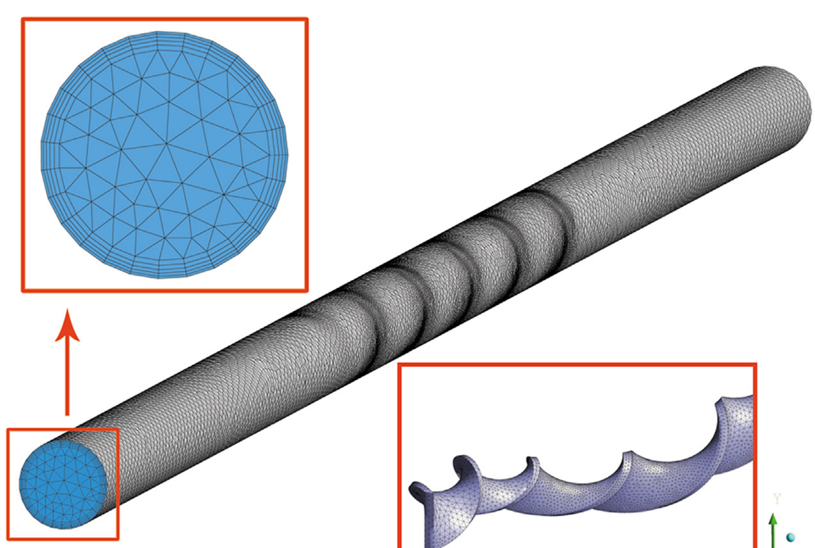

Fig. 2. Detail view of computational mesh.