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Nanofluid heat transfer augmentation and exergy loss inside a pipe equipped with innovative turbulators

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ABSTRACT

Exergy variations for forced convection of nanofluid through a pipe equipped with twisted tape turbulators have been simulated via Finite volume method. Roles of height ratio, pitch ratio and Reynolds number on variation of nanofluid hydrothermal treatment, second law efficiency (η_{II}) and exergy loss (X_d) were presented. Suitable formulas for (X_d) and (η_{II}) are provided. Results reveal that exergy drop reduces with enhance of Reynolds number and height ratio. Second law performance rises with augment of height ratio while it reduces with augment of pitch ratio.

1. Introduction

In recent decade, various researchers investigated about exergy analyses and entropy generation to provide the best geometry of the heat exchanger. Using nanofluid and swirl flow devices are passive techniques for improving thermal efficiency. Sheremet et al. [1] studied the nanofluid unsteady natural flow through a sinusoidal porous medium. Jafaryar et al. [2] simulated H_2O based nanofluid flow through a duct using new turbolentor which is twisted tape with alternate axis. Sheikholeslami et al. [3] employed passive way to improve thermal efficiency of in a pipe. They prove these passive techniques were effective. Ibrahim et al. [4] reported the heat source impact on nanofluid mixed convection over a permeable sheet. They considered dissipative magnetohydrodynamic flow. Mwesigye et al. [5] simulated the roles of utilizing swirl flow inserts on entropy generation. The variation of Bejan number due to changing geometric parameters has been demonstrated by Ko and Wu [6].

Suri et al. [7] demonstrated the effect of perforation on pressure loss. They indicated that thermal efficiency enhances with using perforated turbolentor. Sheikholeslami et al. [8] reported the second law efficiency for turbulent forced convection of nanofluid. They offered new modified turbulators. Sheikholeslami [9] simulated the acceleration role of magnetic field on solidification process. Turkyilmazoglu et al. [10] reported nanofluid laminar condensation over a vertical surface. Sheikholeslami and Shehzad [11] examined the migration of nanofluid in a permeable medium. They selected Darcy model for porous media. Haq et al. [12] illustrated water based nanofluid transportation inside a rhombus. Sheikholeslami et al. [13] elected the mesoscopic method for simulating nanofluid free convection in a three dimensional cubic enclosure. They considered hot sphere obstacle and employed one dimensional magnetic field. Khan et al. [14] studied nonlinear thermal radiation influence on three dimensional fluid flows. Sheikholeslami et al. [15] presented the experimental analysis for exergy loss and entropy generation of nano-refrigerant condensation process. They utilized CuO as nanoparticles. Scientists selected nanofluid as operational fluid in recent years [16–40].

Exergy analysis of nanofluid turbulent flow in a pipe has been investigated by means of FVM. Various values of pitch ratio, Re and height ratio have been reported in graphs.

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Nomenclature

BR	height ratio
Nu	Nusselt number
Re	Reynolds number
b	height of the twisted
d, D	pipe diameter
PR	pitch ratio
X_d	exergy loss
Pr	Prandtl number
p	twisted pitch length
f	Darcy friction factor
T	fluid temperature

Greek symbols

α	thermal diffusivity
ϕ	volume fraction of nanofluid
μ	dynamic viscosity of nanofluid
ρ	density
η_{II}	second law performance

Subscripts

s	particles
f	base fluid
nf	nanofluid

2. Physical model

In this paper, new turbolentor is utilized to improve thermal efficiency (Fig. 1). Three parts (inlet, outlet and test section) are taken into account. CuO-H_2O nanofluid moves in z direction. In current paper, d = 5 mm, D = 20 mm and L = 900 mm. Turbolentor insert in middle part (test section). According to first and third parts, we can ensure about fully developed flow. Tables 1 and 2 are provided the needed information of working fluid.

3. Formulation

Forced convection of nanofluid with high Reynolds number must be presented as:

$$\frac{\partial(u_i)}{\partial x_i} = 0 \tag{1}$$

$$\frac{\partial}{\partial x_j}(u_j \rho_{nf} u_i) = -\frac{\partial p}{\partial x_i} + \frac{\partial}{\partial x_j}\left(\mu_{nf}\left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i}\right)\right) + \frac{\partial}{\partial x_j}\left(-\rho_{nf}\overline{u_j' u_i'}\right) \tag{2}$$

$$\frac{\partial}{\partial x_i}(\rho_{nf} T u_i) = \frac{\partial}{\partial x_i}\left(\left(\mu_t/Pr_t + \mu_{nf}/Pr_{nf}\right)\frac{\partial T}{\partial x_i}\right), \tag{3}$$

$\rho_{nf}\overline{u_j' u_i'}$ and μ_t are:

$$\mu_t\left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i}\right) - \frac{2}{3}\rho_{nf} k \delta_{ij} - \frac{2}{3}\mu_t \frac{\partial u_k}{\partial x_k}\delta_{ij} = -\overline{u_j' u_i'}\rho_{nf} \tag{4}$$

$$\mu_t = \rho_{nf} C_\mu k^2/\varepsilon \tag{5}$$

Formals of k, ε are:

$$\frac{\partial}{\partial x_j}\left(\left(\frac{\mu_t}{\sigma_k} + \mu_{nf}\right)\frac{\partial k}{\partial x_j}\right) - \rho_{nf}\varepsilon + G_k = \frac{\partial}{\partial x_i}(u_i \rho_{nf} k),\ G_k = -\frac{\partial u_j}{\partial x_i}\rho_{nf}\overline{u_j' u_i'} \tag{6}$$

$$\frac{\partial}{\partial x_i}(u_i \rho_{nf}\varepsilon) = \frac{\partial}{\partial x_j}\left(\left(\frac{\mu_t}{\sigma_\varepsilon} + \mu_{nf}\right)\frac{\partial \varepsilon}{\partial x_j}\right) + \frac{\varepsilon}{k} G_k C_{1\varepsilon} - \rho_{nf}\frac{\varepsilon^2}{k} C_{2\varepsilon} \tag{7}$$

$$C_{1\varepsilon} = 1.42,\ C_\mu = 0.0845,\ C_{2\varepsilon} = 1.68, Pr_t = 0.85, \sigma_k = 1, \sigma_\varepsilon = 1.3 \tag{8}$$

The software which we used is ANSYS Fluent 14. Our selected turbulent model is k-ε (RNG). More details were mentioned in previous work [3].

$\rho_{nf}, (\rho C_p)_{nf}, k_{nf}$ and μ_{nf} are [2]:

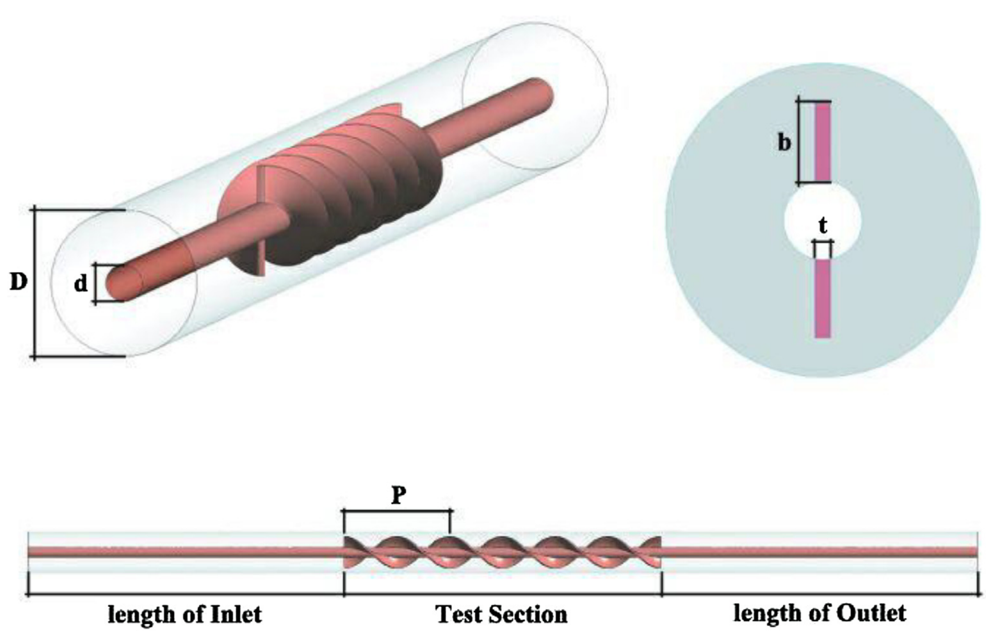

Fig. 1. Geometry of the problem.