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NUMERICAL MODELING AND SIMULATION OF COPPER OXIDE NANOFLUIDS USED IN COMPACT HEAT EXCHANGERS

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ABSTRACT

In this paper, a comparison of heat transfer and pressure drop characteristics of CuO/water nanofluids in a helically coiled heat exchanger held in horizontal and vertical positions is presented. heat transfer of Nanofluid is a new environment, usually metallic nanoscale particles suspended in a base fluid composed. Do nanofluidics compared with conventional fluids have higher coefficients of thermal conductivity and displacing. However, due to the increased use of nanofluidics, sometimes leading to excessive pressure drop can be pumped. The theoretical study of this issue using nano-fluids in the heat exchanger tube and shell and tube heat exchangers are widely used in the industry are the purpose of the project is located.

KEYWORDS: Heat Exchangers, CuO/Water nanofluids, Internal Nusselt Number, Particle Volume Concentration

INTRODUCTION

Heat exchangers are used in a wide variety of applications. Besides the performance of the heat exchanger being improved, the heat transfer enhancement enables the size of the heat exchangerto be considerably decreased. The enhancement in heat transfer can be divided into three techniques. The active techniques require external forces, e.g. electric field, acoustic and surface vibration. assive techniques require special surface geometries or fluid additives. Compound heat transfer technique is the combination of any two or three above mentioned techniques simultaneously. Nanotechnology is trying to overcome all the hurdles faced by the micro/millimeter sized suspended particles while trying to augment the heat transfer. The new class of heat transfer fluids with 1–100 nm sized suspended nanoparticles has been introduced by Choi [1] and conceived the concept of nanofluids in 1995. Choi [1], Wang and Choi [2], Lee et al. [3], and Das et al. [4] measured the thermal conductivity of nanofluids containing Al2O3 and CuO nanoparticles and investigated the effect of base fluid on thermal conductivity of nanofluids. Li et al. [5] suggested the simultaneous control of both the pH and chemical surfactant improve the thermal conductivity of Cu/water nanofluids for practical applications. Xuan and Li [6] investigated the convection heat transfer and flow characteristics of Cu/H2O by flowing through a straight tube with a constant heat flux under laminar and turbulent flow conditions. Masuda et al. [7] reported the Nusselt number of nanofluid increases with increasing Reynolds number and particle volume concentration.

The research groups Xuan and Roetzel [8], Wen and Ding [9], Heris et al. [10–12], and Hwang et al. [13] investigated the effect of nanoparticles and experimentally measured the thermal conductivity of nanofluids. They proposed that the suspended nanoparticles in base fluid lead to the positive impact on heat transport properties. Farajollahi et al. [14] experimentally studied the nanofluid heat transfer in a shell and tube heat exchanger. They found that TiO2/water nanofluid possesses heat transfer behavior better than that of Al2O3/water nanofluids at higher particles volume concentration. Present investigation is a kind of comparison of compound heat transfer enhancement techniques, because the two passive techniques such as helical coil and nanofluids are taken together to enhance heat transfer. The horizontal positioned shell and helically coiled tube exchangers are widely used in chemical reactors, agitated vessels, and food processing industries. The vertical positioned shell and helically coiled tube exchangers are used in cryogenic industries, marine applications, also used for steam generation in absence of gravity-space ship applications. Salimpour [15,16] experimentally investigated on overall heat transfer coefficient of shell and helically coiled heat exchanger using conventional fluid. They proposed the correlations for Nusselt number (Nu), incorporating Dean number (De), and Helical number (He). Prabhanjan et al. [17] suggested that the helically coiled tubes are superior to straight tubes when employed in heat transfer application using conventional fluid. They also reported the tube curvature plays an important role in enhancing heat transfer rate. Srinivasan et al. [18] carried out an experiment on friction factor of a helical coil tube by varying coiled tube diameter and suggested that the critical Reynolds number which relates to the curvature ratio. They reported that the formation of secondary flow in tube side depends on the curvature radius and Dean number (De). Kumar et al. [19] carried out an experiment on shell and helically coiled heat exchanger using nonmetallic Sisal nanofluids of 0.1–0.5% volume concentration and reported that the overall heat transfer coefficient increases over the particle volume concentration at various Reynolds number. They also reported that the addition of nanoparticles in base fluid enhances heat transfer coefficients. Akbarinia [20] studied the effect of laminar flow mixed convection of nanofluids in horizontal curved tubes. He reported that the nanoparticle volume concentration does not affect the secondary flow, axial velocity and skin friction factor. Most of the pipe/tube flows were described using Nusselt number as a function of Reynolds number and Prandtl number.

In case of helically coiled tube, Moris and Nzkayana [21], Kalb and Seader [22] replaced Reynolds number by Dean number which takes the curvature effect into account. In general, flow through the helical coil involves the centrifugal force, gravity force and inertia. When fluid passes through a helical coil, the secondary flow is developed due to curvature effect of coil. This secondary flow provides proper mixing to enhance heat transfer. Based on the literature survey, no comparative study was done and reported on the application of CuO/water nanofluids in horizontal and vertical positioned shell and helically coiled tube heat exchanger with nanofluid. Therefore the objective of this investigation is to compare the heat transfer and pressure drop of horizontal and vertical positioned shell and helically coiled tube heat exchanger by flowing CuO/water nanofluids. Moreover, the tube side Nusselt number and friction factor correlations are developed with the experimental data. This analysis is done by varying nanoparticles volume concentration at different Dean number.

Nomenclature

A_i	inside heat transfer area (m^2)
b	coil pitch (m)
C_p	specific heat capacity (J/kg K)
D	mean coil radius (m)
De	Dean number = $Re_i\,(d_i/2R_c)^{0.5}$
d_i	internal Diameter of the tube (m)
f	friction factor
h	convective heat transfer co-efficient (W/m^2K)
k	thermal conductivity (W/m K)
m	mass flow rate (kg/s)
M	molecular weight
n	no. of turns
Nu	Nusselt number = $h\,d_i/k$
Pr	Prandtl number = $C_p\mu/k$
Q	heat transfer rate (W)
R_c	curvature radius (m)
Re	Reynolds number = $\rho_{nf}\,v_i\,d_i/\mu_{nf}$
T	temperature (K)
vi	velocity (m/s)

Greek symbols

ρ	density (kg/m^3)
φ	volume concentration (%)
μ	dynamic viscosity (kg/m^2s)
δ	internal tube radius d_i/mean coil radius D
ΔP	pressure drop (N/m^2)

Subscripts

eff	effective
i	inside condition
in	inlet
out	outlet
f	base fluids
nf	nanofluids
s	surface
p	particle
w	water
m	mean

MATERIALS AND METHODS

The purpose of this project is to investigate the performance improvement of heat exchanger in the presence of nanofluidics. In this project, a heat exchanger shell tube with an outer shell with four horizontal pipe is considered. Using the properties of nanofluids is presented for consideration and appropriate boundary conditions, the heat exchanger at different volume percentage of nanofluids is investigated. A three-dimensional flow modeling using the software Ansys Fluent done. Also, as a study by the question Patypaka Shanmvgam [37] In 2010, the nanofluids considered as a single phase which is calculated in the following specification.

Characteristics of Nanofluids

Intended for heat exchanger CuO nanofluids with different volume percentages. Using the features provided in the third quarter of nanofluids is calculated. Relations are considered to compute the density, specific heat, thermal conductivity and viscosity are as follows.

$$\rho_{nf} = (1-\varphi)\rho_f + \varphi\rho_p \tag{1}$$

$$C_{nf} = ((1-\varphi)\rho_f c_f + \varphi\rho_p c_p)/\rho_{nf} \tag{2}$$

$$\mu_{nf} = (1+2.5\varphi)\mu_f \tag{3}$$

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$$\frac{k_{nf}}{k_{bf}} = \frac{k_p+(n-1)k_{bf}-(n-1)\varphi(k_{bf}-k_p)}{k_p+(n-1)k_{bf}+\varphi(k_{bf}-k_p)} \tag{4}$$

Assuming spherical particles, nanofluids, fixed n value of 3 is considered. Using the above equations, the characteristics of nanofluids at different volume ratios in Table 1. Cuo of reference data on the thermal properties of the particles [11] and [11] have been extracted.

Table 1: Shows the Characteristics of Nanofluids at Different Volume Ratios [11] and [11]

Fluid	Density (kg/m^3)	Specific Heat (J/kgK)	Thermal conductivity (W/mK)	Viscosity $(Pa\ s)$
$Water$	997.13	4179	0.60500	0.00089
CuO	6302	959.1	76.5	-
$Water + 0.1\%CuO$	1002	4160.6	0.6068	0.000892
$Water + 0.2\%CuO$	1008	4137.6	0.6086	0.000894
$Water + 0.5\%CuO$	1024	4078.5	0.6139	0.000901
$Water + 0.7\%CuO$	1034	4042.7	0.6175	0.000906
$Water + 1.5\%CuO$	1077	3895.2	0.6319	0.000923

SIMULATING

Modeling the nanofluids flow inside the heat exchanger, the pressure, velocity and temperature are obtained by considering the boundary conditions. Despite the characteristics in different parts of the performance parameters of the heat exchanger can be calculated in different states. To determine the performance of the heat exchanger as a characteristic of the Nusselt number, dimensionless heat transfer rate is calculated.

The characteristic parameters of the calculated field as follows:

$$h = \frac{q}{T_{wall} - T_b} \tag{5}$$

$$Nu = \frac{hD}{k} \tag{6}$$

Heat flux is considered, heat flux transition between the horizontal tube and the fluid around them. The results of the physical condition of the fluid at different Reynolds in Tables 2 and 3for Reynolds number 100 is given.

Table 2: Shows the Calculated Nusselt Number for Different nanofluids in REYNOLDS 100

fluid	ρ (kg/m^3)	C_p (J/kgK)	k (W/mK)	μ $(Pa\,s)$	velocity (m/s)	Re	Nu
$Water$	997.13	4179	0.60500	0.00089	0.0015	102.29	5.47
$Water + 0.1\% CuO$	1002	4160.6	0.6068	0.000892	0.0015	102.56	5.49
$Water + 0.2\% CuO$	1008	4137.6	0.6086	0.000894	0.0015	102.94	5.50
$Water + 0.5\% CuO$	1024	4078.5	0.6139	0.000901	0.0015	103.77	5.54
$Water + 0.7\% CuO$	1034	4042.7	0.6175	0.000906	0.0015	104.20	5.57
$Water + 1.5\% CuO$	1077	3895.2	0.6319	0.000923	0.0015	106.54	5.68

Table 3: Nusselt Number is Calculated for Different nanofluids in Reynolds 600

fluid	ρ (kg/m^3)	C_p (J/kgK)	k (W/mK)	μ $(Pa\,s)$	velocity (m/s)	Re	Nu
$Water$	997.13	4179	0.60500	0.00089	0.0088	600.11	9.48
$Water + 0.1\% CuO$	1002	4160.6	0.6068	0.000892	0.0088	601.69	9.50
$Water + 0.2\% CuO$	1008	4137.6	0.6086	0.000894	0.0088	603.94	9.52
$Water + 0.5\% CuO$	1024	4078.5	0.6139	0.000901	0.0088	608.76	9.58
$Water + 0.7\% CuO$	1034	4042.7	0.6175	0.000906	0.0088	611.31	9.62
$Water + 1.5\% CuO$	1077	3895.2	0.6319	0.000923	0.0088	625.00	9.79

RESULTS

As can be seen, with increasing volume percent particles in nanofluids, the calculated Nusselt number increased. Reynolds and Nusselt numbers in a specified amount for different volume percentages in Figure 1 and Figure 2 are drawn. The values of Nusselt numbers for various Reynolds in Figure 3 nanofluids are considered to have been drawn.

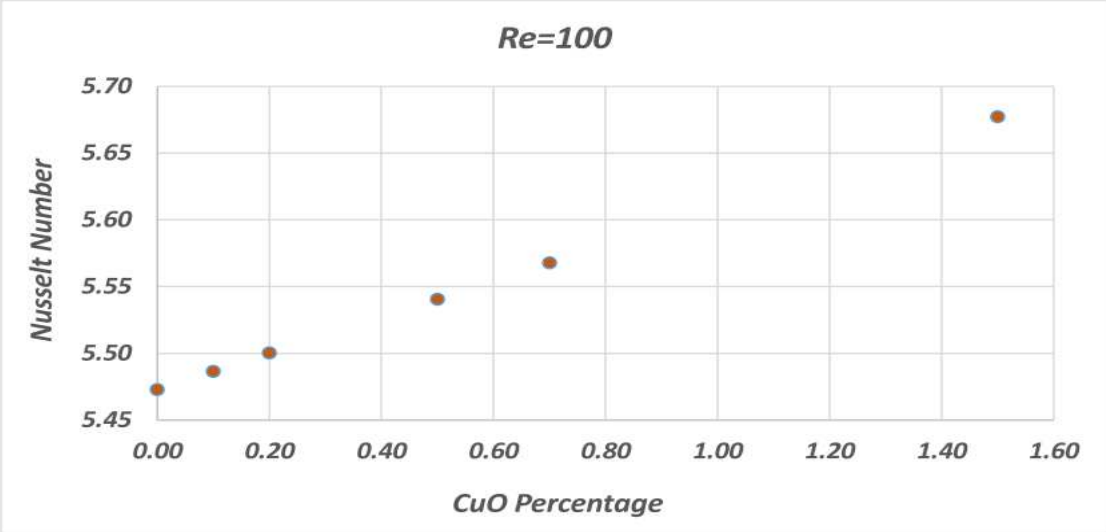

Figure 1: Nusselt Numbers at a Reynolds 100

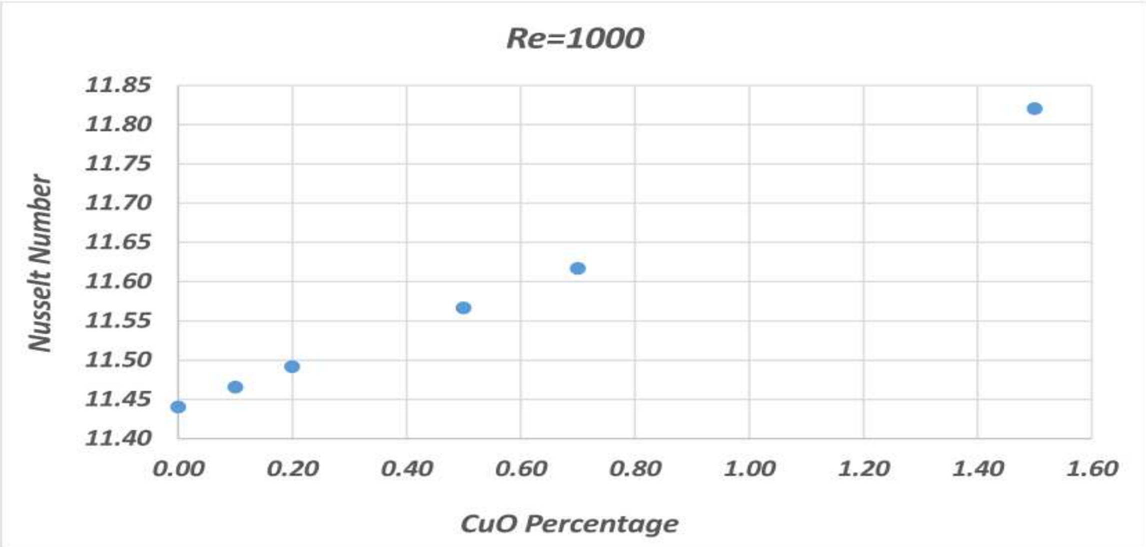

Figure 2: Nusselt Numbers at a Reynolds 1000

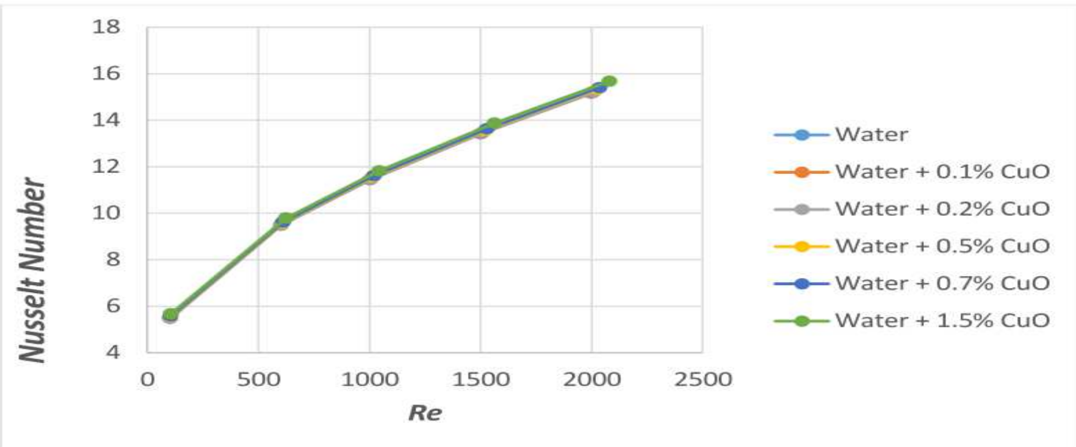

Figure 3: Nusselt Numbers for Various Reynolds

Also, due to the geometry intended temperature and velocity contours in Figures 4 and 5 for Mqt perpendicular to the pipe as shown.

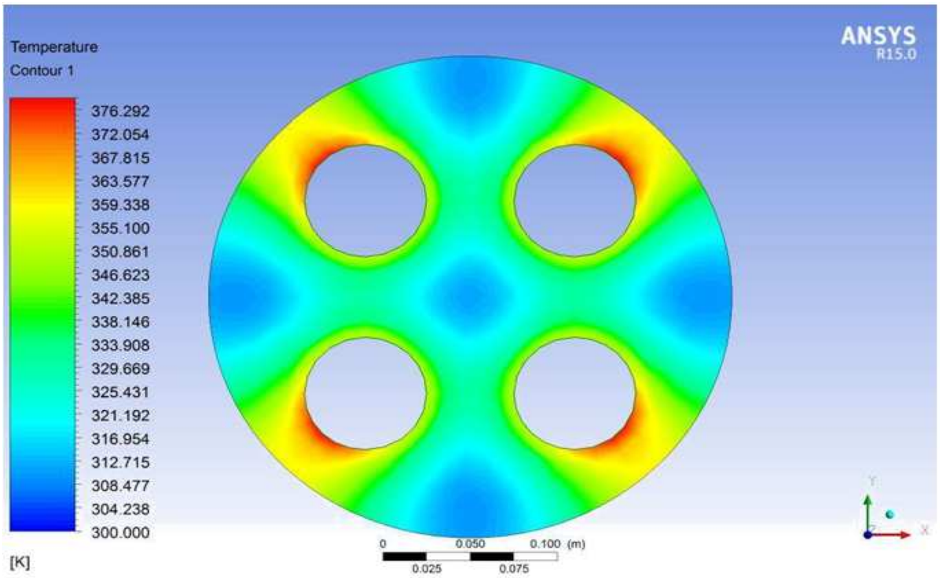

Figure 4: Temperature Contour at the Output

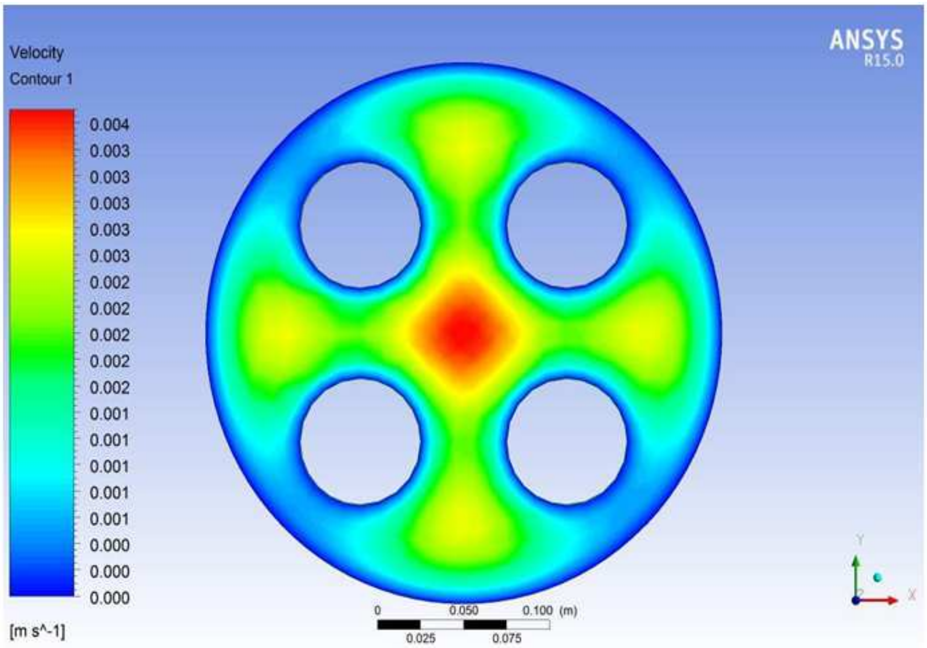

Figure 5: The Velocity Contour at the Output

CONCLUSIONS

Heat transfer and pressure drop studies of a helically coiled tube heat exchanger with CuO/water nanofluid were carried out in horizontal and vertical positions under turbulent region. As can be seen, with increasing volume percent particles in nanofluids, the calculated Nusselt number increased.In this article, and we reached the conclusion that the use of copper oxide nano-fluid heat exchanger is effective in improving the situation. And the thermal efficiency increases as shown in the top diagram.

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