Heat Transfer Enhancement Using Nano Fluid - A Review

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Abstract

This article reports have theoretical study on the heat transfer and flow characteristics of a nano fluids consisting of water flowing in a horizontal shell and tube heat exchanger under flows are investigated. The AL_2O_3 nano particles are used in the present study. The result show that the heat transfer coefficient of nano fluid is slightly higher than that of the base liquid at same mass flow rate and at same temperature. The heat transfer coefficient of the nano fluid increases with an increases in the mass flow rate, also the heat transfer coefficient increases with the increases of the volume concentration of the AL_2O_3 nano fluid, however increasingly the volume concentration cause increasing the viscosity of the nano fluid leading to increase in friction factor.

Keywords: Heat Exchanger, Nano fluid, Heat Transfer, Thermal conductivity.

Introduction

A decade ago, with the rapid development of modern nanotechnology, particles of nanometer-size (normally less than 100 nm) are used instead of micrometer-size for dispersing in base liquids, and they are called nanofluids. This term was first suggested by Choi [1] in 1995. Many researchers have investigated the heat transfer performance and flow characteristics of various nanofluids with different nano particles and base fluid materials. Several following existing published articles which associate with the use of nano fluids are described in the following sections. Abu-Nada, etal. [2] used an efficient finite-volume method to study the heat transfer characteristics of natural convection for CuO/EG/water nano fluid in a differentially heated enclosure. His results show that the dynamic viscosity and friction factor increased due to dispersing the alumina nano particles in water. Chein and Chuang [3] reported experimentally on micro channel heat sink (MCHS) performance using CuO–water nano fluids as coolants. The thermal and physical properties of nano fluids were calculated using the following equations: the Brink man equation [4] for viscosity, the Xuan and Roetzel equation [5] for specific heat and the Hamilton and Crosser model [6] for thermal conductivity.

The results showed that the presence of nano particles creates greater energy absorption than pure water at a low flow rate and that there is no contribution from heat absorption when the flow rate is high. Duangthong suk and Wong wises [7, 8] investigated the effect of thermo physical properties models on prediction of the heat transfer coefficient and also reported the heat transfer performance and friction characteristics of nano fluid respectively. The AL_2O_3 nano particles are used to disperse in water. The results also indicated that the heat transfer coefficient of nano fluid is slightly greater than that of water and use of nano fluid has little penalty in pressure drop. Hwangetal [9] through experimental investigation of flow and convective heat transfer characteristics of AL_2O_3/water nano fluid with convective heat transfer characteristics of AL_2O_3/water nano fluid with particles varying in the range of 0.01–0.3% in a circular tube of 1.812 mm inner diameter with the constant heat flux in fully developed laminar regime reported improvement in convective heat transfer coefficient in the thermally fully developed regime. Li and Xuan [10] and Xuan and Li [11] studied experimentally the convective heat transfer and flow features for Cu–water nano fluids flowing through a straight tube under laminar and turbulent flow regimes with a constant heat flux. The experimental results showed that addition of nano particles in to the base liquid remarkably enhanced the heat transfer performance of the base liquid. Moreover, the friction factor of nano fluids coincided well with that of the water. They also Mir masoumi and Behzadmehr [13] have studied the effects of nano particle mean diameter on the heat transfer and flow behavior in to a horizontal tube under laminar mixed convection condition. Their calculated results demonstrate that the convection heat transfer coefficient significantly increases with decreasing the nano particles mean diameter. However, the hydro dynamics parameters are not significantly changed. They also showed that the non-uniformity of the particles distribution augments when using larger nano particles and/or considering relatively high value of the Grashof numbers. Pak and Cho [14] investigated experimentally the heat transfer performance of Al_2O_3 and TiO_2 nano particles dispersed in water flowing in a horizontal circular tube with a constant heat flux under turbulent flow conditions.

The results showed that the Nusselt number of nano fluids increased with increasing Reynolds number and the volume concentration. However, they still found that the convective heat transfer coefficient of the nano fluids with 3% volume concentration nano particles was 12% lower than that of pure water at a given condition. Finally, a new heat transfer correlation for predicting the convective heat transfer coefficient of nano fluids in a turbulent flow regime was proposed. Putraetal [15] poured AL_2O_3/water and CuO/water nano fluids in to a horizontal circular tube. Under the same aspect ratio, the natural convective heat transfer coefficient of nano fluid was lower than that of base liquid, revealing that the natural convective heat transfer coefficient of nano fluid fell with the increase of particle concentration, aspect ratio and density. The experimental data showed that nano fluids were of no help to the natural convective heat transfer. Xuan and Roetzel [5] used single-phase fluid and solid–liquid two-phase fluid to induce the prediction of heat convection performance of nano fluid. They thought that higher heat convection performance of nano fluid was caused by the higher thermal conductivity of nano fluid and the disordered movement of nano particles. Zamzamian et al [16] investigated the effects of forced convective heat transfer coefficient with AL_2O_3/EG and CuO/EG nano fluid in double pipe and plate heat exchangers. Their results indicate that increasing the nano particle concentration and temperature could enhance the convective heat transfer coefficient of nano fluid, leading to a 2–50% enhancement in convective heat transfer coefficient of the nano fluid. This thesis is aimed at studying the heat transfer enhancement and flow characteristics of AL_2O_3–water nano fluids at a low concentration flowing in a horizontal shell and tube heat exchanger under a turbulent flow condition.

Nomenclature

Cp	Specific heat, J/kg K
d	Nano particle diameter, m
D	Tube diameter, m
f	Friction factor
U	Overall heat transfer coefficient/m^2 K
K	Thermal conductivity, W/m K
m	Mass flow rate, L/s
Nu	Nusselt number
Re	Reynolds number
Pe	Peclet number
Pr	Prandlt number
Q	Heat transfer, W
T	Temperature, 1°C
V	Mean velocity, m/s

Greek symbols

υ	Kinematic viscosity, m^2/s
Ø	Volume concentration, %
ρ	Density, kg/m^3
α	Thermal diffusivity, m^2/s
m	Viscosity, kg/ms
ΔT	1°C

Subscripts

w_i	Water inlet
w_o	Water outlet
n_i	Nano fluid inlet
no	Nano fluid outlet
in	Inlet
out	Outlet
n	Nano fluid
f	Base fluid
ρ	Nano particles

Data Processing:

Heat Transfer Rate

Heat transfer rate can be defined as

$$Q = (m)(Cp)(\Delta T)$$

Where, Q is the heat transfer rate, m is the mass flow rate and ΔT is the temperature difference of the cooling liquid.

Nano Fluid Density

The density of nano fluid presented equations is calculated by using of the Pak and Cho [14] correlations, which are defined as follows:

$$\rho_{nf} = (1-Ø)\rho_f + Ø\rho_p$$

Where, ρ_f is the density of base fluid (Water), ρ_p is the density of nano particle and Ø is the Volume Concentration.

Specific Heat

The specific heat is calculated from Xuan and Roetzel [5] as following:

$$(\rho C_p)_{nf} = (1-Ø)(\rho C_p)_f + Ø(\rho C_p)_p$$

Where, Cp_{nf} is the heat capacity of the nano fluid, Cp_f is the heat capacity of the base fluid and Cp_p is the heat capacity of the nano particles.

LMTD

The logarithmic mean temperature difference:

$$\Delta T_{lm} = \frac{(Twi - Tno) - (Two - Tni)}{\ln (Twi - Tno)/(Two - Tni)}$$

Where, ΔT_{lm} is the logarithmic temperature difference, Twi is the inlet temperature of the water, Two is the outlet temperature of water, Tni is the inlet temperature of the nano fluid and Tno is the outlet temperature of the nano fluid.

Overall Heat Transfer

The overall heat transfer coefficient is,

$$Q = (U)(As)(\Delta T_{lm})$$

Where, U is the overall heat transfer coefficient and As is the surface temperature.

Thermal Conductivity

An alternative formula for calculating the thermal conductivity was introduced by Yu and Choi [17], which is expressed in the following form:

$$K_{nf} = K_f \frac{(K+2Kf-2\emptyset(Kf-K))}{(K+2Kf+\emptyset(Kf+K))}$$

Where, K_{nf} is thermal conductivity of the nano fluid, K is thermal conductivity of the nano particle and K_f is the base fluid thermal conductivity.

Viscosity

The viscosity of the nano fluid Drew and Passman [18] suggested the well-known Einstein′s equation for calculating viscosity, which is applicable to spherical particles in volume fractions less than 5.0 vol%, and is defined as follows:

$$\mu_{nf} = (1+ 2.5\varnothing)\, \mu_w$$

Where, μ_{nf} is the nano fluid viscosity and μ_w is the water viscosity.

The properties of the nano fluid shown in the above equations are evaluated from water and nano particles at room temperature.

Result and Discussion

Friction factors and Nusselt numbers for single phase flow has been calculated from the Gnielinski equation [19]. The Gnielinski equation is defined as:

$$f = (1.58 \ln Re - 3.82)^{-2}$$

Where f is the friction factor and Re is the Reynolds number.

Nusselt Number

$$Nu = \frac{(0.125f)(Re-1000)Pr}{1+12.7(0.125f)^{0.5}(Pr^{2/3}-1)}$$

Where, Nu is the Nusselt number and Pr is the Prandlt number.

Friction factor for each flow rate for nano fluid can be found with the help of Duangthong suk and Wongwises correlation [20] as Gnielinski equation [19] for single phase flow cannot be used for calculating Friction factor as well as Nusselt number.

$$f = 0.961\, Re^{-0.375} \varnothing^{0.0552}$$

Nusselt number is calculated from Duangthong suk and Wongwises correlation [20] as follows:

$$Nu = 0.074\, (Re_{nf}^{0.707})(Pr_{nf}^{0.385})(\varnothing^{0.074})$$

The Kinematic viscosity can be calculated from:

$$v = \frac{\mu}{\rho}$$

Calculation of Reynolds [21], Peclet and Prandlt numbers [22] are as follows:

$$Re = \frac{VD}{v}$$

Where, V is the fluid velocity and D is the tube diameter.

$$Pe = \frac{VD}{\alpha nf}$$

Where, Pe is Peclet number and α_{nf} is thermal diffusivity.

$$Pr = \frac{vnf}{\alpha nf}$$

Thermal diffusivity is,

$$\alpha_{nf} = \frac{Knf}{\rho nf\, Cp}$$

In order to apply the nano fluids for practical application, in addition to the heat transfer performance of the nano fluid it is necessary to study their flow features. Study with 0.3, 0.5, 0.7, 1 and 2 volume concentrations suspended nano particles are used to calculate the friction factor for each volume concentration and for all the mass flow rates.

It was concluded that the heat transfer characteristics of the nano fluid increased. The trends shown by the nano fluid is due to the fact that the nano particles presented in the base fluid increase the thermal conductivity and the viscosity of the base liquid at the same time.

Conclusion

The convective heat transfer performance and flow characteristics of AL_2O_3 nano fluid flowing in a horizontal shell and tube heat exchanger has been theoretically investigated. The effect of particle concentration and the Reynolds number on the heat transfer performance and flow behavior of the nano fluid has been determined.

Important conclusions have been obtained and are summarized as following:

1) Dispersion of the nano particles into the distilled water increases the thermal conductivity of the nano fluid, this augmentation increases with the increase in particle concentrations.

2) Friction factor increases with the increase in particle volume concentration. This is because of the increase in the viscosity of

the nano fluid and it means that the nano fluid incur little penalty in pressure drop.

3) At a particle volume concentration of the use of AL_2O_3/water nano fluid gives significantly higher heat transfer characteristics.

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