Case Studies in Thermal Engineering 8 (2016) 94–104

Contents lists available at ScienceDirect

Case Studies in Thermal Engineering

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

Adaptive Neuro-Fuzzy Inference System of friction factor and heat transfer nanofluid turbulent flow in a heated tube

Adnan Mohammed Hussein

Al-Haweeja Institute, Northern Technical University, Iraq

ARTICLE INFO

Article history:
Received 14 June 2015
Received in revised form
3 June 2016
Accepted 5 June 2016
Available online 8 June 2016

Keywords:
Nanofluid
CFD
ANFIS
ANSYS
FLUENT

ABSTRACT

In this paper, estimating of hydrodynamics and heat transfer nanofluid flow through heated tube has been conducted by using Adaptive Neuro-Fuzzy Inference System (ANFIS). The CFD data related to three types of nanofluids (Al_2O_3, SiO_2 and TiO_2) flow in horizontal tube with 19 mm diameter and 2000 mm length. Heat flux around tube is fixed at 5000 W/m^2, the range of Reynolds number is (3000–30,000) and volume concentrations are (1% and 2%). ANFIS model has three input data presented by Reynolds number, volume concentration of nanofluids and materials and two output presented predicting friction factor and Nusselt number in the tube. The simulation results of proposed algorithm have been compared with CFD simulator in which the mean relative errors (MRE) are 0.1232% and 0.1123 for friction factor and Nusselt number respectively. Finally, ANFIS models can predict hydrodynamics and heat transfer of the higher accuracy than the developed correlations.

1. Introduction

Large wide of world using tube in engineering applications and is significant in practical applications, such as heat exchangers, steam generators, chemical reactors, membrane separations, and piping systems [1]. Recent research has been focused on practical tube applications based on emerging both soft computing fields like Computational fluid dynamic (CFD), and computational intelligence such as ANN, GA, PSO, and fuzzy logic [2].

The heat transfer enhancement by used aluminum oxide nanofluid with different volume concentration and constant wall temperature studied experimentally by Sundar and Sharma [3]. It was concluded that the friction factor and heat transfer enhancement by 10% and 40% respectively. The single-phase approach may be used for heat transfer and pressure drop prediction of new nanofluids. Numerical study of convection flow of a Al_2O_3-water nanofluid inside the tube under turbulent flow with the wall uniform temperature was presented by Bianco et al. [4]. Their results showed the convective heat transfer coefficient for conventional liquid is lower than nanofluids and friction factor data was agreed with experimental data of Pak and Cho[5].

Many researchers have introduced different forms of neural-fuzzy networks and its applications in bioinformatics, petroleum engineering and pattern recognition [6–7]. Group of Artificial intelligence methods was used to estimate the convective heat transfer coefficient and pressure drop during annular flow numerically such as multilayer perceptron (MLP), generalized regression neural network (GRNN) and radial basis networks (RBFN), likewise, the Adaptive Neuro-Fuzzy Inference System (ANFIS) have been used to decide best approach of heat transfer [8].

E-mail address: adnanphd2012@gmail.com

http://dx.doi.org/10.1016/j.csite.2016.06.001

Nomenclature

C	specific heat capacity [J/kg °C]
D	diameter [m]
f	friction factor
h	convection heat transfer coefficient [W/m^2 °C]
k	thermal conductivity [W/m °C]
n	number of runs
Nu	Nusselt Number [$h\,D/k$]
P	Pressure [N/m^2]
Pr	Prandtle Number [$C.\ \mu/k$]
Re	Reynolds Number [$\rho D\ u/k$]
u	Velocity [m/s]
G	Response parameters
μ	Viscosity [N s/m^2]
ρ	Density [kg/m^3]
ϕ	Volume concentration
ANFIS	Adaptive Neuro-Fuzzy Inference System
CFD	computational fluid dynamic
MR%	Maximum Error
MAE%	Mean Average Error

Subscripts

f	liquid phases
p	solid particle
nf	nanofluid
h	hydraulic

Reynolds number, velocity and flow rate have been used as inputs to estimate friction factor of an open channel flow with ANFIS by Samandar [9]. Experimental data from the laboratory have been used to learn algorithm and training with ANFIS model, in addition, the simulation results of friction factor were compared with experimental results. A good correlation was obtained between the experimental data and predicted results of Balcilar et al. [10]. ANFIS is a hybrid scheme based to a combination of neural networks and Fuzzy logic, which is an efficient tool for modeling different kind of uncertainty associated with imprecision and vagueness [6,10–14].

This paper, focus on hydrodynamic and heat transfer under turbulent three types of nanoparticles (Al_2O_3, SiO_2 and TiO_2) suspended in water flow in a heated straight tube for two volume concentration 1% and 2% by ANFIS. Firstly, introduce a brief description of a heated tube and its boundary conditions. Secondly, ANFIS with three input parameters and two output to predict the friction factor and Nusselt number. Finally, the results of proposed algorithm shows it effectiveness compared with CFD simulation for different Reynolds number, volume concentrations and materials of nanofluid flow through the heated tube.

2. Theoretical analysis

2.1. Physical model

Fig. 1 shows the test rig as included straight horizontal tube of 19 mm diameter and 2000 mm length with wire heater around it to fix heat flux at 5000 W/m^2. The nanofluid is flowing inside tube with high velocity and Reynolds number range (3000–30,000) so it will gain heat from input to output that taken in this case.

The simulation results are compared to the equations for the friction factor (1) and Nusselt number (2) that correlated by Blasius and Dittus-Boelter respectively [1]:

$$f = \frac{0.316}{Re^{0.25}} \tag{1}$$

$$Nu = 0.023 \times Re^{0.8} \times Pr^{0.4} \tag{2}$$

These two equations correlated for pure water that used for verification process.

The thermal properties of nanofluid were calculated by using the equations below [15]:

Density (ρ_{nf}) of nanofluid can be calculating by:

$$\rho_{nf} = \varphi \rho_p + (1 - \varphi)\rho_f \tag{3}$$

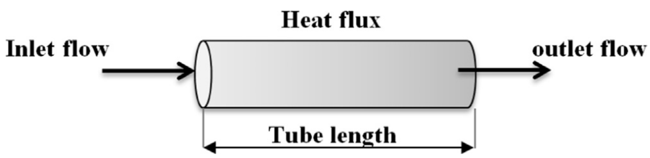

Fig. 1. Schematic of physical model.