Energy Conversion and Management 88 (2014) 214–217

Contents lists available at ScienceDirect

Energy Conversion and Management

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

Numerical and experimental investigation of heat transfer behavior in a round tube with the special conical ring inserts

A.R. Anvari [a], K. Javaherdeh [a,*], M. Emami-Meibodi [b], A.M. Rashidi [c]

[a] Faculty of Engineering, The University of Guilan, Rasht, Iran
[b] Radiation Application Research School, Nuclear Science and Technology Research Institute, P.O. Box 89175-389, Yazd, Iran
[c] Nanotechnology Research Center, Research Institute of Petroleum Industry (RIPI), West Blvd. Azadi Sports Complex, P.O. Box 14665-1998, Tehran, Iran

ARTICLE INFO

Article history:
Received 28 August 2012
Accepted 13 August 2014
Available online 7 September 2014

Keywords:
Heat transfer enhancement
Conical rings
Nusselt number
Pressure drop
CFD

ABSTRACT

In the present study an experimental investigation was carried out in order to find the role of the conical rings for the heat transfer enhancement and pressure drop change in a pipe with constant heat flux boundary condition. The conical rings were placed in two different arrangements: converging conical ring (CR array) and diverging conical ring (DR array). Also numerical study was performed through Computational Fluid Dynamics (CFD) calculations. The CFD predictions show suitable agreement with the experimental data of Nusselt number but overestimate pressure drop values. The predictions and the experimental results show that in the case of water as working fluid (despite air as working fluid), the conical ring inserts have an unfavorable effect on the enhancement efficiency of the heat-transfer in the heat exchangers.

1. Introduction

Heat exchangers are the main part of a chemical process where directly deal with energy consumption. Heat powerhouses, plants of chemical products and air conditioning facilities (refrigerators, car radiators, etc.) are some examples of industries where apply heat exchangers. Reaching more economical profit is the aim of heat transfer knowledge in the design step. Heat transfer enhancement methods are of large interest in this way. For example Bergles and Craus introduced 16 methods for increasing heat exchangers efficiency [1]. They are classified into passive and active techniques. The passive technique includes the use of treated surfaces, rough surfaces, extended surfaces, displaced enhancement devices, coiled tubes, additives for liquids and gases and swirl flow devices include helical strip or cored screw type tube inserts, twisted tapes, V-Shaped turbulator and inclined vortex rings [2–5]. Many studies have been conducted previously to analyze the heat transfer and friction factor of conical turbulator inserts [6–13]. Many efforts have been undertaken to use the Computational Fluid Dynamics (CFD) modeling for designing heat transfer enhancement devices [14–18].

Promvonge and Eiamsa-ard [7–9] and Yakut et al. [12,13] have studied the enhancement efficiency of the tube with CR and DR array of conical ring inserts for air as working fluid. In this work we investigate a similar system with water as working fluid.

2. Experimental work

The details of the experimental setup have been described in our previous work [6]. It consists of a horizontal straight copper tube with 138 mm inner diameter, 158 mm outer diameter, and 1100 mm length with the constant heat flux boundary conditions.

The 35 conical turbulators were made of aluminum with 13.8 mm in length and 13.6 mm and 6.8 mm in end diameters. They were placed inside the test tube with two different arrangements: (1) diverging arrangement (DR) and (2) converging arrangement (CR).

In the present work a CFD modeling was carried out in order to find the pressure drop and heat transfer in a tube equipped with different modified inserts fabricated based on a conical turbulators. The CFD predicted results have been compared with the experimental observations.

3. Results and discussion

The best heat exchanger is one with the lowest pressure drop and the highest heat transfer coefficient. The pressure drop is related to the friction factor through

* Corresponding author. Tel.: +98 (131)6690528x3109.
E-mail address: javaherdeh@guilan.ac.ir (K. Javaherdeh).

http://dx.doi.org/10.1016/j.enconman.2014.08.030
0196-8904/© 2014 Published by Elsevier Ltd.

Nomenclature

a	a constant
b	a constant
c	a constant
D	inner diameter of tube (m)
d	a constant
f	friction factor
L	length of tube (m)
N	number of data point
Nu	Nusselt number
Nu_0	a constant
P	pressure (pa)
Pr	Prandtl number
Re	Reynolds number
U	mean velocity of fluid (m s^{-1})
y	interested value including f, ΔP or Nu

Greek letters

ρ	density (kg m^{-3})
μ	viscosity (pa s)

Subscript

s	smooth tube
pp	constant pumping power
a	tube with turbulator (augmented)

Superscript

Cal.	calculated
Exp.	experimental

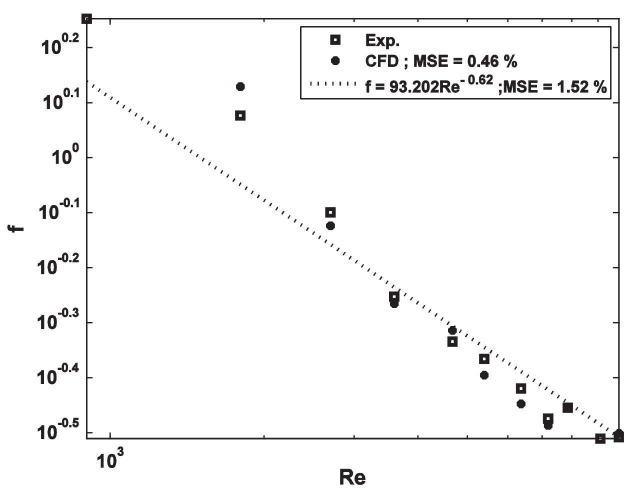

Fig. 1. The experimental data, CFD and predicted friction factor for smooth tube.

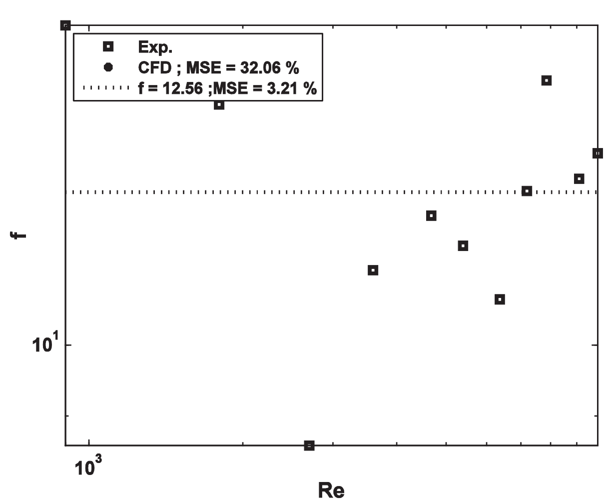

Fig. 2. The experimental data, CFD and predicted friction factor for the tube equipped with CR arrangement of conical ring insert.

$$f = \frac{\Delta P}{(L/D)(\rho U^2/2)} \quad (1)$$

The present smooth tube data is found to obey a correlation in a similar form with the previous correlations [19] of friction factor as

$$f = a_s \mathrm{Re}^{b_s} \quad (2)$$

where $a_s = 93.202$ and $b_s = -0.62$. Fig. 1 compares the experimental data, CFD and predicted friction factor for smooth tube. The mean square error percent is defined as

$$\mathrm{MSE} = \frac{100}{N}\sum_{i=1}^{N}\left(1 - \frac{y_i^{Cal.}}{y_i^{Exp.}}\right)^2 \quad (3)$$

where N is number of data points, y is the interested value and subscripts *Cal.* and *Exp.* denote to calculated and experimental values, respectively. In the case of tube with conical ring insert, the pressure drop data of present study can be well correlated according to

$$f_a = C \quad (4)$$

where for CR array $C = 12.56$ and for DR array $C = 16.141$. Figs. 2 and 3 compare the experimental data, CFD and predicted f for the tube equipped respectively with CR and DR arrangement of conical ring insert. The CFD method overestimates the pressure drop values of tube with conical ring inserts. Eqs. (4) and (1) can be used to calculate the friction factor of tube with conical ring inserts. Also the Nusselt number calculated based on the present experimental data can be correlated through

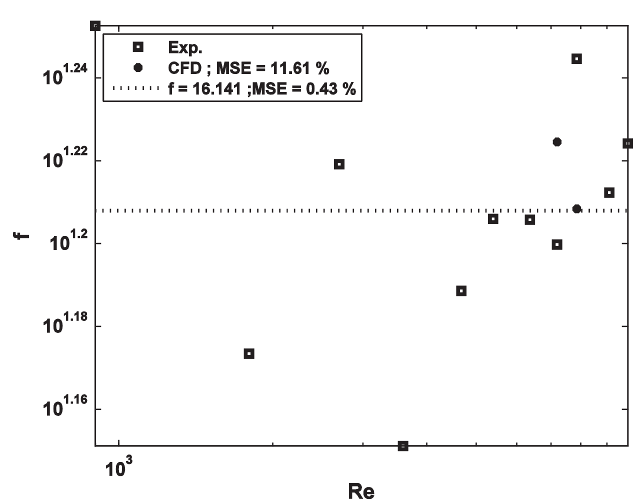

Fig. 3. The experimental data, CFD and predicted friction factor for the tube equipped with DR arrangement of conical ring insert.