International Communications in Heat and Mass Transfer 38 (2011) 69–74

Contents lists available at ScienceDirect

International Communications in Heat and Mass Transfer

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

Study on the heat transfer and flow characteristics in a spiral-coil tube ☆

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ARTICLE INFO

Available online 21 November 2010

Keywords:
Heat transfer characteristics
Flow characteristics
Spiral-coil tube

ABSTRACT

In the present study, numerical and experimental results of the heat transfer and flow characteristics of the horizontal spiral-coil tube are investigated. The spiral-coil tube is fabricated by bending a 8.00 mm diameter straight copper tube into a spiral-coil of five turns. The innermost and outermost diameters of the spiral-coil are 270.00 and 406.00 mm, respectively. Hot and cold water are used as working fluids. The k–ε standard two-equation turbulence model is applied to simulate the turbulent flow and heat transfer characteristics. The main governing equations are solved by a finite volume method with an unstructured nonuniform grid system. Experiments are performed to obtain the heat transfer and flow characteristics for verifying the numerical results. Reasonable agreement is obtained from the comparison between the results from the experiment and those obtained from the model. In addition, the Nusselt number and pressure drop per unit length obtained from the spiral-coil tube are 1.49 and 1.50 times higher than those from the straight tube, respectively.

1. Introduction

Convective heat transfer and flow developments in the curved tube strongly depend on the behavior of secondary flow. The secondary flow in the curved tube is caused by the centrifugal force. This force has significant effect on the enhancement of heat transfer. Therefore, the spiral-coil tube have been widely used in several heat transfer applications, for example, heat recovery processes, air conditioning and refrigeration systems, chemical reactors, food and dairy processes. Naphon and Wongwises [1] reviewed the heat, mass transfer and flow characteristics in the curved tube which the spiral coils are well known types of curved-tubes. Most of the previous studies on this topic have been carried out within the heat transfer and performance of the spiral-coil heat exchanger by experiment. Few studies have been conducted using numerical methods in describing the heat transfer and flow fields in the spiral-coil tube. Ho et al. [2,3] used the relevant correlations of the tube-side and air-side heat transfer coefficients in the simulation to determine the thermal performance of the spiral-coil heat exchanger under cooling and dehumidifying conditions. Naphon and Wongwises [4] determined the performance and heat transfer characteristics of spiral-coil tube heat exchanger under wet-surface conditions. Later, Naphon and Wongwises [5] conducted the experiments with the same experimental apparatus were also conducted under dry- and wet-surfaces conditions to study the heat transfer characteristics. Naphon and Wongwises [6] experimentally and theoretically studied on the heat transfer and performance of a spiral-coil finned tube heat exchanger under dry-surface conditions. Prasad et al. [7] presented the studies on ionic mass transfer in the presence of spiral coil turbulence promoters in batch fluidized beds. Neeraas et al. [8] experimental studied on the shell-side heat transfer and pressure drop in gas flow for spiral-wound LNG heat exchanger. A test plant has been constructed for measurements of local heat-transfer coefficients and frictional pressure drops on the shell side of spiral-wound LNG heat exchangers. Murai et al. [9] observed the structure of air–water two-phase flow in helically coiled tubes. Li et al. [10] studied on the condensation heat transfer of R-134a in horizontal straight and helically coiled tube-in-tube heat exchangers. The results indicate that the condensation heat transfer coefficients of the helical section were 4%–13.8% higher than that of the straight section. Zdaniuk et al. [11] determined the heat transfer and friction in helically-finned tubes for eight helically-finned tubes and one smooth tube. Salimpour [12] calculated the heat transfer coefficients of shell and coiled tube heat exchangers with three different coil pitches. Khan et al. [13] investigated on diabatic flow of R-134a through spiral capillary tube with various geometric parameters. Mittal et al. [14] numerical analyzed the adiabatic flow of refrigerant through a spiral capillary tube by using a homogenous model including the metastable liquid region. Lee [15] studied on the air-side heat transfer characteristics of spiral-type circular fin-tube heat exchangers used as evaporators in household refrigerators. Ali [16] considered the pressure drop correlations for flow through regular helical coil tubes. Jayakumar et al. [17] applied the CFD method to analyze the single-phase flows inside helically coiled tubes. Mittal et al. [18] investigated the flow of R-407C in an adiabatic helical capillary tube.

☆ Communicated by: W.J. Minkowycz.
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0735-1933/$ – see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.icheatmasstransfer.2010.10.007