International Journal of Heat and Mass Transfer 54 (2011) 2673–2682

Contents lists available at ScienceDirect

International Journal of Heat and Mass Transfer

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

Condensation heat transfer and flow characteristics of R-134a flowing through corrugated tubes

Suriyan Laohalertdecha [a,b], Somchai Wongwises [b,*]

[a] The Joint Graduate School of Energy and Environment (JGSEE), King Mongkut's University of Technology Thonburi, Bangmod, Bangkok 10140, Thailand

[b] Fluid Mechanics, Thermal Engineering and Multiphase Flow Research Laboratory (FUTURE), Department of Mechanical Engineering, King Mongkut's University of Technology Thonburi, Bangmod, Bangkok 10140, Thailand

ARTICLE INFO

Article history:
Received 8 March 2010
Received in revised form 14 December 2010
Accepted 14 December 2010
Available online 2 March 2011

Keywords:
Condensation
Nusselt number
Two-phase friction factor
Smooth tube
Corrugated tube

ABSTRACT

This article presents the condensation heat transfer and flow characteristics of R-134a flowing through corrugated tubes experimentally. The test section is a horizontal counter-flow concentric tube-in-tube heat exchanger 2000 mm in length. A smooth copper tube and corrugated copper tubes having inner diameters of 8.7 mm are used as an inner tube. The outer tube is made from smooth copper tube having an inner diameter of 21.2 mm. The corrugation pitches used in this study are 5.08, 6.35, and 8.46 mm. Similarly, the corrugation depths are 1, 1.25, and 1.5 mm, respectively. The test conditions are performed at saturation temperatures of 40–50 °C, heat fluxes of 5–10 kW/m^2, mass fluxes of 200–700 kg/m^2 s, and equivalent Reynolds numbers of 30000–120000. The Nusselt number and two-phase friction factor obtained from the corrugated tubes are significantly higher than those obtained from the smooth tube. Finally, new correlations are developed based on the present experimental data for predicting the Nusselt number and two-phase friction factor for corrugated tubes.

© 2011 Elsevier Ltd. All rights reserved.

1. Introduction

Heat transfer enhancement techniques are the methods used for increasing the heat transfer performance of heat exchangers. Microfin tube is a type of rough surface used in heat transfer enhancement techniques and has been successfully implemented in the air conditioning and refrigeration industries for effective tube-side performance. This success is because of their ability to significantly improve the heat transfer coefficient [1–3] with only a moderate increase of the friction penalty. Moreover, the corrugated tube is another one type that is widely used in heat exchanger applications for the purpose of heat transfer enhancement, size reduction, and an easier manufacturing process. Many researchers have studied heat transfer enhancement using corrugated tubes as shown in Table 1. Some examples of these studies are described below.

Dong et al. [4] investigated the friction factor and heat transfer characteristics of four spirally corrugated tubes with various geometrical parameters. The working fluids are water and oil. The test runs are conducted at Reynolds numbers varying from 6000 to 93000 for water and 3200 to 19000 for oil. Their results indicated that the maximum heat transfer coefficient and friction factor obtained from corrugated tubes increase by approximately 120% and 160% when compared to smooth tubes.

Barba et al. [5] presented the experimental results of single-phase heat transfer and pressure drop of ethylene glycol flowing in a corrugated tube at moderate Reynolds numbers varying from 100 to 800. The inside heat transfer coefficient in the corrugated tube increases up to 4.27–16.79 times higher than that of the smooth tube, while the friction factor increases up to a factor of 1.83–2.45. Based on the experimental data, Nusselt number and friction factor correlations are proposed for the periodically fully developed region.

Rainieri and Pagliarini [6] studied the thermal performances of corrugated tubes. Axial symmetrical and helical corrugated tubes with different pitch values were considered. The tests were conducted at Reynolds numbers ranging between 90 and 800. Ethylene glycol is used as the working fluid. The results showed that the helical corrugation induces significant swirl components.

Among all these previous studies, the most productive studies have continually been performed by Zimparov [7]. Extended performance evaluation criteria for enhanced heat transfer surfaces at constant wall temperature were studied. Zimparov [8] presented heat transfer and isothermal friction pressure drop results of two single-start spirally corrugated tubes combined with five twisted tape inserts with different relative pitches. The friction factors and inside heat transfer coefficients obtained from these tubes were higher than those obtained from the smooth tube. Moreover, Zimparov [9,10] applied a simple mathematical model for predicting the friction factors and heat transfer coefficients in a spirally corrugated configuration combined with a twisted tape insert flowing in the turbulent flow regime. The calculated friction factors

* Corresponding author. Tel.: +662 470 9115; fax: +662 470 9111.
E-mail address: somchai.won@kmutt.ac.th (S. Wongwises).

0017-9310/$ - see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.ijheatmasstransfer.2010.12.034

Nomenclature

A	surface area of the test section (m^2)
C	Chisholm parameter
c_p	specific heat at constant pressure (J/kg K)
D	diameter (m)
e	corrugation depth (m)
f	friction factor
G	mass flux (kg/m^2 s)
h	heat transfer coefficient (W/m^2 K)
i	specific enthalpy (J/kg)
k	thermal conductivity (W/m K)
L	length of the test tube (m)
LMTD	logarithmic mean temperature difference
m	mass flow rate (kg/s)
Nu	Nusselt number
p	corrugation pitch (m)
Pr	Prandtl number
Q	heat transfer rate (W)
Re	Reynolds number
q''	heat flux (W/m^2)
T	temperature (°C)
v	specific volume (m^3/kg)
w	corrugation width (m)
x	average quality
X	Martinelli parameter

Greek letters

α	void fraction
β	helix angle (degree)
ε	relative roughness (m)
ρ	density (kg/m^3)
ϕ_l^2	two-phase multiplier
μ	dynamic viscosity (Pa s)
ΔP	pressure drop (Pa/m)

Subscripts

a	acceleration
avg	average
c	corrugated tube
f	friction
in	inlet
i	inside
l	liquid
out	outlet
o	outside
ph	pre-heater
ref	refrigerant
s	smooth tube
sat	saturation
tp	two-phase
TS	test section
v	vapor
w	water

and heat transfer coefficients were compared with the experimental data. The results showed that the agreement between predicted and experimental data is fairly good.

Vicente et al. [11,12] experimentally studied the mixed convection heat transfer and isothermal pressure drop in corrugated tubes for laminar, transition, and turbulent flow regions. At a high Rayleigh number, the Nusselt number obtained from these tubes is 30% higher than that obtained from the smooth tube. The friction factors of the corrugated tube were between 5% and 25% higher than those of the smooth tube.

Naphon et al. [13] studied the heat transfer and pressure drop characteristics of water flowing in horizontal double pipes with helical ribs. Nine test sections with different characteristic parameters were tested, namely helical rib height to diameter $h/d = 0.12$, 0.15, and 0.19 and helical rib pitch to diameter $p/d = 1.05$, 0.78, and 0.63. It was found that the helical ribs have a significant effect on the heat transfer and pressure drop augmentations. Both the proposed correlations for the heat transfer coefficient and friction factor give good agreement with the present data to within 15%.

Targanski and Cieslinski [14] studied the evaporation for the pure R407C and R407C/oil mixtures in two smooth tubes and two enhanced tubes experimentally. The advantages of the micro-fin tube and corrugated tube were quantified and discussed. Test runs were performed as follows: inlet and outlet vapour quality were set at 0 and 0.7, respectively, and mass flux density ranged from 250 to 500 kg/m^2 s. The experiments were conducted at an average saturation temperature of 0 °C. It was found that the corrugated tube and micro-fin tube had a significant effect on the heat transfer coefficient and pressure drop augmentations.

Bilen et al. [15] experimentally investigated the heat transfer and friction characteristics of air flow in different grooved tubes under turbulent flow regime. Reynolds numbers ranging from 10000 to 38000 were tested. The circular, trapezoidal, and rectangular grooves were used as the test section. The tube's length-

Table 1
Experimental investigation on the corrugated tube with various working fluid and tube configurations.

Sources	D_i (mm)	e/D_i	p/D_i	β (degree)	Phase
Dong et al. [4]	16.04–22.82	0.0243–0.0398	0.438–0.623	78.8–82.1	Single phase
Barba et al. [5]	14.5	0.103	0.793	45	Single phase
Rainieri and Pagliarini [6]	14	0.107	1.143–4.571	–	Single phase
Zimparov [7]	13.68–13.73	0.0407–0.0569	4.7–15.3	67.4–68	Single phase
Zimparov [8]	13.39–13.65	0.0371–0.0441	2.4–7.7	79.3–82.2	Single phase
Zimparov [9]	12.44–13.90	0.0224–0.0569	7.45–21.17	67.4–90	Single phase
Zimparov [10]	12.44–13.90	0.0224–0.0569	7.45–21.17	67.4–90	Single phase
Vicente et al. [11]	18	0.0239–0.0572	0.608–1.229	68–80	Single phase
Vicente et al. [12]	18	0.0239–0.0572	0.608–1.229	68–80	Single phase
Naphon et al. [13]	8.1	0.12–0.19	0.63–1.05	45	Single phase
Targanski and Cieslinski [14]	8.8	0.0511	0.681	77.75	Two phase (evaporation)
Bilen et al. [15]	36	0.0833	0.333–0.416	90	Single phase
Laohalertdecha and Wongwises [16]	8.7	0.1724	0.584–0.9724	74.2–79.47	Two phase (condensation)
Laohalertdecha and Wongwises [17]	8.7	0.1724	0.584–0.9724	74.2–79.47	Two phase (evaporation)

Download English Version:

https://daneshyari.com/en/article/659558

Download Persian Version:

https://daneshyari.com/article/659558

Daneshyari.com