Experimental Thermal and Fluid Science 35 (2011) 887–895

Contents lists available at ScienceDirect

Experimental Thermal and Fluid Science

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

Two-phase flow of R-134a refrigerant during flow boiling through a horizontal circular mini-channel

Sira Saisorn [a,c], Jatuporn Kaew-On [b,c], Somchai Wongwises [c,*]

[a] King Mongkut's Institute of Technology Ladkrabang Chumphon Campus Chumphon 86160, Thailand
[b] Department of Physics, Faculty of Science, Thaksin University, Phattalung 93110, Thailand
[c] Fluid Mechanics, Thermal Engineering and Multiphase Flow Research Lab. (FUTURE), Department of Mechanical Engineering, King Mongkut's University of Technology Thonburi, Bangmod, Bangkok 10140, Thailand

ARTICLE INFO

Article history:
Received 18 December 2009
Received in revised form 24 October 2010
Accepted 21 January 2011
Available online 31 January 2011

Keywords:
Flow boiling
Mini-channel
Flow pattern
Heat transfer

ABSTRACT

This research focuses on heat transfer to R-134a during flow boiling in a 1.75 mm internal diameter tube. Flow visualisation and heat transfer experiments are conducted to obtain heat transfer coefficients for different flow patterns. The measured data in each flow regime are compared with predictions from a three-zone flow boiling model. The calculations are in fair agreement with the experimental results which correspond in particular to slug flow, throat-annular flow and churn flow regimes under conditions of low heat flux.

1. Introduction

In recent years, intense research effort has been devoted to the flow boiling heat transfer characteristics of small flow passages such as mini- and micro-channels owing to the rapid development of micro-scale devices used for several engineering applications including medical devices, high heat-flux compact heat exchangers, and cooling systems for various types of equipment.

Several advantages can be obtained when small channels are selected for applications. In compact heat exchanger implementations, for instance, small channels can provide a larger contact area with the fluid per unit volume and support high pressure operating conditions. Capillary force or surface tension is likely to play an important role in two-phase flow and heat transfer characteristics, resulting in significant differences in the flow phenomena between ordinarily sized channels and small channels.

The criteria for the classification of small channels have been given by different investigators as reported in Saisorn and Wongwises [1]. For instance, arbitrary channel classifications associated with the hydraulic diameter, D_h have been proposed. Mehendale et al. [2] employed the hydraulic diameter as an important parameter for defining the heat exchangers as follows:

– Micro-heat exchanger: $1\ \mu m \leqslant D_h \leqslant 100\ \mu m$
– Meso-heat exchanger: $100\ \mu m \leqslant D_h \leqslant 1$ mm
– Compact heat exchanger: $1\ mm \leqslant D_h \leqslant 6$ mm
– Conventional heat exchanger: $D_h > 6$ mm

Kandlikar [3] proposed criteria for different-sized channels used in engineering applications:

– Micro-channels: $10\ \mu m \leqslant D_h \leqslant 200\ \mu m$
– Mini-channels: $200\ \mu m \leqslant D_h \leqslant 3$ mm
– Conventional channels: $D_h > 3$ mm

With regard to two-phase flow research, there have been a relatively small number of publications in the area of small channels compared with those done for ordinarily sized channels. Hydrodynamic and transport phenomena in small channels, which have limited and confined space, are less well understood compared to those in larger channels. Recent works concerned with two-phase heat transfer characteristics in mini- and micro-channels are outlined in the following paragraphs.

Huo et al. [4] studied experimentally boiling heat transfer of R-134a fluid flowing in small vertical tubes of 2.01 and 4.26 mm internal diameter. In the range of low vapour quality, the heat transfer coefficient in both tubes increased with increasing heat flux and saturated pressure but was independent of vapour quality. These results were attributed to nucleate boiling being the dominant heat transfer mode. Over other ranges of vapour quality, however, the dominant heat transfer mode was not addressed as a

* Corresponding author. Tel.: +66 2 470 9115; fax: +66 2 470 9111.
E-mail address: somchai.won@kmutt.ac.th (S. Wongwises).

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doi:10.1016/j.expthermflusci.2011.01.008