Applied Thermal Engineering 49 (2012) 2–8

Contents lists available at SciVerse ScienceDirect

Applied Thermal Engineering

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

CO_2 and R410A: Two-phase flow visualizations and flow boiling measurements at medium (0.50) reduced pressure

R. Mastrullo [a], A.W. Mauro [a,*], J.R. Thome [b], G.P. Vanoli [c]

[a] DETEC, Università degli Studi di Napoli FEDERICO II, p.le Tecchio, 80, 80125, Napoli, Italy
[b] Laboratory of Heat and Mass Transfer (LTCM), Swiss Federal Institute of Technology, Lausanne (EPFL), Lausanne CH-1015, Switzerland
[c] DING, University of Sannio, Palazzo ex INPS – Piazza Roma, 21 – 82100 Benevento, Italy

A R T I C L E I N F O

Article history:
Received 4 November 2010
Accepted 11 October 2011
Available online 20 October 2011

Keywords:
Flow boiling
CO_2
R410A
Reduced pressure
Heat transfer

A B S T R A C T

The conversion to more environmentally friendly refrigerants is of prime importance for refrigeration and air-conditioning industries. A first option for the substitution of the fluids which use was banned could be natural refrigerants, such as CO_2, or HFC mixtures with low global warming and zero ozone depletion impacts. To determine the heat transfer characteristics during flow boiling of CO_2 a remarkable amount of literature on flow boiling of CO_2 has been published, especially during the last decade. The experiments on this fluid pointed out that, at medium reduced pressure, the heat transfer coefficients trends versus vapor quality are quite different than those commonly encountered with other refrigerants at ordinary temperatures and several interpretations for this were proposed.

In this work tests for CO_2 and R410A are carried out to study the behaviour of the local heat transfer during evaporation at medium reduced pressure (0.50). The tests were run on a smooth, horizontal, stainless steel tube with an inner diameter equal to 6.00 mm, varying the mass flux between 200 and 350 kg m^{-2} s^{-1} and the heat flux between 5.0 and 20.0 kW m^{-2} over the whole range of vapor qualities.

It was verified by experiments that for R410A at a medium reduced pressure the peripheral local heat transfer coefficient trends, as the two-phase flow structures and flow regime transitions, are similar to those for CO_2, at the same reduced pressure.

1. Introduction

Due to environmental issues such as ozone depletion and global warming, the refrigeration, air-conditioning and heat pump industries have started the conversion to environmentally friendly refrigerants. Depending on the size of the systems, the operating and ambient conditions, different options are available among natural refrigerants and HFC mixtures. In the last decade the interest of scientific and industrial research has been focused on ammonia, carbon dioxide (R744), hydrocarbons and other HFC mixtures, such as R404A, R407C, R410A [1–3].

The application of HFC mixtures has been recently introduced also in cascade air-to-water heat pumps for sanitary water production, increasing the working temperature during evaporation at the high temperature side. More recently the use of CO_2, in saturated conditions and as secondary fluid, has been considered in a wider range of temperature, due to low pumping energy required.

In such systems the refrigerant side heat transfer resistance is not negligible for the sizing of evaporators with the accuracy currently required and one important aspect is the knowledge of two-phase characteristics during flow boiling, as confirmed by the large literature production on this theme (see, for example [4,5]).

Among other fluids, flow boiling of carbon dioxide has been intensively investigated. In effect, this fluid evaporates at much higher reduced pressures than other refrigerants (at the same evaporation temperatures). Hence, the thermodynamic and transport properties are remarkably different than those of conventional fluids. In particular, the surface tension and the liquid viscosity are much lower, causing a large increase in nucleate contribution to evaporation, while decreasing pressure gradients. As pointed out by Bredesen et al. [6], using carbon dioxide the heat transfer efficiency at refrigerant side could be considerably enhanced by increasing heat flux without punishment in pressure loss. However, the CO_2 heat transfer coefficient trends are completely different than those of other fluids at ordinary temperatures, as the works in literature show.

This study refers to flow boiling in a smooth tube with 6.00 mm inner diameter and the objective is to report experiments for two

* Corresponding author. Tel.: +39 081762198; fax: +39 0812309364.
E-mail address: alfonsowilliam.mauro@unina.it (A.W. Mauro).

1359-4311/$ – see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.applthermaleng.2011.10.021