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Flow boiling of R32 inside a brazed plate heat exchanger

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ABSTRACT

This paper presents measurements of heat transfer coefficient obtained during flow boiling of R32 inside a brazed plate heat exchanger (BPHE). Although R32 is known as a very interesting refrigerant for its thermodynamic and thermophysical properties, very limited flow boiling data are published in the open literature for R32 working in brazed plate heat exchangers.

The present experimental data are measured to investigate the effect of refrigerant heat flux, mass velocity, inlet vapor quality and superheating at the outlet. The saturation temperature is kept constant at around 5 °C, which is a usual temperature level for evaporation in liquid coolers. As a significant result, differently from other studies on flow boiling with HFC refrigerants, mass flux is found to be very important, meaning a high contribution of the convective term on the heat transfer coefficient.

The present data are also analyzed to assess available correlations for flow boiling inside BPHEs, in order to provide useful information on the accuracy of predicting methods that can be used for evaporators with R32.

Ébullition en écoulement du R32 à l'intérieur d'un échangeur de chaleur à plaques

Mots clés : R32 ; Échangeur de chaleur à plaques (BPHE) ; Ébullition en écoulement ; Expériences

1. Introduction

Brazed plate heat exchangers (BPHE) are widely used in many industrial applications due to their high efficiency, compactness and cost effectiveness. The flexibility in their design allows different solutions that are investigated in order to achieve high heat transfer coefficient while maintaining low pressure losses. This kind of heat exchanger has been extensively studied in single phase conditions, while two-phase heat transfer needs more investigation because of the complex phenomena involved (e. g. multiphase flow, different heat exchange mechanisms, possible dry out. . .). Different authors performed experimental tests on BPHEs with the typical

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Nomenclature

A_{ht}	heat transfer area [m^2]
Bd	Bond number [-]
Bo	boiling number [-]
c_p	specific heat capacity [J kg^{-1} K^{-1}]
C_{Ra}	surface roughness divided by reference value of 0.4 μm [-]
d	diameter [m]
D_h	hydraulic diameter [m]
E	enhancement factor [-]
G	mass velocity [kg m^{-2} s^{-1}]
Ge_1,Ge_2	coefficient for Nu correlation in Hsieh and Lin (2003)
HTC	heat transfer coefficient [W m^{-2} K^{-1}]
HTC_0	reference value of HTC at p_{red}^*; q_0; Ra_0 [W m^{-2} K^{-1}]
h	specific enthalpy [J kg^{-1}]
h_{LV}	specific enthalpy of vaporization [J kg^{-1}]
K_{global}	global heat transfer coefficient [W m^{-2} K^{-1}]
M	molecular weight
$\dot{m}$	mass flow rate [kg s^{-1}]
p_{co}	corrugation pitch [m]
p_{red}	reduced pressure [-]
p_{red}^*	reference reduced pressure = 0.1
Pr	Prandtl number [-]
q	heat flux [W m^{-2}]
q_0	reference heat flux = 20 000 W m^{-2}
Q	heat flow rate [W]
Ra	surface roughness [μm]
Ra_0	reference surface roughness = 0.4 μm
S	suppression factor [-]
s	plate thickness [m]
T	temperature [°C]
Re	Reynolds number [-]
We	Weber number [-]
x	thermodynamic vapor quality [-]
X_{tt}	Martinelli parameter [-]

Greek symbols

β	Chevron angle [degrees]
Φ	enlargement factor [-]
ΔT	temperature difference [K]
λ	thermal conductivity [W m^{-1}K^{-1}]
ρ^*	density ratio [-]

Subscripts

boil	boiling condition
cb	convective boiling
eq	equivalent
EXP	experimental
h	hydraulic
in	inlet
L	liquid
ln	logarithmic
m	mean value
out	outlet
pool	pool boiling
r	refrigerant
red	reduced
sat	saturation condition
SH	superheating condition
V	vapor
w	water
wall	referred to aluminum wall
x1	evaluated in the position where refrigerant is saturated vapor

refrigerants used in air-conditioning (R407C, R134a, R410A, R32. . .), but only recently some vaporization tests with R32 have been published (Longo et al., 2015b). As reported in Table 1, R32 displays a latent heat that is higher than the latent heat of other common refrigerants, that is, the heat flux is higher at the same mass flow rate and equal working inlet/outlet conditions.

Fundamental understanding of the flow boiling mechanism is not easy due to the complex nature of two-phase flow, therefore quantitative prediction of the flow boiling heat transfer coefficient is always obtained through empirical correlations. These correlations usually cover a specified plate geometry and limited working conditions.

Table 1 – Latent heat at 5 °C saturation temperature for different fluids.

Fluid	Latent heat at T_{sat} = 5 °C [kJ/kg]
R407C	204.7
R134a	194.7
R410A	215.1
R32	307.3

Yan and Lin (1999) performed experiments on evaporation heat transfer and pressure drop of R134a in plate heat exchangers and proposed a correlation for the prediction of Nusselt number for the single-phase flow and another correlation for two-phase flow. Hsieh and Lin (2002) and Hsieh and Lin (2003) explored R410A subcooled flow boiling heat transfer and proposed empirical correlations. Han et al. (2003) performed experiments on evaporation of refrigerants R410A and R22 in plate heat exchangers with different values of chevron angle and corrugation pitch. Ayub (2003) presented an extensive literature review of available single-phase correlations for plate heat exchangers and new two-phase boiling and pressure drop correlations for flooded and direct expansion evaporators based on data collected with ammonia and R22. Longo and Gasparella (2007a) presented the experimental heat transfer coefficients and pressure drop measured during refrigerant R410A vaporization inside a small brazed plate heat exchanger (BPHE): the effects of heat flux, refrigerant mass flux, saturation temperature and outlet conditions were investigated. A similar experimental study has been performed with R134a as the working fluid in Longo and Gasparella (2007b). Huang et al. (2012) presented two-phase heat transfer and