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Evaporating heat transfer and pressure drop of hydrocarbon refrigerants in 9.52 and 12.70 mm smooth tube

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Abstract

Experimental results of heat transfer characteristic and pressure gradients of hydrocarbon refrigerants R-290, R-600a, R-1270 and HCFC refrigerant R-22 during evaporating inside horizontal double pipe heat exchangers are presented. The test sections have one tube diameter of 12.70 mm with 0.86 mm wall thickness, another tube diameter of 9.52 mm with 0.76 mm wall thickness was used for this study. The local evaporating heat transfer coefficients of hydrocarbon refrigerants were higher than those of R-22. The average evaporating heat transfer coefficient increased as the mass flux increased. It is showed the higher values in hydrocarbon refrigerants than R-22. Comparing the heat transfer coefficient of experimental results with that of other correlations, the obtained results from the experiments had coincided with most of the Kandlikar's correlation. Hydrocarbon refrigerants have higher pressure drop than R-22 in 12.7 mm and 9.52 mm. This results form the study can be used in the case of designing heat transfer exchangers using hydrocarbons as the refrigerant for the air-conditioning systems.

Keywords: Hydrocarbon refrigerant; Evaporation; Heat transfer coefficient; Pressure drop; Natural refrigerant

1. Introduction

Due to the environmental problems by CFCs and HCFCs, the development of new alternative refrigerants with the high efficient machine which can reduce energy consumption has been becoming an urgent issue [1,2]. HFCs or non-azeotropic refrigerant mixtures [3] has been being regarded as alternative refrigerants. However, HFC's can make acids and toxic substances when they are resolved in a compound into their forming elements by sunlight [4], and though, they have zero ODP (ozone depletion potential), but they have high GWP (global warming potential). Besides of that fact, it is hard to treat non-azeotropic refrigerant mixtures efficiently and is difficult to reproduce the primary constant composition due to its variation caused by leakage for repairing. So, new alternative refrigerants having no

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Nomenclature

BO	boiling number, q/Gi_{lg}
C_p	specific heat at constant pressure (kJ/kg K)
CO	convection number, $((1-x)/x)^{0.8}(\rho_v/\rho_l)^{0.5}$
d	diameter (m)
F_{fl}	fluid dependent parameter
G	mass velocity (kg/m^{2}s)
h	heat transfer coefficient (kW/m^{2}K)
i	enthalpy (kJ/kg)
i_{lg}	latent heat of vaporization (J/kg)
k	thermal conductivity (kW/m K)
m	mass flow rate (kg/h)
n	number of local tube
q	heat flux (kW/m^2)
Q	heat capacity (kW)
Re	Reynold number, $\rho uD/\mu$
S	suppression factor
T	temperature (K)
x	quality

Greek symbols

Δ	difference
μ	dynamic viscosity (Pa s)
ρ	density (kg/m^3)

Subscripts

avg	average
CBD	convective boiling dominant
e	evaporator
eq	equivalent
i	inner
in	inlet
l	liquid
loc	local
NBD	nucleate boiling dominant
o	outer
out	outlet
r	refrigerant
tp	two phase
v	vapor
w	source water

poisonous characteristics, no flammability and should be similar to conventional refrigerant in terms of thermodynamic property are required.

Under these circumstances, additional and active studies regarding the so-called ''natural refrigerants'' have been under way. Especially HC's refrigerants are examined positively as an alternative refrigerant for (H)CFC because it is easily available and its GWP and ODP are almost close to zero. But, the developed countries like US and Japan have not adapted them except for Europe due to flammability of HC's. However, according to James [5], in case of the household refrigerators, the possibility of explosion by flammability can be negligible since the HC's charge quantity is about half of general CFC refrigerant's one. Besides, if some simple safety device (e.g. ventilation system or leakage detector) is installed, it can overcome that problem in the large size air-conditioning and refrigerating system. But, the researches for performance of the refrigeration and air-conditioning systems using the HC's as a refrigerant are not enough, especially, the study on characteristics of evaporating heat transfer is the one of those.

Kandlikar [6] introduced a general correlation about fluid boiling in the vertical·horizontal tube. Kwon [7] experimented regarding the characteristics of evaporating heat transfer using R-290, R-410A and compared with those of R-22. According to his report, evaporating heat transfer coefficient of R-290 was higher than that of R-22 or R-410A, but the research on evaporating heat transfer of natural refrigerants is still ridiculously rare.

In this scenarios, the purpose of this paper is to obtain basic data for the purpose of designing the evaporator that uses HC's refrigerants and is to compare experimentally, the evaporating heat transfer characteristic and the pressure drop of R-1270 (propylene), R-290 (propane), R-600a (iso-butane) taking R-22 as base at the smooth tube.

2. Experimental apparatus and method

2.1. Experimental apparatus

Fig. 1 shows the schematic of the experimental apparatus including basic air-conditioning and refrigerating system consisted of compressor, condenser, expansion valve, evaporator and peripheral device. The system also consists of two main flow loops: a refrigerant loop and heat source water for evaporating or condensing loop. In the test section of the experiment, the evaporator is a double-tube type heat exchanger divided into three sections, which are inner tube, outer tube and annular section.

The heat exchanger (test section) is shown in Fig. 2. The inner diameter of the inner tube (copper) is 10.92 mm, 8 mm, and outer and inner diameters of the outer tube (copper) are 19.94 and 22.22 mm respectively.