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Review

Flow boiling characteristics and flow pattern visualization of refrigerant/lubricant oil mixtures

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ABSTRACT

A comprehensive review of flow boiling characteristics and flow pattern visualization of refrigerant/lubricant oil mixtures is presented in this paper. First, various parameters influenced by the lubricant oil in convective boiling of refrigerants, such as mass velocity, vapor quality, oil concentration and geometric characteristics of the heat transfer tube are discussed. The effects of the unavoidable introduction of the lubricant oil on the thermodynamics properties of a refrigerant are described. Then, a review of the main experimental studies of flow boiling of refrigerant/lubricant oil mixtures is presented and also describes research with halocarbons, carbon dioxide, hydrocarbons and ammonia. There is no agreement among these studies regarding the effect of the oil in the evaporator, with studies showing an increase or decrease in the heat transfer coefficient. However, in relation to pressure drop, all the results presented the same trend, increasing the pressure drop with increasing oil concentration. Next, the flow patterns of refrigerant/oil mixtures are illustrated together with a selection of video images. It is possible to notice the difference in frothing formation with respect to the particular refrigerant and tube geometry. Some predictions of oil effects on the heat transfer coefficient and pressure drops based on the mixture physical properties are then presented and the trends compared to data. Finally, some suggestions for future work are given.

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Caractéristiques de l'ébullition en écoulement et visualisation de la configuration de l'écoulement des mélanges frigorigène/huile de lubrification

Mots clés : Frigorigène ; Ébullition ; Enquête ; Écoulement ; Mélange ; Huile ; Transfert de Chaleur ; Chute de pression ; Imagerie ; Distribution ; Vitesse

Nomenclature

A	empirical constant
B	empirical constant
c_p	specific heat, kJ kg^{-1} K^{-1}
(dp/dz)	two-phase frictional pressure gradient, Pa m^{-1}
G	mass velocity, kg s^{-1} m^{-2}
h	heat transfer coefficient, W m^{-2} K^{-1}
k	thermal conductivity, W m^{-1} K^{-1}
p	pressure, Pa
q	heat flux, W m^{-2}
T	temperature, K
x	vapor quality

Greek symbol

μ	dynamic viscosity, N s m^{-2}
ρ	density, kg m^{-3}
σ	surface tension, N m^{-1}
ω	oil mass fraction

Subscripts

bub	bubble point
inlet	inlet
Local	local mass concentration
m	mixture
M–T	relative to Moreno Quibén and Thome (2006) model
o	oil
R	refrigerant
ref/oil	relative to the refrigerant/oil mixture
sat	saturation
w	wall

1. Introduction

In vapor compression processes, the presence of oil is intrinsic and unavoidable since the oil is required to lubricate the moving parts for proper functioning of the compressor. Some lubricant oil, depending on each installation, thus flows through all the components of the system, where in heat exchangers the presence of oil can affect the flow pattern and both the heat transfer and pressure drop depending on the concentration. Due to a wide variety of refrigeration, heat pump and air-conditioning systems, such as domestic, commercial and industrial installations, in general, this amount of lubricant oil circulating in the system can vary from as low as 0.1% up to 8.0% by weight in the refrigerant flow.

In the open literature, a great number of papers involving refrigerant–oil mixtures can be found for different test conditions and often present conflicting results with one another. Even so, it is still possible to affirm that some thermodynamics properties of refrigerant/oil mixtures, such as density, viscosity, surface tension and miscibility, can modify, specifically, the heat transfer and pressure drop, and thus affect directly the coefficient of performance (COP) of the system. Fig. 1 illustrates statistical results on the number of the publications in the literature according to the time period of publication involving flow boiling or nucleate boiling of refrigerant/oil mixtures. It is interesting to note that in the beginning of the 1990's, there was a peak, due mainly to the signature of the Montreal Protocol that heralded in numerous new refrigerants. Another important and recent incentive for this work is the revival of interest in natural refrigerants, such as carbon dioxide, ammonia and hydrocarbons, as indicated in the last column in the graph.

The objective of this paper is to review and analyze the main parameters and design methodologies affected by the oil's presence: physical properties, flow patterns, boiling heat transfer and two-phase pressure drops.

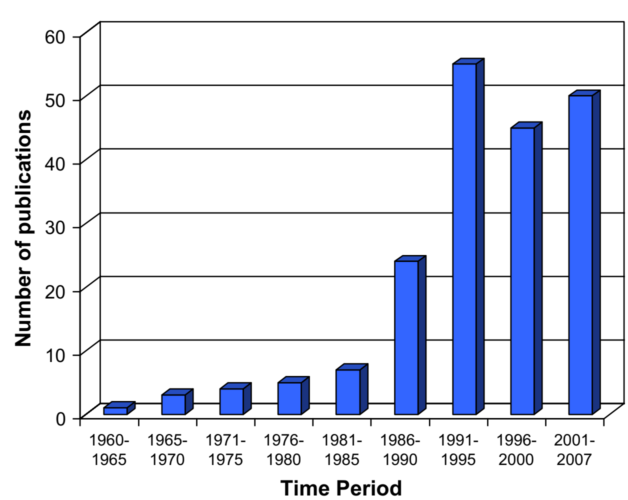

Fig. 1 – Number of publications in the literature according to the time period of publication.