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Review

The effect of oil in refrigeration: Current research issues and critical review of thermodynamic aspects

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ARTICLE INFO

Article history:
Received 10 May 2007
Received in revised form 17 September 2007
Accepted 24 September 2007
Published online 2 October 2007

Keywords:
Refrigeration system
Compression system
Review
Lubrication
Oil
Procedure
Measurement
Solubility
Modelling

ABSTRACT

A lubrication agent is necessary in almost all the refrigeration vapour compression systems, particularly for the correct operation of the compressor. However, a certain portion of the oil always circulates with the refrigerant through the cycle. This circulation is at the origin of a deviation from the theoretical behaviour (i.e. based on pure refrigerant) of the components. This article aims at reviewing the oil-related researches in the field of refrigeration. Previous reviews in the literature focused on the thermo-hydraulic consequences of the presence of oil; we will analyse here its thermodynamical consequences. In a first part, a brief literature review will give an overview of current scientific and technological issues concerning the impact of oil on components or on whole refrigeration systems. The typical approaches and methods employed to address this problem will be described. These researches require sound tools for the evaluation of thermodynamic properties of refrigerant–oil mixtures. The second part of this article is hence a critical review of these tools, and focuses particularly on liquid–vapour equilibrium, absorption–diffusion, and mixture enthalpy calculation.

Effets de l’huile de lubrification dans le domaine du froid : Problématiques actuelles et synthèse critique sur les aspects thermodynamiques

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doi:10.1016/j.ijrefrig.2007.09.006

Mots clés:
Système frigorifique
Système à compression
Enquête
Lubrification
Huile
Procédure
Mesure
Solubilité
Modélisation

RÉSUMÉ

La présence d'un lubrifiant est nécessaire dans pratiquement tous les systèmes frigorifiques à compression mécanique de vapeur, principalement pour garantir le fonctionnement correct du compresseur. Cependant, une partie de l'huile circule avec le frigorigène à travers le circuit, ce qui modifie le comportement théorique (i.e. sans huile) des composants ou du système. L'objectif de cet article est de proposer une synthèse des travaux relatifs à la présence d'huile dans le domaine du Génie Frigorifique. Comme des synthèses portant sur les aspects thermo-hydrauliques de cette question ont été publiés auparavant, nous nous concentrerons ici sur les aspects thermodynamiques. Dans un premier temps, une analyse bibliographique mettra en évidence les questions techniques et scientifiques actuelles concernant l'impact de l'huile sur les composants ou les systèmes complets. Les méthodes et approches typiquement employées pour répondre à ces questions seront décrites. On montrera que, pour une compréhension correcte de ces résultats, il est impératif de disposer d'outils fiables pour le calcul des propriétés thermodynamiques des mélanges huile–frigorigène. C'est pourquoi, dans un deuxième temps, cet article proposera une synthèse critique de tels outils, particulièrement pour la description des équilibres liquide–vapeur, des phénomènes d'absorption–diffusion et du calcul de l'enthalpie des mélanges.

Nomenclature

a, b, m, n	EOS parameters
C	mass concentration
C_p	specific heat, J kg^{-1} K^{-1}
C_g	total oil mass fraction
C_L	local oil mass fraction
d^+	hard sphere diameter
D	diffusion coefficient, m^2 s^{-1}
dz	element height, m
f	fugacity, Pa
$g(d^+)$	pair radial distribution function
h	specific enthalpy, J kg^{-1}
M	molar mass, kg mol^{-1}
$\dot{m}$	mass flow rate, kg s^{-1}
P	pressure, Pa
Pe	Poynting effect
R	ideal gas constant, J mol^{-1} K^{-1}
r	number of segments per molecule
T	temperature, K
t	time, s
V	volume, m^3
x	liquid mole fraction
y	vapour mole fraction

Greek symbols

α, β, κ	EOS parameters
Δh	enthalpy change, kJ kg^{-1}
ρ	molar density, mol m^{-3}
ω	acentric factor

Subscripts

0	reference
bub	bubble point
c	critical
i, j	component number
L	liquid
oil	oil
pert	perturbation
r	refrigerant
ref	reference
sat	saturation
t	total
V	vapour

1. Introduction

In the refrigeration and air-conditioning vapour compression systems, oil is necessary for a correct working of the compressor. Its main role is indeed to ensure the existence of a thin oil film allowing the lubrication of the mechanical moving elements (pistons, connecting rod/crank, valves, ...), i.e. to protect them against wear. The lubricant simultaneously ensures several secondary roles among which serving as a tightness element, limiting the noise, or helping the evacuation of chemical impurities or deposits that may be present in the system. Lastly, in many situations, the oil is also used as a heat transfer medium for cooling the compressor. All these favourable actions of oil show that oil is definitely useful in refrigeration units. However, the presence of a lubricant is also accompanied by several drawbacks, among which the most often cited is a reduction in heat transfer coefficients in the two-phase heat exchangers (condenser and evaporator).

The presence of oil also induces changes in the flow configurations, increases pressure drops, modifies the thermodynamic equilibrium and thermodynamic properties of the refrigerant (liquid–vapour equilibrium, enthalpy, viscosity, surface tension, etc.). The question of the impact of oil in refrigeration is hence still of uttermost importance. It was also