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A study on the flow characteristics of refrigerant and oil mixture in compressor suction line

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ABSTRACT

This paper discusses the experimental results of oil retention amount and pressure drop in the gas line of refrigerant. R410A and polyvinylether oil were used as refrigerant and lubricant, respectively. The experiment was conducted under various pipe inner diameters of 14.1, 17.3 and 26.0 mm, and refrigerant mass flux and oil circulation ratio (OCR) were varied from 40 to 250 kg m^{-2} s^{-1} and 0.5–4.0%, respectively. The oil retention amount tends to increase as refrigerant mass flux decreases and OCR increases. The oil retention amount in vertical pipe was higher than that in horizontal pipe. The empirical expressions for predicting the oil retention amount and pressure drop were suggested. The mean absolute percentage errors of each expression for predicting the oil retention amount in horizontal and vertical pipes were 18.1% and 14.1%, respectively, and those for predicting the pressure drop in horizontal and vertical pipes were 22.2% and 20.1%, respectively.

Une étude des caractéristiques d'écoulement d'un mélange de frigorigène et d'huile dans une conduite d'aspiration de compresseur

Mots clés : Lubrifiant ; Rétention d'huile ; Chute de pression ; Huile PVE ; R410A ; Conduite d'aspiration

1. Introduction

A heat pump system consists of compressor, condenser, evaporator, expansion device and pipe line. Among these components, the moving part of compressor typically needs a lubrication oil to reduce friction between metal moving parts and prevent possible damage of the compressor. Although the lubrication oil can enhance the compressor performance, small amounts of oil in compressor is discharged by the refrigerant which passes through the compressor. The discharged oil circulates through the entire heat pump system

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Nomenclature

d	Diameter [m]
dP	Pressure difference [kPa]
f	Friction factor [-]
G	Mass flux [kg m^{-2} s^{-1}]
HP	Horizontal pipe
IP	Injection position
m	Mass [kg]
L	Length [m]
OCR	Oil circulation ratio [%]
P	Pressure [Pa]
Re	Reynolds number [–]
T	Temperature [°C]
VP	Vertical pipe

Greek symbols

α	Void fraction [–]
ε	Efficiency [–]
ρ	Density [kg m^{-3}]

Subscripts

1	Location for the pipe length of 1 m
2	Location for the pipe length of 2 m
3	Location for the pipe length of 3 m
G	Gas phase
i	Inner
OR	Oil retention
TEO	Total extracted oil
TIO	Total injected oil
tot	Total

with the refrigerant and some is retained in components of the heat pump system. This causes increment of pressure drop, reduction of heat transfer effect and the durability problem of the compressor. The research on the flow characteristics of refrigerant and oil mixture in heat pump system is aiming at solving these problems quantitatively.

Many studies on the flow characteristics of refrigerant and oil mixture in the heat pump system have been conducted. Shedd and Newell (1997) suggested a new optical method for measuring the oil film thickness. Their method is a non-intrusive, automated procedure for various fluids and flow configurations. Lebreton and Vuillame (2001) calibrated an ultrasonic device to measure the real time oil concentration in the liquid phase refrigerant. This research compared the oil concentration measurement from a sampling method with that from an ultrasonic probe. Luz III (2005) proposed a design of an oil concentration sensor using ultraviolet absorption spectroscopy. This research suggested an analytical model and calibration methods to develop a high accuracy oil concentration ratio sensor. Fukuta et al. (2006) developed a refractive index sensor for measuring oil circulation ratio in the liquid line. This research conducted a transient measurement of oil circulation ratio (OCR) in a real system by using the developed sensor and showed that the sensor works nicely. Guo et al. (2012) developed a criterion for oil return in various types of suction pipes. Cho (2013) suggested an optical method to measure the liquid film thickness in an annular flow regime. An experiment was conducted and the results of the liquid film thickness measurements using the optical method and the sampling method were compared. The relative measurement error was about ±20%.

Crompton et al. (2004) presented an experimental oil hold-up, void fraction and slip ratio with respect to quality. R134a/POE, R134a/PAG, R134a/alkylbenzene, R22/alkylbenzene and R410A/POE were used as test mixtures of refrigerants and oils. They detached the test section from the main frame and measured the mass of the refrigerant and oil. Sheth and Newell (2005) used R22 as a refrigerant in their study and collected oil hold-up data for an air-conditioning system. They showed the experimental oil hold up and refrigerant mass data in a compressor, a condenser, a liquid line, an evaporator and a compressor suction line. Zoellick and Hrnjak (2010) measured the oil retention amount and pressure drop at the compressor suction line with respect to refrigerant mass flux, oil circulation ratio (OCR) and pipe diameter. They used R410A and POE oil and considered the horizontal and vertical pipe configurations. They measured oil retention amount by weighing the mass of oil directly. Ramakrishnan and Hrnjak (2012) investigated the oil retention amount and pressure drop in the compressor suction line. The experimental setup and method of this research were similar to those of Zoellick and Hrnjak (2010). Unlike Zoellick and Hrnjak (2010), Ramakrishnan and Hrnjak (2012) focused on the low refrigerant mass flux condition and used R134a, R1234yf and R410A as refrigerants and POE oil as a lubricant.

Mehendale and Radermacher (2000) studied the oil transport with vapor, liquid and two phase refrigerant. This research showed, both experimentally and theoretically, critical mass flow rate for preventing oil film flow reversal in a vertical pipe. An experiment on flow visualization was also conducted as well. The momentum equation for a liquid film of the annular flow and an empirical correlation for interfacial friction factor were used to conduct theoretical analysis. The results of the experiment and the theoretical analysis were compared and the accuracy of theoretical model was good. Hwang et al. (2000) presented an experimental method to measure the oil film thickness and to observe the flow pattern in a vertical upward pipe. The flow pattern of refrigerant and oil mixture was churn or annular flow in the vertical upward flow and the oil film thickness data was presented. Lee (2003) presented experimental oil retention data and theoretical models for computing the oil retention amount in each component of air conditioning system. Carbon dioxide and polyalkylene glycol (PAG) were used as refrigerant and oil, respectively. The oil retention amount was measured by an oil injection and extraction device. Cremaschi (2004) also presented experimental oil retention data and theoretical models for computing the oil retention amount in each component of an air conditioning system. The experimental setup was similar to Lee's experiment (2003). An oil injection and extraction device was used for measuring oil retention. R22/BWMO (Blended white mineral oil), R410A/BWMO, R410A/POE, R134a/POE and R134a/PAG were used as refrigerant and oil mixtures. Kim and Kim (2013) studied the oil retention