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Comparison of the heating performance of an inverter-driven heat pump system using R410A vapor-injection into accumulator and compressor

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ABSTRACT

In cold regions, a refrigerant injection technique has been used for enhancing heating capacity and avoiding the excessively high discharge temperature which is detrimental to reliability of a heat pump system. The heat pump system in this study having an additional refrigerant injection line into the accumulator was tested to compare with the heating performances of classic vapor-injection cycle. The heat pump system was designed to inject vapor refrigerant into the compressor and accumulator, selectively. Although the refrigerant injection into the compressor (classic vapor-injection cycle) was more effective to enhance heating capacity, the refrigerant injection into the accumulator could decrease discharge temperature and increase both heating capacity and COP slightly at the condition of high compressor frequency. In terms of mass balance, the injection stream into the accumulator substituted the evaporator's suction stream flowing to the compressor, so the mass flow rate of condenser was not increased as much as the amount of injected refrigerant.

Comparaison de la performance en mode chauffage d'un système à pompe à chaleur utilisant l'injection de vapeur de R410A dans l'accumulateur et le compresseur

Mots clés : Accumulateur ; Pompe à chaleur ; Injection ; Performance ; R410A

1. Introduction

In recent years, a vapor-injection (VI) technique has been used to enhance the performance of a heat pump system for tropical and cold regions. The VI technique enables wide application of heat pump system especially in severe operating conditions by increasing the efficiency of compression process. A cycle using the VI technique injects saturated or super-heated vapor into a compressor's injection port. The VI cycles are categorized by the methods to acquire the saturated

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Nomenclature

AHRI	Air-Conditioning, Heating, and Refrigeration Institute
AMCA	Air Movement and Control Association
ANSI	American National Standards Institute
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
AVI	accumulator-vapor-injection
COP	coefficient of performance
CVI	compressor-vapor-injection
DB	dry-bulb
FTVI	flash tank vapor-injection
h	enthalpy [kJ kg^{-1}]
IHX	internal heat exchanger
IHXVI	internal heat exchanger vapor-injection
LI	liquid-injection
$\dot{m}$	mass flow rate [g s^{-1}]
MFM	mass flow rate meter
P	pressure [kPa]
Q	capacity [kW]
R	injection ratio [%]
RH	relative humidity [%]
T	temperature [°C]
V	volume flow rate [m^3 s^{-1}]
VI	vapor-injection
W	total power input [kW]
WB	wet-bulb

Greek symbol

ρ	density [kg m^{-3}]

Subscripts

air	airside
cond	condenser side
evap	evaporator side
heat	heating condition
in	inlet
inj	injection stream side
out	outlet

or super-heated vapor refrigerant being injected. One is flash tank vapor-injection (FTVI) cycle and the other is internal heat exchanger vapor-injection (IHXVI) cycle. Schematics of two typical VI cycles are illustrated in Fig. 1. The FTVI cycle uses a flash tank to separate liquid and vapor from the expanded two-phase refrigerant; whereas, the IHXVI cycle uses internal heat exchangers to vaporize the two-phase refrigerant. In the IHXVI cycle, the injection stream sub-cools the main stream at the internal heat exchangers. The IHXVI cycle usually shows a wider operating range than the FTVI cycle, because controllability of mass flow rate of injection stream into compressor is better than that of the FTVI cycle (X. Wang et al., 2009; Xu et al., 2011).

The liquid-injection (LI) cycle injects liquid refrigerant into the injection port or suction port of compressor as shown in Fig. 2. Although the wet compression occurs, it has been used for decreasing extraordinarily high discharge temperature of the compressor to assure reliable operation of the compressor and to prevent degradation of the refrigerant and oil in a system. Additionally, the liquid refrigerant injection technique has been also applied in commercial heat pump system to improve the cycle performances, because the idea of refrigerant injection technique can enhance heating and cooling capacity by increasing the mass flow rate of condenser (Dutta et al., 2001; Cho et al., 2003).

Heating and cooling performances of the classic VI and LI cycles have been evaluated. Ma and Zhao (2008) compared the performance of a heat pump system having a flash tank with a system having a sub-cooler. They showed better efficiency in the system with a flash tank than the system with a sub-cooler at low ambient temperature of −25 °C. B. Wang et al. (2009) suggested the model to optimize the refrigeration system using gas-injected scroll compressor with proposition of universal control and design methods. X. Wang et al. (2009) investigated the performance variation of two-stage heat pump system with vapor-injected scroll compressor using

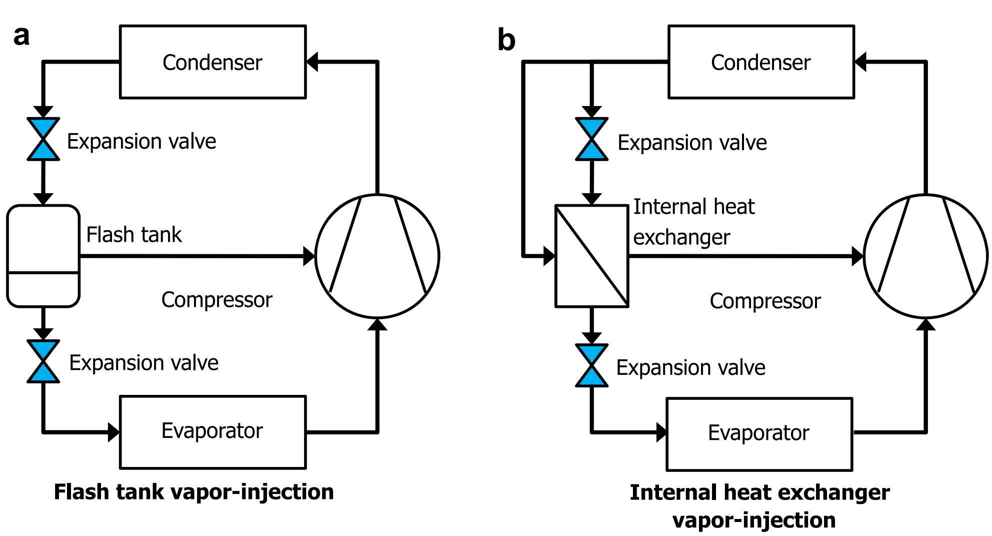

Fig. 1 – Schematics of classic vapor-injection cycles.