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Review

Recent advances in vapor compression cycle technologies

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ABSTRACT

This paper comprehensively reviews the recent studies on advanced vapor compression cycle technologies. These technologies are categorized in three groups: subcooling cycles, expansion loss recovery cycles, and multi-stage cycles. The subcooling cycle research is focused on a suction-line heat exchanger, thermoelectric subcooler and mechanical subcooler. The expansion loss recovery cycles are mainly focused on utilizing an expander and ejector. The multi-stage cycle research includes a vapor or liquid refrigerant injection cycle, two-phase refrigerant injection cycle. All these advanced vapor compression cycle technology options are reviewed, and their effects are discussed. In recent years, the research and development have been made to improve the performance of the VCC. This paper presents the improved cycle options and their comprehensive review. From the review results, several future research needs were suggested.

Récents progrès dans les technologies de cycle à compression de vapeur

Mots clés : Cycle à compression de vapeur ; Sous refroidissement ; Ejecteur ; Détendeur ; Injection ; Cycle à saturation

1. Introduction

Energy saving has become an important issue due to the limited energy resources and ever increasing demands. In the US, the energy use by a space cooling, space heating, water heating, and refrigeration represents about 76% of total energy consumption for the residential buildings (Department of Energy, 2015), in which energy systems are mainly relying on a vapor compression cycle (VCC). This VCC has inherent thermodynamic losses as compared to an ideal reverse Carnot cycle. Those are thermodynamic losses associated with single phase

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Nomenclature

Symbols

c_p	specific heat capacity
Δq	refrigeration effect
h	specific enthalpy
P	pressure
Q	heat transfer capacity
s	specific entropy
T	temperature

Subscripts

c	critical
L	saturated liquid
vap	vaporization

Acronyms

ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
COP	coefficient of performance
DESC	double expansion subcooler
DOE	Department of Energy
EEV	electric expansion valve
FTSC	flash tank and subcooler
IHX	internal heat exchanger
PR	pressure ratio
SLHX	suction line heat exchanger
TXV	thermostatic expansion valve
VCC	vapor compression cycle

gas compression and isenthalpic expansion. The first loss results in high discharge refrigerant temperature, high compression work, and high condenser heat release. The second loss results in large throttling losses and low refrigeration capacity. To reduce these thermodynamic losses, many researchers investigated the improved cycle options, such as subcooling cycles (suction line heat exchanger, thermoelectric subcooler, and mechanical subcooler), expansion loss recovery cycles (expander and ejector), multi-stage cycles (a vapor or liquid refrigerant injection cycle, two-phase refrigerant injection cycle and saturation cycle). In this paper, each cycle options are reviewed in terms of performance improvement.

2. Subcooling cycles

Typically, the state of the refrigerant entering the expansion device in the VCC is subcooled liquid, so that liquid can be expanded in the expansion device and provides a stable refrigerant flow rate. When the degree of subcooling is increased, the typical expansion process, the isenthalpic process approaches to the isentropic process as shown in Fig. 1. Moreover, increased subcooling degree can increase the refrigeration effect (Δq) and potentially improve the coefficient of performance (COP). Any other heat sink of appropriate temperature could be used to increase subcooling, but the following three methods are mainly applied; a suction line heat exchanger (SLHX), mechanical subcooler, and thermoelectric subcooler.

2.1. *Suction line heat exchanger*

The use of the SLHX has been widely applied to VCCs. The SLHX or internal heat exchanger (IHX) is often employed as a means for protecting system components. The SLHX ensures subcooled liquid refrigerant to be supplied to the expansion device inlet and superheated vapor refrigerant to the compressor inlet. Fig. 2 shows the schematic diagram and P–h diagram of the vapor compression cycle with the SLHX. The SLHX is located between the condenser outlet and expansion valve inlet and between the evaporator outlet and compressor inlet. Cold refrigerant from the suction line is used to cool down the refrigerant at condenser outlet. Reduced refrigerant temperature of the condenser outlet decreases the enthalpy of the evaporator inlet. In turn, this increases the evaporator capacity. However, the increased temperature of the compressor inlet decreases the compressor efficiency, which degrades the system performance. The increase of the suction temperature decreases the compressor volumetric efficiency which is proportional to the inverse of the suction temperature. Therefore, these two aspects should be considered in the application with the SLHX. Domanski

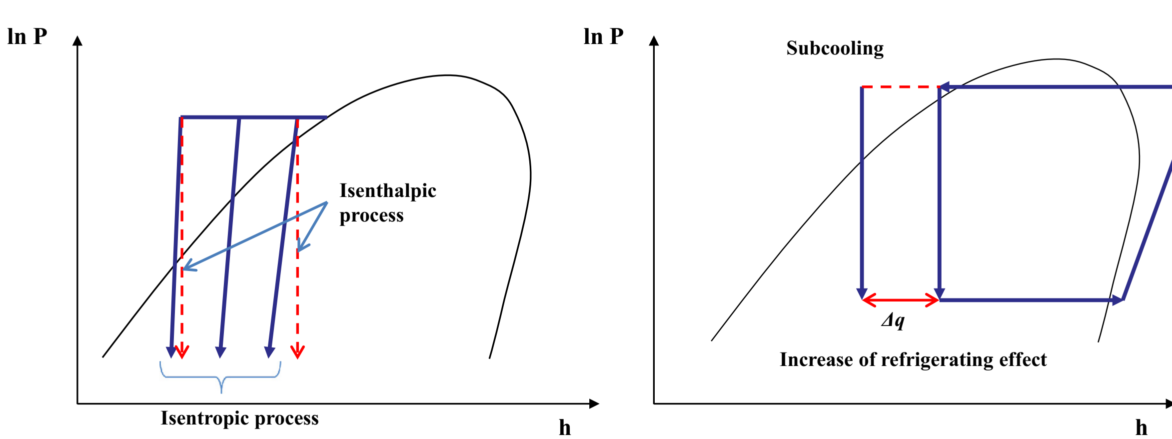

Fig. 1 – P–h diagram of the vapor compression cycle with liquid subcooling.