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A novel ejector-absorption combined refrigeration cycle

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ABSTRACT

This paper presents a novel ejector-absorption combined refrigeration cycle. When the temperature of the heat source is high enough, this cycle will work as a double-effect cycle. If the temperature of the heat source is lower than required temperature of heat source used to drive conventional double-effect absorption refrigeration cycle but much higher than required temperature of heat source used to drive conventional single-effect absorption refrigeration cycle, the *COP* of new cycle will also be higher than that of conventional single-effect absorption refrigeration cycle. Simulation results show that the *COP* of the cycle is 30% higher than that of the conventional single-effect absorption refrigeration cycle at some working conditions even in the later case.

Nouveau cycle frigorifique associant un éjecteur et l'absorption

Mots clés : Système frigorifique ; Système à absorption ; Système à éjecteur ; Conception ; Simulation ; Performance

1. Introduction

Conventional compression refrigerators need to consume a great amount of electricity. IIR has estimated that approximately 15% of all the electricity produced in the whole world is employed for refrigeration and air-conditioning processes of various kinds, in addition, the refrigerants used in the compression refrigerator such as CFCs, HCFCs have caused serious environmental problems such as ozone depletion and global warming (Santamouris and Argiriou, 1994; Wimolsiri). The absorption refrigeration cycle that can use waste heat and solar thermal energy as driven force has attracted more and more attentions (Srikhirin et al., 2006; Fan et al., 2007). GAX absorption refrigeration cycle and multiple-effect absorption refrigeration cycles such as double-effect absorption refrigeration cycle, triple-effect absorption refrigeration cycle were proposed to improve the performance of the absorption refrigeration cycle (Altenkirch and Tenckhoff, 1911; Vliet et al.,

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Nomenclature

COP	coefficient of performance
m	mass flow rate, kg s^{-1}
h	specific enthalpy, kJ kg^{-1}
p	pressure, kPa
q	heat exchanged, W
μ	entrainment ratio
x	concentration, kg kg^{-1}
η	relative increasing ratio
w_p	pump power, W
t	temperature, °C
φ_1	velocity coefficients of primary nozzles
φ_2	velocity coefficients of mixing chamber
φ_3	velocity coefficients of diffuser
φ_4	velocity coefficients of mixing chamber entrance
k	adiabatic exponent
λ	gas reduced isentropic velocity (the ratio of gas isentropic-flow velocity and critical velocity)
Π	relative pressure (the ratio of isentropic-flow pressure and stagnation pressure in a given section)
e	gas reduced mass–velocity (the ratio of isentropic mass–velocity and critical mass–velocity)
u	velocity, m s^{-1}
v	specific volume, m^3 kg^{-1}
f	area of cross section, m^2

Subscripts

sin	single-effect cycle
new	new cycle
1, 2,...	state points
e	evaporator
gh	high-pressure generator
gl	low-pressure generator
r	refrigerant
con	condenser
s	heat source
ab	absorber
p	working fluid
h	secondary fluid
c	mixed fluid
lim	limit state

1982; Devault and Marsala, 1990). Although the COP of these cycles are much higher than that of conventional single-effect cycle, the grade of heat source used to drive these cycles are much higher than that of heat source used to drive conventional single-effect cycle. There is an obvious blank between the grade of heat source used to drive these cycles and that of heat source used to drive conventional single-effect cycle. To make efficient use of the heat at this grade, Erickson (1991), Inoue (2003) and Wang and Zheng (2009) proposed several configurations of one and half effect absorption refrigeration cycle by combining single-effect cycle with two-stage cycle. The heat input to the combined cycles is used to drive one sub-cycle, part of the heat rejected by this sub-cycle is used to drive another sub-cycle to generate additional refrigerant vapor, so the COP of these cycles are much higher than that of the conventional single-effect cycle. Nevertheless, the refrigeration systems with the cycles are complicated and the initial investment in system components will obviously increase (Wang et al., 2000). Ejector is regarded as an attractive component used to improve the performance of the absorption refrigeration cycles (Riffat et al., 2005; He et al., 2009). Gu and Yu (1993) proposed an ejector-absorption combined refrigeration cycle, high-pressure vapor from generator injects part of the vapor out from evaporator to condensing pressure, so the injected vapor does not need to be separated from generator and the COP of this cycle is much higher than that of the conventional single-effect cycle. Although its COP is much lower than that of the double-effect cycle because of the high compression ratio and low efficiency of the ejector, its structure is much simpler (Jiang et al., 2002). Kuhlenschmidt (1973) proposed a novel ejector-absorption combined refrigeration cycle, the cycle employs two-stage generators similar to that used in a double-effect absorption system. Unlike the double-effect absorption system, the vapor from low-pressure generator is used to inject the vapor from the evaporator to a higher pressure, so the pressure of the low-pressure generator can be lower than condensing pressure and the grade of heat source can be lower than that of heat sources used to drive the double-effect absorption cycle. Although it has a higher COP than that of the conventional single-effect cycle, relative increasing ratio cannot be high because of high entrainment ratio and low efficiency of ejector. To make efficient use of high-grade heat with a simple structure refrigeration system, this paper proposes a novel ejector-absorption combined refrigeration cycle based on parallel flow double-effect absorption refrigeration cycle.

2. Cycle description

The proposed cycle is shown in Fig. 1. Figs. 2 and 3 show p–t diagram of the solution and p–h diagram of the refrigerant respectively. H_2O/LiBr is used as working pair in this paper. The working principle of the cycle is described as follows. The water vapor (1) is separated from the solution in the generator. Part of

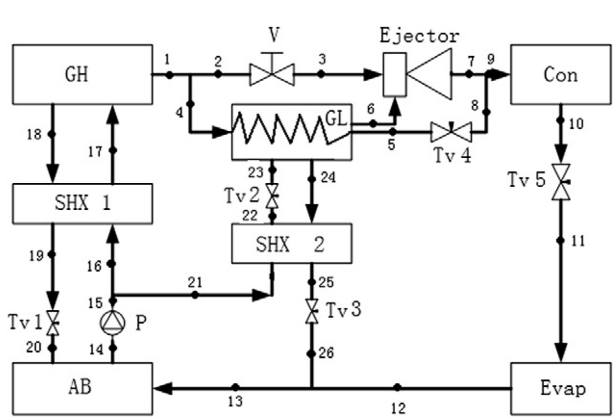

Fig. 1 – Schematic diagram of a new ejector-absorption combined refrigeration cycle.