



Performance improvement of an ejector cooling system with thermal pumping effect (ECSTPE) by doubling evacuation chambers in parallel



Sheng Zhang^{a,b}, Yong Cheng^{c,*}

^a Department of Architecture and Civil Engineering, City University of Hong Kong, Kowloon, Hong Kong, China

^b Institute of Refrigeration and Cryogenics, Zhejiang University, Hangzhou, China

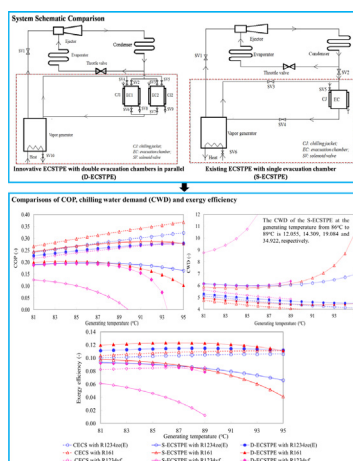
^c Faculty of Urban Construction and Environmental Engineering, Chongqing University, Chongqing, China

HIGHLIGHTS

- Innovative D-ECSTPE effectively mitigates waste problems of existing S-ECSTPE.
- Performance improvement mechanisms of D-ECSTPE are identified.
- Performance improvement regarding COP, CWD and exergy efficiency is evaluated.
- Promising environment-friendly refrigerants are investigated for D-ECSTPE.
- Further performance improvement methods are discussed.

GRAPHICAL ABSTRACT

The existing ejector cooling system with thermal pumping effect (S-ECSTPE) can operate without consuming electricity, but directly chills high-pressure vapor with high temperature (HPVHT) in its single evacuation chamber, causing waste problems of thermal energy and chilling water. For an innovative ECSTPE with double evacuation chambers in parallel (D-ECSTPE), HPVHT in one evacuation chamber is reused to pre-pressurize refrigerant in the other evacuation chamber. It is identified that both thermal energy transfer and mass transfer of the HPVHT during the pre-pressurization help to mitigate the waste problems. Case studies showed that compared to the S-ECSTPE, the D-ECSTPE with environment-friendly refrigerants R1234yf, R161 and R1234ze (E) reduced the wasted thermal energy and chilling water by at least 66.83% and 81.14%, respectively. As a result, the COP increased by at least 19.38% and the chilling water demand (CWD) decreased by at least 13.86%. The exergy efficiency of the D-ECSTPE was generally larger than those of the S-ECSTPE and the conventional ejector cooling system (CECS). Ideally, further increasing the number of parallel evacuation chambers could finally remove all the wasted thermal energy and chilling water, as well as gaps of COP and CWD between the S-ECSTPE and the CECS.



ARTICLE INFO

Article history:

Received 12 September 2016

Received in revised form 15 November 2016

ABSTRACT

The existing ejector cooling system with thermal pumping effect (S-ECSTPE) operates without consuming electricity, but has waste problems of thermal energy and chilling water. An innovative ECSTPE with double evacuation chambers in parallel (D-ECSTPE) can effectively mitigate these waste problems. The high-

* Corresponding author.

E-mail address: yongcheng6@cqu.edu.cn (Y. Cheng).

Accepted 24 November 2016

Keywords:

Performance improvement
Ejector cooling
Thermal pumping effect
Double paralleled evacuation chambers
Environment-friendly refrigerants

pressure vapor with high temperature (HPVHT) in one evacuation chamber, which is directly chilled by chilling water in the S-ECSTPE, is reused in the D-ECSTPE to pre-pressurize refrigerant in the other evacuation chamber. Performance improvement mechanisms of the D-ECSTPE are explained from both thermal energy transfer and mass transfer of the HPVHT. Case studies showed that the severer the waste problems of the S-ECSTPE, the greater COP increase and reduction in chilling water demand achieved by the D-ECSTPE. Also, the D-ECSTPE performed well with environment-friendly refrigerants (e.g., R1234yf, R161 and R1234ze(E)), which were unsuitable for the S-ECSTPE due to severe waste problems. Compared to the S-ECSTPE, the D-ECSTPE with R1234yf, R134a, R161, R1234ze(E), R1234ze(Z), R1233zd(E), R365mfc and R141b increased the COP by at least 49.44%, 26.30%, 22.33%, 19.38%, 4.39%, 3.55%, 2.14% and 1.77%, respectively, and reduced the chilling water demand by at least 29.77%, 18.04%, 15.55%, 13.86%, 3.36%, 2.76%, 1.72% and 1.37%, respectively. In all cases, the D-ECSTPE reduced the wasted thermal energy and chilling water of the S-ECSTPE by at least 65.83% and 81.14%, respectively, and its exergy efficiency was generally superior to those of the S-ECSTPE and conventional ejector cooling system. An additional increase in the number of paralleled evacuation chambers can further improve the system performance.

© 2016 Elsevier Ltd. All rights reserved.

Nomenclature

h	specific enthalpy (kJ/kg)
m	mass flow rate (kg/s)
E	exergy (kJ)
M	mass (kg)
Q	thermal energy/electricity (kJ)
t	time (s)
Vol	volume (m ³)
w	entrainment ratio (–)

Abbreviations

COP	coefficient of performance (–)
CWD	chilling water demand (–)
CECS	conventional ejector cooling system
ECSTPE	ejector cooling system with thermal pumping effect
S-ECSTPE	ECSTPE with single evacuation chamber
D-ECSTPE	ECSTPE with double evacuation chambers in parallel
T-ECSTPE	ECSTPE with three evacuation chambers in parallel
HPVHT	high-pressure vapor with high temperature
SV	solenoid valve

Greek symbols

γ	initial ratio (–)
----------	-------------------

Subscripts

c	condenser
e	evaporator
ev1	evacuation chamber 1
ev2	evacuation chamber 2
g	generator
G	gaseous refrigerant
L	liquid refrigerant
mp	mechanical pump
pf	primary fluid
r	reference environment
vg1	HPVHT used as primary fluid
vg2	HPVHT used for pressurization
vg3	HPVHT used for feeding back
i	cooling stage
ii	pre-pressurization sub-process
iii	pressurization/chilling sub-process
iv	feeding back sub-process
1	beginning of the pre-pressurization sub-process
2	beginning of the pressurization/chilling sub-process
3	beginning of the feeding back sub-process

1. Introduction

Ejector cooling systems are sustainable refrigeration technologies [1]. Conventional ejector cooling systems (CECSs) differ from traditional mechanical cooling systems by replacing the mechanical compressors with ejectors. Mechanical compressors consume significant amounts of electricity and cause air pollution [2]. In contrast, ejectors can be driven by low-grade thermal energy, which mitigates energy and environmental problems [1]. Due to the absence of mechanical compressors, the circulation pumps in CECSs are the only moving part needing frequent maintenance and the only mechanical part consuming electricity [3]. Circulation pumps are used to feed part of the liquid refrigerant from the condenser back to the generator, where the liquid refrigerant is heated into high-pressure vapor with high temperature (HPVHT) and used as driving force of the CECS [4]. There are four different methods for eliminating circulation pumps from ejector cooling systems: the bi-ejector cooling system [5,6], the heat pipe/ejector cooling system [7,8], the gravitational ejector cooling system [9,10], and

the ejector cooling system with thermal pumping effect (ECSTPE) [11,12]. Ejector cooling systems that lack circulation pumps can operate without electricity consumption and have a longer lifespan [3]. The ECSTPE, in particular, is the most promising refrigeration technology using a pump-free ejector cooling system, which has been proved to be practical by both numerical simulations and experimental studies [13,14].

However, compared to the CECS, the ECSTPE has inherent waste problems of thermal energy and chilling water [11,13,15,16]. The characteristic of the existing ECSTPE is that only a single evacuation chamber is used to couple with the vapor generator in one set of the multi-function generator (S-ECSTPE) (Fig. 1) [13]. The HPVHT generated from the vapor generator flows into the evacuation chamber to pressurize the liquid refrigerant, and then feeds the pressurized liquid refrigerant back to the vapor generator. Afterwards, the evacuation chamber filled with HPVHT is directly chilled by the chilling water. As a result, the thermal energy in the HPVHT is discarded and more chilling water is required. Huang et al. [11] proposed an S-ECSTPE in which the vapor generator

Download English Version:

<https://daneshyari.com/en/article/4916709>

Download Persian Version:

<https://daneshyari.com/article/4916709>

[Daneshyari.com](https://daneshyari.com)