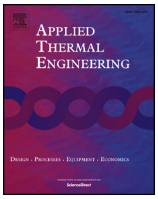
Applied Thermal Engineering 140 (2018) 43–50

Contents lists available at ScienceDirect

Applied Thermal Engineering

journal homepage: www.elsevier.com/locate/apthermeng



Research Paper

Performance study of an enhanced ejector refrigeration cycle with flash tank economizer for low-grade heat utilization

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HIGHLIGHTS

- An enhanced ejector refrigeration cycle with flash tank economizer is presented.
- The performances of the presented cycle are compared with those of the basic cycle.
- The presented cycle shows higher COP and cooling capacity under given conditions.
- There exists an optimal inlet temperature of economizer for maximum performances.

ARTICLE INFO

Keywords:
Ejector
Ejector refrigeration
Flash tank economizer
Performance

ABSTRACT

This paper presents an enhanced ejector refrigeration cycle (EERC) by introducing a flash tank economizer and an auxiliary ejector to improve the performance of a conventional ejector refrigeration cycle (CERC). The proposed cycle could increase the overall entrainment ratio of the ejectors, the cycle cooling capacity and COP due to reduction of flash gas delivered to the evaporator. Thermodynamic performances of the EERC using R134a and R600a are evaluated in detail and compared with those of the CERC using the thermodynamic first law. Calculation results show that there is an optimal inlet temperature of flash tank economizer in EERC. The maximum COPs of EERC with R134a and R600a increase by 10.7% and 9.9% compared to the CERC, respectively. Also, the cooling capacities of EERC have the same improvement values. Furthermore, the EERC shows better performances under a higher evaporating temperature. The obtained results indicate that the EERC would be beneficial to the development of ejector refrigeration technology.

1. Introduction

Ejector refrigeration is a thermally driven technology that has been used for cooling applications for many years [1–4]. Compared to other thermally driven refrigeration systems, ejector refrigeration systems have some advantages such as their simplicity, reliability, low installation and operational costs [5]. However, their major drawbacks are that they are less efficient than vapor compression systems and other thermally driven technologies, as well as they require a restricted range of operating conditions. Therefore, significant efforts have been devoted to the development of ejector refrigeration systems. Especially, the system performance enhancement draws more attentions to research and development needs.

As well known, ejector refrigeration systems can operate with various working fluids. However, the performance of an ejector refrigeration system is directly dependent on the used working fluid for the required operating conditions. Thus, many works have been carried out to evaluate the effects of working fluids on the ejector refrigeration system performance, including the suitable working fluid selections [6,7], advanced exergy analysis method application [8], and the assessments of environmentally friendly working fluids [9,10].

In order to improve the performance of ejector refrigeration systems, some theoretical or experimental studies have been carried out regarding the optimization of the ejector geometric parameters. Khalil et al. [11] developed a mathematical model to design R134a ejector, and determined the optimum ejector dimensions. Varga et al. [12] carried out experimental and numerical analysis of a variable area ratio steam ejector, and confirmed that its operation is beneficial. Yan et al. [13] employed a calibrated CFD model to evaluate the influence of 6 key ejector geometry parameters on the performance of an air-cooled ejector cooling system, and indicated the performance improvement can be achieved by using the optimization parameters such as area ratio, nozzle exit position and diffuser length. Zhang et al. [14] also employed CFD and experiment methods to indicate that the geometry

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https://doi.org/10.1016/j.applthermaleng.2018.05.038
Received 20 November 2017; Received in revised form 5 April 2018; Accepted 9 May 2018

Nomenclature

COP	coefficient of performance
h	enthalpy ($J \cdot kg^{-1}$)
$\dot{m}$	mass flow rate ($kg \cdot s^{-1}$)
P	pressure (Pa)
$\dot{Q}$	heat flow rate (W)
s	entropy ($J \cdot kg^{-1} \cdot K^{-1}$)
t	temperature (°C)
q	vapor quality
$\dot{W}$	power (W)

Greek symbols

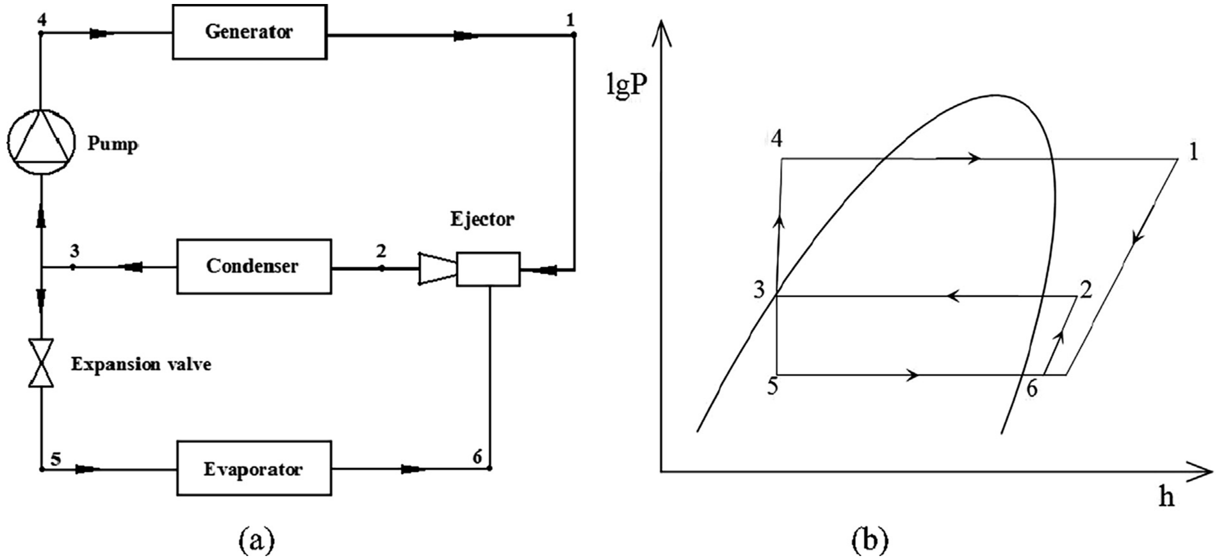
u	velocity ($m \cdot s^{-1}$)
μ	entrainment ratio
η	efficiency

Subscripts

c	condenser
d	diffuser section of ejector
e	evaporator
eje	ejector
fte	flash tank economizer
g	generator
m	mixing section of ejector
mf	mixed fluid
n	nozzle
n1	inlet of nozzle
n2	outlet of nozzle
p	pump
pf	primary fluid
s	isentropic procedure
sf	secondary fluid

parameters had an important influence on the performance of the ejector and should be designed properly to get a better performance. Chesi et al. [15] analyzed a complex system in which a solar powered ejection cycle is coupled with a vapor compression cycle, and showed that the performance of the complex system can be enhanced by using the ejection machine to subtracting heat from the condenser vapor compression machine. Chen et al. [16] theoretically studied a hybrid ejector and CO_2 vapor compression system for vehicles and indicated that the better system performance could be achieved for CO_2 VC subsystem. Pereira et al. [17] experimentally investigated a variable geometry ejector using R600a as working fluid, and showed that using a variable geometry ejector benefits the improvement in COP of the ejector refrigeration cycle. Overall, the adjustable ejector performs better than the conventional constant area ejector [18].

On the other hand, many researchers have focused on the improved cycle options for enhancing the performance of the ejector refrigeration systems [19,20]. More recently, Zhao et al. [21] presented thermodynamic investigation of a booster-assisted ejector refrigeration system, and stated that both COP and entrainment ratio can be increased by increasing booster outlet pressure. Tan et al. [22] studied an auto-cascade ejector refrigeration cycle with refrigerant R32/R236fa blend, and indicated that the cycle can provide a new way to obtain lower refrigeration temperature utilizing low-grade thermal energy. Ding et al. [23] performed a numerical study and design of a two-stage ejector, and showed that the proposed two-stage ejector can be used for subzero refrigeration applications. He et al. [24] performed initial ratio optimization for the ejector cooling system with thermal pumping effect and demonstrated that the optimal TLCS (time length of cooling stage) control method effectively improves the system performance. Allouche et al. [25] simulated an integrated solar-driven ejector cooling system including the PCM storage unit using the TRNSYS software package, and showed that the application of PCM contributes to improved cooling cycle COP. Zhang and Cheng [26] proposed a new ejector cooling system with thermal pumping effect, and theoretically revealed that the system achieves significant performance improvements, especially with the environment-friendly refrigerants. Butrymowicz et al. [27] conducted theoretical and experimental investigations of the efficiency enhancement due to internal heat transfer in ejection refrigeration system and found that the application of the internal heat exchanger leads to the improvement of COP up to 20%. Carrillo et al. [28] carried out a comparison analysis on different configurations of ejector cooling systems, and the results presented have shown a qualitative analysis to decide the most favorable cycle and working conditions for a desired application. Recently, Chen et al. [29] experimentally investigated on a two-stage ejector refrigeration system driven by two heat sources and indicated that it is capable of supplying more



(a) (b)

Fig. 1. A conventional ejector refrigeration cycle (CERC) system (a); The corresponding thermodynamic cycle on a pressure-enthalpy diagram (b).