

Experimental performance study of sorption refrigerators driven by waste gases from fishing vessels diesel engine



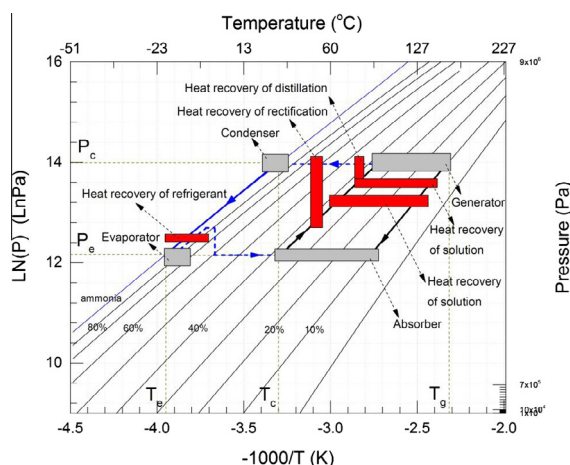
Lu Zisheng*, Wang Ruzhu

Institute of Refrigeration and Cryogenics, Key Laboratory for Power Machinery and Engineering of M.O.E, Dongchuan Rd. 800#, School of Mechanical Engineering, Shanghai Jiao Tong University, Shanghai 200240, China

HIGHLIGHTS

- The pressure-heat recovery can improve sorption performance.
- Multi-step heat recovery ammonia water sorption refrigerator has highest $q_{e,v}$.
- Small-channel exchanger is used to solve the problem of the performance degradation.
- Sorption refrigerator has no problem of corrosion if it is heated indirectly.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:

Received 3 February 2016

Received in revised form 30 March 2016

Accepted 24 April 2016

Available online 29 April 2016

Keywords:

Heat recovery

Adsorption

Absorption

Refrigerator

Fishing vessels

Waste gases

ABSTRACT

This paper presents different sorption refrigerator technologies for fishing vessels. The pressure-heat recovery and multi-step heat recovery processes are studied to improve the Coefficient of Performance (COP). Small-channel heat transfers are used to solve the problem of the performance degradation caused by fishing vessels' shaking. The results show that the multi-step heat recovery ammonia water sorption refrigerator has the highest refrigeration capacity per unit volume of 15.4 kW/m³.

© 2016 Elsevier Ltd. All rights reserved.

1. Introduction

With the economic and social development, fishing vessels play a more and more important role in China, which population rises

quickly and now the number has attained 1.06 million. However, the marine fishing is an energy-intensive industry due to the usage of heavy oil for compression refrigeration system. It may cause not only the problem of energy shortage, but also the problem of emission of pollutants and greenhouse gases, because the sulfur content of marine fuel oil is usually 100 times higher than that in normal

* Corresponding author.

E-mail address: zslu@sjtu.edu.cn (Z. Lu).

Nomenclature

<i>COP</i>	Coefficient of Performance
<i>SCP</i>	Specific Cooling Power (W/kg)
<i>q</i>	cooling/heating power (kW)
<i>T</i>	temperature (°C)
<i>m</i>	mass flow (kg/s)
<i>C</i>	the specific heat (kJ/(kg °C))
<i>V</i>	volume (m ³)

Subscripts

<i>e</i>	cooling
<i>c</i>	chilled water
<i>i</i>	inlet
<i>o</i>	outlet
<i>h</i>	heating
<i>w</i>	water
<i>v</i>	volume

bus fuel oil. Moreover, in the context of high oil prices, it is necessary to save energy for fishing vessels.

One feasible way to solve this problem is to use the waste heat from exhaust gases of engines to drive sorption refrigeration system, because the thermally-driven cooling systems can be driven by the waste exhausted gases and they only use natural refrigerant, without the problems of the environmental pollution and greenhouse gases emission.

Many researchers have studied the sorption refrigeration technologies. The main research activities are focused on adsorbents, advanced cycles, heat & mass transfer and valve-less design, etc. The most commonly used adsorption working pair is silica gel–water, zeolite–water and activated carbon–ammonia, etc. For example, one silica gel–water adsorption cooling system was investigated by I.I. El-Sharkawy. The test results show that the system with hot water buffer storage has less fluctuating cooling energy production compared to that of the system without hot water buffer storage. Moreover, the system with hot water buffer storage generates higher cooling capacity at the beginning and the end of the cycle [1]. D.C. Wang tested many different silica gel samples according to their application surroundings in silica gel–water adsorption cooling systems. The experimental results indicated that the adsorption capacity of the silica gel was influenced by many factors. But pollution by solid particulates was the primary factor to decline the adsorption capacity [2]. In general, the working pair of silica gel–water cannot be used in the fishing vessel's refrigeration system, because the evaporating temperature cannot attain negative value.

Another commonly used adsorbent is zeolite. D. Karamanis investigated the water vapor adsorption properties of raw and hydrothermally treated fly ashes with NaOH. Samples were characterized by elemental analysis, X-ray diffraction, thermogravimetry, reflectance measurements and water vapor adsorption isotherms, etc. Moreover, the water adsorption properties and the associated temperature variations were studied. The results show that the zeolitic materials prepared from the fly ash samples have a significant potential for solar cooling applications [3]. A thermally powered adsorption cooling prototype using natural zeolite–water as working pair has been designed and built by İ. Solmuş. The results show that the mean COP (Coefficient of Performance) and SCP (Specific Cooling Power) is about 0.25 and 6.4 W/kg, respectively. In addition, research has been carrying out a novel adsorbent bed to improve the system performance. Solar powered adsorption cooling systems using natural zeolite–water as working pair could be a reliable and economical solution to meet this increasing cooling demand partially. The results show that the cyclic adsorption capacity varies with different condenser, evaporator and adsorbent temperatures. The maximum adsorption capacity of natural zeolite is only 0.12 kg/kg [4,5]. M. Aung successfully built and experimentally investigated the performance of zeolite adsorption cooling system. The hot water inlet temperatures range from 55 to 80 °C while cooling water and chilled water inlet temperature were maintained at 29.5 °C and 12 °C, respectively. It is found out that

the zeolite adsorption cooling system could be driven with a very low grade waste heat as low as 55 °C. Such a very low waste heat driven system could help not only to recover the energy from the exhaust gas emanating from the industries but also to reduce CO₂ emission to the environment [6]. However, the cyclic adsorption capacity is too low in these above systems due to the using of pure physical adsorbent of zeolite.

Activated carbon–ammonia is also an attractive working pair in adsorption cooling systems. E.E. Anyanwu and other researchers investigated a solid adsorption refrigerator, using activated carbon as adsorbent and methanol or ammonia as adsorbate. The results show that the COP or solar COP varies with the working conditions. The COP is 0.05–0.09, 0.02, 0.09 and 0.10 in [7–10] and the solar COP is 0.18 and 0.07 in [11,12], respectively. L. Gordeeva analyzed the factors dominating sorption dynamics in an activated carbon–methanol chiller and made practical recommendations on optimizing the specific cooling power. The notable findings show that the initial adsorption rate is a linear function of the temperature jump/drop applied; the adsorption dynamics is invariant with respect to the ratio of the heat transfer area to the adsorbent mass [13]. However, one of the most serious problems facing of these adsorption cooling systems is its poor heat and mass transfer performance.

Therefore, many novel designs of heat transfers in adsorption and absorption cooling systems are investigated. C.H. Chen investigated silica gel circulating fluidized beds for the dehumidification of air conditioning systems. The results show that single-tube fluidized bed can increase adsorption/desorption performance by 20% and lower the pressure drop by about 30%. The new bed system has the highest Energy Factor 0.554 kg/kW h [14]. Dynamic optimization of adsorbent-heat exchangers represents a key issue for the broader diffusion of adsorption cooling and heating technologies, because the mass-heat transfer performance directly affects Specific Cooling Power (SCP). G.J.V.N. Brites studied the influence of the design parameters on the overall performance of an adsorption refrigerator. The main parameters are studied, such as the mass of adsorbent, the number of fins in the adsorber, the thermal contact resistance, and the evaporation surface area [15]. S. Santamaria analyzed the dynamic behavior of the adsorption finned flat-tube beds with much more complex geometry. The results show that it is not necessary to precisely select the adsorbent grain size. Moreover, the specific cooling power amounts to 50–66% of that obtained with the reference (ideal) one [16]. A. Li presents a zeolite–water chiller. The zeolite is thinly coated onto the surfaces of fin-tube heat exchanger for faster rates of heat and mass transfer. Another feature of the adsorption chiller is the use of a lever-counterweighted valve which can be open or closed by the pressure difference between the reactors and the condenser or evaporator. The results show that when the hot water inlet temperatures range from 65 to 85 °C, the adsorption/desorption cycle time is about 200–300 s at optimum cooling and COP [17]. A. Busso studied a small commercial ammonia–water absorption refrigerator. The COP is about 0.18 when the weak and strong solution

Download English Version:

<https://daneshyari.com/en/article/6683078>

Download Persian Version:

<https://daneshyari.com/article/6683078>

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