Available online at www.sciencedirect.com
ScienceDirect
journal homepage: www.elsevier.com/locate/ijrefrig

Experimental and thermodynamic investigation of an ammonia/water diffusion absorption machine

*Souha Mazouz**, *Rami Mansouri*, *Ahmed Bellagi*

U.R. Thermique and Thermodynamique des Procédés Industriels, Ecole Nationale d'Ingénieurs de Monastir, ENIM, University of Monastir, Tunisia

ARTICLE INFO

Article history:
Received 19 February 2014
Received in revised form
18 May 2014
Accepted 4 June 2014
Available online 12 June 2014

Keywords:
Diffusion absorption
Refrigeration
Ammonia–water
Performance

ABSTRACT

In this paper the results of experimental and thermodynamic investigations on a commercial absorption diffusion device are presented. Two alternative experimental methods, steady state and dynamic method, are used to evaluate the characteristics and the cooling capacity of the machine. All essential features of the machine are determined specially the overall heat transfer coefficients $(UA)_{ext}$ and $(UA)_{int}$, respectively, 0.43 W K^{-1} and 0.21 W K^{-1}. The tests are performed under practical interior ambient air conditions and variable heat loads. For a heat supply of 42 W and a generator temperature of 185 °C, a COP of 0.12 is found.

Etude expérimentale et thermodynamique d'une machine à absorption à diffusion d'ammoniac/eau

Mots clés : Absorption á diffusion ; Réfrigération ; Ammoniac-eau ; Performance

1. Introduction

In a perspective of sustainable development and a more rational use of energy, the research challenge is to find innovative technologies that balance the demands of efficient cold chain and minimized environmental impacts. This is the reason behind the renewed interest for absorption technique for production of cold. This technique, although old for over a century, has several advantages. By using heat as driving force, it bypasses electricity and makes possible the valorization of waste heat of intermediate temperatures (150–200 °C) and the use of solar thermal energy provided by solar collectors such as evacuated-tube collectors. Diffusion absorption machines (DAR) have another major advantage: they operate at a uniform pressure and therefore have no moving part. The absence of any mechanical work input allows a silent and very reliable machine suitable for hotel rooms, offices and camping cars.

Many papers dealing with the performance and the optimization of the DAR cycle have been published. Comparison

* *Corresponding author*. Tel.: +216 98 826 181.
E-mail address: souhamazouz@yahoo.com (S. Mazouz).
http://dx.doi.org/10.1016/j.ijrefrig.2014.06.002

Nomenclature

$a, b, c, d, e, \alpha, \beta$	regression parameters
COP	coefficient of performance
c_p	heat capacity, $J\,K^{-1}$
$\dot{Q}$	heat transfer, W
T	temperature, K
$\tilde{T}$	mean evaporator temperature, K
t	time, s
(UA)	global heat transfer coefficient, $W\,K^{-1}$

Subscripts

0	initial time
a	ambient
abs	absorber
cond	condenser
elec	electric
evap	evaporator
ext	exterior
gen	generator
i	refrigerator interior
id	COP achieved with Carnot thermodynamic cycle
i,0	interior temperature at the beginning of the tests
int	interior
rec	rectifier
w	water
w,0	water temperature at the beginning of the tests

between the working fluid systems NH_3–H_2O, NH_3–$LiNO_3$ and NH_3–NaSCN absorption systems is found in the papers of Bourseau and Bugarel (1986). Solar operated absorption diffusion refrigerating systems are reported in Valizadeh and Ashrafi (1996), Gutierrez (1988) and Wang (2012). Al Shemmeri and Wang (2003) developed a mathematical model for analyzing the performance and operating parameters of this type of machine. The results show that the influence of the gas–gas exchanger is critical. Substitution of the pressure equalizing gas hydrogen by helium has been also investigated by Herold (1996), Prakash-Maiya (2003). Recently, Wang et al. studied a diffusion absorption refrigerator in which the systems R23/R134a DMF and helium are used as, respectively, as refrigerants, absorbent and diffusion gas. With a generator temperature between 110 and 160 °C and ambient temperature in the range 10–28 °C, a very low evaporating temperature has been reached −40 °C, but the COP was less than 0.07 (Wang et al., 2011). The performance of the TFE–TEGDME and NH_3–H_2O DAR cycles was compared in terms of the COP and circulation ratio by Zhen et al. (2013). They concluded that the TFE–TEGDME mixture is a good working fluid for the DAR cycle. In 1995, Chen et al. (1996) developed a simulation model for a 15 kW cooling capacity machine. The basic configuration reached a COP of 0.4. They also conceived a new generator which reuses the rejected heat in the rectifier. The new configuration has slightly improved the COP (5%) compared to the original one. Akam et al. (1999) conducted an experimental study of a refrigeration absorption–diffusion loop. Tests are carried out for two heating modes: electricity and butane combustion gas. They concluded that in both modes of heating, operation of the machine is not a problem but the COP values are higher in the case of electric heating.

Another study of a diffusion–absorption machine, using helium as inert gas, has been published by Srikhirin and Aphornratana (2002). Mass and energy balances are applied to each element of the cycle. For the modeling of the bubble pump, a correlation established from an air-lift is used. They noted that the bubble pump must be designed so that the rates of refrigerant flow and weak solution are equal. If too much solution is pumped, then heat loss occurs. They found a COP ranging from 0.09 to 0.15 for a cooling capacity between 100 and 180 W.

Zohar et al. (2005) have developed a thermodynamic model for the simulation of an absorption–diffusion refrigeration cycle. Simulations were performed using the solver EES (Engineering Equation Solver) (EES, 2003). It is found that the largest COP is reached for a concentration of the rich solution ranging between 0.25 and 0.3 and a driving heat temperature in the range 195–205 °C. The recommended values for the concentrations of ammonia rich and poor solutions are, respectively, 0.3 and 0.1. Helium has been found preferable to hydrogen as inert gas leading to a higher COP. On the basis of a thermodynamic model of the machine, Zohar et al. (2007) tried two configurations of a machine with and without sub-cooling of the condensate before it enters the evaporator. This study shows that the COP of the cycle without sub-cooling of the refrigerant liquid is 14–20% higher and the best performance is obtained when the mass fraction of ammonia-rich solution varies in the range from 0.25 to 0.4. They also showed that better the degree of rectification the higher the COP. Starace and De Pascalis (2012, 2013) elaborated a thermodynamic model of the DAR cycle without any assumption about the purity of the refrigerant ammonia exiting the rectifier. This model was compared with that of Zohar et al. and the results show a higher accuracy in predicting the real operation of the system. The model was experimentally validated using a prototype with a bubble pump coupled to a domestic magnetron to reduce the starting transient of the circuit. Jakob et al. (2008) studied both experimentally and theoretically a 2.5 kW diffusion machine performed by solar energy and designed for air-conditioning. With a generator temperature of 115 °C and an evaporator temperature of 5 °C, an experimental COP of 0.38 is found.

The objective of the present paper is to present a methodology for the evaluation of the cooling capacity of a commercial absorption diffusion machine in both steady state and transient mode. First, the coefficients of heat transfer between the refrigerator interior and ambient air and between the refrigerator interior and the evaporator $(UA)_{ext}$ and $(UA)_{int}$, are determined. The evolution of the COP with supplied generator heat is also evaluated and discussed.

To this purpose, a series of tests in transient and steady mode is performed with heating powers ranging from 10 to 70 W by room temperature between 20 and 30 °C.

2. Operating principle and experimental procedure

The machine is a small capacity refrigerator designed for hotel rooms and camping cars. It runs on electrical power and