

Available online at www.sciencedirect.com

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

Advanced exergy analysis of an absorption cooling machine: Effects of the difference between the condensation and absorption temperatures

Sunyoung Gong ^a, Kiari Goni Boulama ^{b,*}

^a Department of Chemical Engineering, University of Waterloo, Waterloo, Ontario N2L3G1, Canada

^b Department of Mechanical and Aerospace Engineering, Royal Military College of Canada, Kingston, Ontario K7K7B4, Canada

ARTICLE INFO

Article history:

Received 1 February 2015

Received in revised form 13 April 2015

Accepted 15 July 2015

Available online 21 July 2015

Keywords:

Absorption refrigeration

Exergy analysis

Avoidable irreversibility

Unavoidable irreversibility

Endogenous irreversibility

Exogenous irreversibility

ABSTRACT

The water–LiBr absorption machine was analyzed with the purpose of identifying the endogenous, exogenous, avoidable and unavoidable fractions of the exergy destruction. The latter was observed to be largely of endogenous nature, with the desorber and absorber being the major contributors. When the difference between the absorption and condensation temperatures was raised, both the first and second law efficiencies degraded. Furthermore, the absorber endogenous avoidable irreversibility was much larger than that at the desorber when the absorption temperature was lower than the condensation temperature, and the situation reversed when the absorption temperature became higher than the condensation temperature. The same trends were observed in terms of the exogenous avoidable exergy destruction. However, the endogenous unavoidable exergy destruction at the absorber was initially smaller than that at the desorber, and the two components equally contributed to the total endogenous unavoidable irreversibility when the absorption temperature became higher than the condensation temperature.

© 2015 Elsevier Ltd and International Institute of Refrigeration. All rights reserved.

Analyse exergétique avancée d'une machine de refroidissement à absorption : effets de la différence de température entre la condensation et l'absorption

Mots clés : Froid à absorption ; Analyse exergétique ; Irréversibilité évitable ; Irréversibilité inévitable ; Irréversibilité endogène ; Irréversibilité exogène

* Corresponding author. Department of Mechanical and Aerospace Engineering, Royal Military College of Canada, Kingston, Ontario K7K7B4, Canada. Tel.: +1 613 541 6000; Fax: +1 613 542 8612.

E-mail address: Goni.Boulama@rmc.ca (K. Goni Boulama).

<http://dx.doi.org/10.1016/j.ijrefrig.2015.07.021>

0140-7007/© 2015 Elsevier Ltd and International Institute of Refrigeration. All rights reserved.

Nomenclature

COP	coefficient of performance [-]	\dot{W}	mechanical power [kW]
ECOP	exergy efficiency [-]	X	mass fraction of water in working fluid [-]
\dot{E}	exergy flow rate [kW]	<i>Subscripts</i>	
e	specific exergy [kJ kg ⁻¹]	Abs	absorber
f	circulation ratio [-]	Cond	condenser
h	specific enthalpy [kJ kg ⁻¹]	D	destruction
\dot{m}	mass flow rate [kg s ⁻¹]	Des	desorber
P	pressure [kPa]	Evap	evaporator
\dot{Q}	heat transfer rate [kW]	in/out	going into/leaving component
s	specific entropy [kJ kg ⁻¹ K ⁻¹]	Pump	pump
T	temperature [°C, K]		

1. Introduction

A considerable number of studies have been conducted to investigate different aspects of absorption cooling machines. According to Sun et al. (2012), the absorption refrigeration principle was introduced in the 1700s based on the observation that ice could be produced by evaporating pure water from a sulfuric acid solution in an evacuated vessel. In 1860, Ferdinand Carré patented an ammonia–water absorption machine. The water–lithium bromide absorption cycle, hereafter referred to as water–LiBr cycle, was introduced in 1950. Current fast growing environmental awareness in the society and increasing fossil fuel costs are motivating a renewed interest for absorption refrigeration. In fact, one of the most important advantages of absorption refrigeration machines compared to conventional vapor compression machines is that they can be powered by low grade heat sources, such as solar energy, geothermal energy and residual heat rejected by industrial processes.

Research on absorption refrigeration is partially oriented toward the search for the most efficient refrigerant-absorbent pairs, the requirements of which include chemical stability, low-toxicity, high affinity for the refrigerant at low temperature and easy separation at high temperature (Srikhirin et al., 2001; Sun et al., 2012). Ammonia–water and water–lithium bromide emerge as the most efficient working fluid pairs in most applications, while hydrofluorocarbons in ionic solutions (Kim et al., 2013), R134a–dimethylformamide (Meng et al., 2013), monomethylamine–water (Pilatosky et al., 2001) and alkane mixtures (Chekir and Bellagi, 2011) are also present in the literature. On a different note, Chekir and Bellagi (2011) proposed a cycle design modification, with the rectifier being cooled by the weak solution before it enters the desorber. The benefits of inserting recovery heat exchangers between the desorber and the absorber and/or between the condenser and the evaporator have also been examined by Sozen (2001). Other design modifications include half, single, multiple and variable effect cycles, combined compression–absorption cycles, combined ejector–absorption cycles, etc. (Sirwan et al., 2013; Xie et al., 2012; Xu et al., 2013). Sozen et al. (2004) demonstrated that solar energy could be used to drive an ejector–absorption system over 8–9 months per year in Turkey. Kalinowski et al. (2009) also

showed that 5.2 MW waste heat can be recovered from a 9 MW gas turbine to generate cooling using an absorption refrigeration machine. Other combined absorption cooling and power generation applications are available in the scientific literature (Zhang and Lior, 2004), as well as on the commercial market (Margalef and Samuelsen, 2010).

Most published studies on absorption refrigeration assessed the efficiency solely based on the coefficient of performance (COP) (Kalinowski et al., 2009; Kim et al., 2013; Margalef and Samuelsen, 2010; Meng et al., 2013; Sirwan et al., 2013; Xie et al., 2012; Xu et al., 2013). Kaushik and Arora (2009) analyzed a water–LiBr absorption cooling machine and observed that the COP increased with the desorber temperature and decreased when the absorber temperature increased. Bulgan (1995) observed that the COP of an ammonia–water refrigeration machine increased when the evaporator temperature increased. These observations are consistent with those of Le Lostec et al. (2013).

Second law approaches and exergy analysis are currently gaining increased attention because of the additional information they provide on the quality of the energy conversion processes. Several studies directly compared the actual cycle COP to the COP that would be achieved by a reversible refrigeration machine operated under the same conditions (Gomri, 2009; Pilatosky et al., 2001; Sozen et al., 2004; Wonchala et al., 2014). Palacios-Bereche et al. (2010) presented a methodology for the calculation of the exergy of water–lithium bromide solutions, identifying both a physical component and a chemical component to the exergy, and insisting on the importance of accounting for the activity of the two constituents in the calculation of the chemical exergy. Sencan et al. (2005) conducted an exergy analysis of a water–LiBr absorption machine used in cooling or heating modes and observed that the absorber and desorber concentrated most of the exergy losses. They also noted that when the heat source temperature increased, the COP slightly increased, but the exergy efficiency deteriorated. Sedighi et al. (2007) also noted that the absorber and the desorber were in fact the components with the largest exergy destruction in their base cycle setting. However, when a heat exchanger was inserted in the cycle to preheat the weak solution exiting the absorber using the enthalpy of the strong solution leaving the desorber, the exergy destruction at the

Download English Version:

<https://daneshyari.com/en/article/788622>

Download Persian Version:

<https://daneshyari.com/article/788622>

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