

A resorption cycle for the cogeneration of electricity and refrigeration



Liwei Wang^{a,b,*}, Felix Ziegler^c, Anthony Paul Roskilly^{b,1}, Ruzhu Wang^a, Yaodong Wang^b

^a Institute of Refrigeration and Cryogenics, Shanghai Jiao Tong University, Shanghai 200240, China

^b Sir Joseph Swan Centre for Energy Research, Newcastle University, Newcastle NE1 7RU, UK

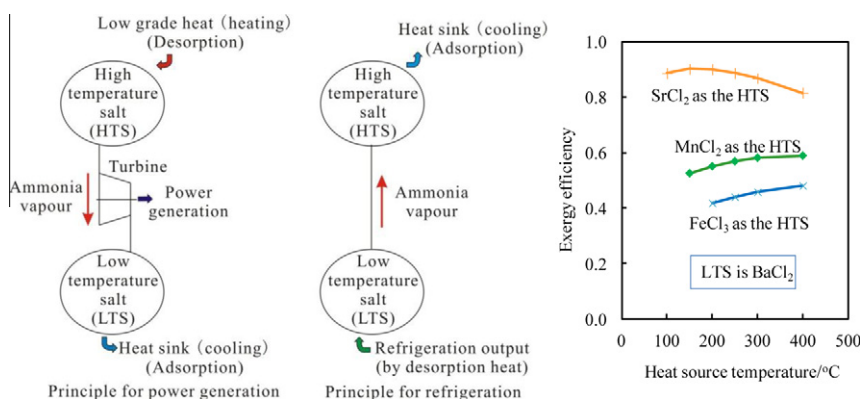
^c Technische Universitat Berlin, KT2, Marchstrasse 18, 10587 Berlin, Germany

HIGHLIGHTS

- ▶ A resorption cogeneration cycle for electricity and refrigeration is proposed.
- ▶ The cycle improved refrigeration COP by 10 times compared with Goswami cycle.
- ▶ The highest exergy efficiency of the cogeneration cycle is as high as 0.9.
- ▶ The cycle also features in safety and simple structure.

GRAPHICAL ABSTRACT

A novel resorption cycle driven by low grade heat for cogeneration of electricity and refrigeration is studied. The cycle features in high exergy efficiency, very little or no ammonia liquid inside and simple structure.



ARTICLE INFO

Article history:

Received 23 October 2012

Received in revised form 11 January 2013

Accepted 12 January 2013

Keywords:

Resorption

Refrigeration

Electricity generation

Exergy efficiency

ABSTRACT

This paper describes a novel resorption cycle driven by the low grade heat for the cogeneration of electricity and refrigeration, which is based on ammonia adsorption refrigeration technology. The presented cycle features a variable endothermic process which stands for higher adaptability if compared with the traditional Rankine cycle, very little or no ammonia liquid in the system which is a safety feature, solid adsorbents inside the beds, and simple structure for the fact of no rectifying equipment and circulation pumps required by the working fluids. This cycle can be utilised for the heat source with the temperature higher than 100 °C, and it has an electricity generation exergy efficiency of up to 0.69 and a refrigeration coefficient of performance (COP) of up to 0.77. If compared with the Goswami cycle, which is established based on the absorption Kalina cycle for the cogeneration of electricity and refrigeration, the novel resorption cycle kept the merit of the high exergy efficiency for electricity generation, meanwhile, it overcame the limitation of the low refrigeration coefficient of performance (COP) of Goswami cycle, and improved the COP by 10 times. The optimum overall exergy efficiency is as high as 0.9, which is 40–60% improved compared with the Goswami cycle under the same working conditions.

© 2013 Elsevier Ltd. All rights reserved.

* Corresponding author at: Institute of Refrigeration and Cryogenics, Shanghai Jiao Tong University, Shanghai 200240, China. Tel.: +86 21 34206056; fax: +86 21 34206814.

E-mail addresses: lwwang@sjtu.edu.cn (L.W. Wang), Felix.Ziegler@tu-berlin.de (F. Ziegler), tony.roskilly@ncl.ac.uk (A.P. Roskilly), rzwang@sjtu.edu.cn (R.Z. Wang), y.d.wang@newcastle.ac.uk (Y.D. Wang).

¹ Tel.: +44 191 222 5869.

Nomenclature

$a, b, n,$ and k	the stoichiometric factors of the reaction
C	specific heat (kJ/(kg K))
COP	coefficient of refrigeration performance
H	enthalpy (kJ)
m	mass of ammoniate HTS (kg)
M	molar mass (mol)
Q	heat (kW)
t_c	cycle time
T	temperature (K)
W	electricity (kW)
ΔH	enthalpy change (kJ)
ΔU	internal energy change (kJ)
ΔS	entropy change (kJ)
\bar{E}	exergy (kW)
\dot{m}	mass flowrate (kg/s)
η	exergy efficiency

Subscripts

ad	adsorption
am	ammonia
c	cooling
de	desorption
el	electricity
env	environmental
ex	exergy
h	heat, heating
H	high temperature salt
hr	heat recovery
L	low temperature salt
Me	metal element
ref	refrigeration

1. Introduction

The utilisation of low grade heat is one of the main options to overcome the developing constraints which are related to the ever rising energy demand [1,2]. The conventional Rankine cycle is a well known power cycle for the utilisation of the low grade heat, and its primary challenge limiting performance is the isothermal endothermic and exothermic processes which often cannot match the temperature profiles of the heat source and sink perfectly. Using an ammonia–water mixture, as in the Kalina cycle [3], is attractive because it allows the exploitation of available exergy to be maximised due to the adjustable temperature variation during the liquid–vapour phase change by controlling the ammonia concentration. The Kalina cycle, under special circumstances [4], generally produces higher exergy efficiency when compared to the Rankine cycle [5,6]. A totally different approach for harvesting the waste heat for power production is the use of thermoelectric systems. This technology has great appeal in terms of its simplicity, but its energy efficiency is only about 0.1 for a heat source temperature lower than 350 °C [7].

Combining the electricity generation with refrigeration may improve the exergy efficiency. This is done in the so-called Goswami cycle [8], in which a heat exchanger (precooler) is added before the absorber in a Kalina cycle so as to recover the low temperature potential of the expanded cold gas stream for refrigeration. Of course, as this heat is only specific heat and not latent heat from a phase change, the Goswami cycle suffers from a fundamental limitation of a low refrigeration coefficient of performance (COP), which is only approximately 0.05 [9], although the exergy efficiency of the cogeneration cycle can reach 0.5 [10].

Chemisorption refrigeration technology is attractive because of the wide range of chloride salts that can absorb ammonia, which allows high flexibility in the application of different temperature heat sources. Cycles of this kind have been theoretically studied extensively by Alefeld and other researchers from the 1980s [11–13]. The working principle [14] is fundamentally the same as that of absorption refrigeration. Consequently, the cycle will have a comparable COP for refrigeration if it was used for the cogeneration cycle.

Resorption [15–19] is a form of absorption or chemisorption with the advantage of improved safety. It also utilises the heat of decomposition in the refrigerating process [20], which provides the potential for performance improvement for the energy conversion [21]. This paper proposes a novel resorption cogeneration cycle for electricity and refrigeration that has high refrigeration COP,

has a reduced operating pressure, possesses little or no ammonia liquid in the system, and has a great potential for a very simplified system for the recovery of the low grade heat. In order to have an overall understanding of this new type of cycle, the different working pairs are compared by analysing energy and exergy efficiency, and the performance is compared with the Goswami cycle operating under the same working conditions.

2. Resorption cycle for the cogeneration of electricity and refrigeration

2.1. The principle of the cycle

The resorption cogeneration cycle presented in Fig. 1 utilises a turbine located between the high temperature salt (HTS) and low temperature salt (LTS) beds to generate electrical power. A superheater and a precooler are integrated in the system to optimise the performance, and two different working phases which take place one after the other are involved.

The first phase is the power generation phase. The thermodynamic diagram is shown in Fig. 2a. In this process the endothermic reaction of the ammoniate HTS at temperature T_{deH} with heat input Q_{de} (Figs. 1 and 2a) adds an internal energy difference of ΔU_{deH} and provides the reaction enthalpy ΔH_{deH} (for decomposition process) to the ammoniate HTS, as well generates ammonia vapour with the enthalpy of H_{am1} , which is superheated to temperature T_h by isobaric heat addition Q_h . The ammonia vapour with the enthalpy of H_{am2} is (in the ideal case) isentropically expanded to produce mechanical work W in the turbine. The expanded ammonia may additionally generate some refrigeration effect Q_{ref1} in an isobaric process at temperature T_{ref} by the enthalpy difference in the precooler if the temperature after expansion T_{Lo} is lower than the refrigeration temperature T_{ref} . This is comparable to the situation in the Goswami cycle. Finally the ammonia vapour with enthalpy of H_{am4} is adsorbed in Bed 1 by the LTS at temperature T_{adL} and releases heat Q_{adL} to the environment. Consequently, the internal energy and enthalpy of ammoniate LTS are decreased by ΔU_{cl} and ΔH_{adL} , respectively.

The second phase is the resorption refrigeration phase, and the thermodynamic diagram is shown in Fig. 2b. In this process the refrigeration Q_{ref2} (Figs. 1 and 2b) is generated due to the sum of the decomposition heat ΔH_{deL} and internal energy difference ΔU_{deL} of the ammoniate LTS in Bed 2. The generated vapour with the enthalpy of H_{am5} has to be adsorbed in Bed 2 by the HTS and the heat of adsorption Q_{adH} is rejected to the environment at the temperature of T_{adH} . Simultaneously, the internal energy and

Download English Version:

<https://daneshyari.com/en/article/6693028>

Download Persian Version:

<https://daneshyari.com/article/6693028>

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