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Finite-time thermodynamics optimization of an irreversible parallel flow double-effect absorption refrigerator

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ABSTRACT

Finite-time thermodynamics optimization analysis based on the coefficient of performance and the ecological coefficient of performance criteria has been carried out. This was done analytically and numerically for a double-effect parallel flow absorption refrigerator with losses of heat resistance, heat leakage and internal irreversibility. The maximum of the coefficient of performance and the corresponding optimal conditions have been derived analytically. The optimum performance parameters, which maximize the coefficient of performance objective function have been investigated. The effects of irreversibility parameters on the general and optimal performances on the basis of COP and ECOP functions have been discussed. The results obtained may provide the basis for designing real double-effect parallel flow absorption refrigerators.

Optimisation thermodynamique à temps fini d'un réfrigérateur à absorption double-effet à écoulements parallèles irréversibles

Mots clés : Système frigorifique à absorption double effet ; Thermodynamique à temps fini ; Optimisation ; Coefficient de performance ; Coefficient de performance écologique

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Nomenclature

A	total heat-transfer area [m^2]
COP	coefficient of performance
ECOP	ecological coefficient of performance
I	internal irreversibility parameter
K	thermal conductance [$kW\ K^{-1}$]
$\dot{Q}$	rate of heat transfer [kW]
R	specific cooling load [$kW\ m^{-2}$]
S	specific entropy generation rate [$kW\ K^{-1}\ m^{-2}$]
T	temperature [K]
U	overall heat-transfer coefficient [$kW\ K^{-1}\ m^{-2}$]
a	distribution rate of the total heat reject quantity between the condenser and the absorber
b	ratio of the total heat between the HP generator and the LP generator

Symbol

$\dot{\sigma}$	entropy generation rate [$kW\ K^{-1}$]
ξ	heat leakage coefficient [$kW\ K^{-1}\ m^{-2}$]

Subscripts

1	working fluid in the high generator
2	working fluid in the low generator
3	working fluid in evaporator
4	working fluid in absorber
5	working fluid in condenser
A	absorber
C	condenser
E	evaporator
G	generator
HP	high pressure
LP	low pressure
env	environment conditions
L	heat leakage
max	maximum
m	at maximum COP

1. Introduction

Absorption refrigeration processes take place in finite-size devices in finite-time; therefore, it is impossible to meet reversibility conditions between the absorption refrigeration system and the surroundings. Thus, the classical thermodynamic performance bound could not properly give the bound of absorption system (Bhardwaj et al., 2003; Kaushik et al., 2002; Ngouateu Wouagfack and Tchinda, 2013a). For this reason, the finite-time thermodynamics approach has been introduced to establish the performance bound of absorption system. The finite-time thermodynamics tends to model real systems in a way closer to reality. It enables to distinguish the irreversibilities due to internal dissipation of the working fluid and that due to the finite-rate heat transfer between the system, the external heat reservoir and heat-sink. It tries to bridge the gap between thermodynamics and heat transfer. It deals with thermodynamic performance optimization of real finite-time and finite-size thermodynamic systems. The applications of finite-time thermodynamics include all the processes with thermal phenomena of all devices and systems operating with the constraints of finite-time and finite-size. The endoreversible cycle is the fundamental physical model adopted in finite-time thermodynamics. The finite-time thermodynamics has been first proposed by Henri B. Reitlinger in 1929 (Vaudrey et al., 2014) and later extended to nuclear energy (Chambadal, 1957; Novikov, 1958). This method has been popularized in many works including Curzon and Ahlborn (1975), Leff and Teeters (1978), Blanchard (1980), Bejan (1982, 1996, 1997), Andresen (1983), Feidt (1987), Sieniutycz and Salamon (1990), De Vos (1992, 1995), Radcenco (1994), Bejan et al. (1996), Chen (1997), Bejan and Mamut (1999), Berry et al. (2000), Sieniutycz (2002), Zheng et al. (2003a,b), Stitou and Feidt (2005), Chen et al. (2011a,b), Li et al. (2013) and Feng et al. (2015a,b,c), in many review articles including Sieniutycz and Shiner (1994), Hoffmann et al. (1997), Chen et al. (1999), Durmayaz et al. (2004), Feidt (2013), Qin et al. (2013) and Ngouateu Wouagfack and Tchinda (2013b), and in books Wu et al. (1999) and Chen and Sun (2004). Significant results have been obtained and are provided in the literature. In the case of absorption refrigerators, the optimal operating region of endoreversible (Yan and Chen, 1989; Chen and Yan, 1993; Chen, 1995; Wijeysundera, 1996; Wu et al., 1997; Ng et al., 1997; Chen, 1997; Chen and Sun, 2004; Chen et al., 2004, 2011a,b, 2013) and irreversible (Chen and Schouten, 1998; Chen et al., 1999, 2002, 2006; Ngouateu Wouagfack, 2012; Ngouateu Wouagfack and Tchinda, 2011a; Qin et al., 2010; Zheng et al., 2003a,b, 2004) single effect absorption refrigerator have been established. For double-effect absorption refrigerator systems, most of the theoretical work considers the mass and energy conversion approach to calculate the coefficient of performance of the system (Arora and Kaushik, 2009; Arun et al., 2000, 2001; Domínguez-Inzunza et al., 2014; Ezzine et al., 2004a,b, 2005; Farshi et al., 2011, 2012; Gebreslassie et al., 2010; Huicochea et al., 2011; Kaushik and Arora, 2009; Li et al., 2014; Sedigh and Saffari, 2011; Shahata et al., 2012; Torrella et al., 2009; Vasilescu et al., 2011; Xu and Dait, 1997) and the exergy efficiencies (Arora and Kaushik, 2009; Farshi et al., 2013a,b; Gomri, 2010; Gomri and Hakimi, 2008; Kaushik and Arora, 2009; Shahata et al., 2012). Chua et al. (2000) used the process average temperature to study the impact of the various dissipative mechanisms on the inverse of the coefficient of performance (COP^{-1}). Much work has yet to be done on the finite-time thermodynamics approach for double-effect absorption refrigerators except the work of Göktun and Er (2000). They used the finite-time thermodynamics approach to compare an irreversible double-effect absorption system affected by three internal irreversibilities parameters with an irreversible cascaded absorption refrigeration system. They did not establish the bound of the operating region of the system.

In this paper, the finite-time performance of a parallel flow double-effect absorption refrigerator cycle with losses of heat resistance, heat leakage and internal irreversibility are derived. The irreversibility parameters and heat leakage effects on the COP and on the ECOP of the irreversible cycle are investigated.