INTERNATIONAL JOURNAL OF REFRIGERATION 56 (2015) 81–98

Available online at www.sciencedirect.com

ScienceDirect

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

Exergoeconomic performances of the desiccant-evaporative air-conditioning system at different regeneration and reference temperatures

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ARTICLE INFO

Article history:
Received 1 June 2014
Received in revised form
3 November 2014
Accepted 13 November 2014
Available online 22 November 2014

Keywords:
Thermodynamics
Exergoeconomic
Desiccant dehumidification
Evaporative cooling

ABSTRACT

This paper presented the exergoeconomic evaluation of the developed desiccant-evaporative air-conditioning system. The developed system was evaluated based on the steady-state conditions at different regeneration and reference temperatures. The exergoeconomic evaluation method was implemented to the system components and the whole system to evaluate the exergy efficiency, exergy destruction ratios, cost rates, relative cost differences and exergoeconomic factors. The regeneration and reference temperatures affected the exergy efficiencies, exergy destruction ratios, cost rates, relative cost differences and exergoeconomic factors. The desiccant wheel, heating coil and evaporative cooler had a high cost rate (investment cost, operation and maintenance cost, and exergy destruction cost). The exit air fan, outdoor air fan and evaporative cooler had a high relative cost difference. The exit air fan, outdoor air fan and secondary heat exchanger had a high exergoeconomic factor. Replacement of the desiccant wheel with a higher dehumidification performance could decrease the high cost rate. A higher efficiency evaporative cooler and heating coil were needed. Cheaper air fans (outdoor air fans and exit air fans) were needed.

Performances exergo-économiques d'un système de conditionnement d'air évaporatif à déshydratant à différentes températures de régénération et de référence

Mots clés : Thermodynamique ; Exergoéconomique ; Deshumidification á deshydratant ; Refroidissement évaporatif

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http://dx.doi.org/10.1016/j.ijrefrig.2014.11.007

Nomenclatures

c	cost per exergy rate ($/kW)
e	specific exergy (kJ kg^{-1})
f	exergo-economic factor
i	interest rate
$\dot{m}$	mass flow rate (kg s^{-1})
n	total operating period (Year)
r	relative cost difference
t	time (sec)
$\dot{C}$	exergy cost rate ($/h)
CRF	capital recovery factor
D	destruction
DW	desiccant wheel
$\dot{E}$	exergy rate (kW)
EC	evaporative coil
F_{OA}	outdoor air fan
F_{EA}	exit air fan
HC	heating coil
HX_1	primary heat exchanger
HX_2	secondary heat exchanger
IC	investment cost ($)
L	loss
MX	flow mixer
N	annual operating hour
OMC	operation and maintenance cost ($)
$\dot{Q}$	heat transfer rate (kW)
T	temperature (°C)
$\dot{W}$	work rate (kW)
$\dot{Z}$	capital cost rate ($/h)

Greek symbols

ω	humidity ratio (g kg^{-1})
φ	annual maintenance factor
ε	exergy efficiency

Superscript

CI	component investment
OM	operating and maintenance

Subscript

$1,2..$	air state point
e	exit
D	destruction
DW	desiccant wheel
EC	evaporative coil
F	fuel
F_{OA}	outdoor air fan
F_{EA}	exit air fan
HC	heating coil
HX_1	primary heat exchanger
HX_2	secondary heat exchanger
i	inlet
k	kth component
L	loss
$\dot{m}$	mass flow rate
N	node
P	product
q	heat
r	reference conditions
Tot	total
w	work
W	water

1. Introduction

Maintenance of the indoor environmental conditions is one of the energy intensive parts of a house's or building's operation. In hot and humid climates, air dehumidification and cooling consume a large percentage of buildings' electric energy (Kong et al., 2012). As people stay indoors most of the time, it is expected that the maintenance of the indoor environment will become more intensive as the population explosion, urbanization and industrialization became more prevalent (Enteria, 2013).

The desiccant-based air-conditioning system is one of the most promising alternative systems in the maintenance of indoor temperature and humidity. The desiccant-based system can control air thermal contents (latent and sensible) (Enteria, 2013), micro-organisms (viruses and bacteria) (Goswami et al., 1997) and chemical contents (such as VOCs) (Fang et al., 2008). As the system can be supported by different energy sources, it is flexible depending on the on-site available energy sources (Enteria and Mizutani, 2011). However, since the desiccant-based air-conditioning system consumes energy from different sources (such as electric, thermal and hydro) (Enteria and Mizutani, 2011), exergy analysis is important (Bejan et al., 1996). In addition, as different sources of energy have different costs, the combined exergy and economic analysis is a very important factor for the system evaluation. Hence, application of the exergoeconomic evaluation is an important component for determining the thermal and economic performance of the thermal systems (Bejan et al., 1996; Tsatsaronis, 1996).

Tsatsaronis (1993) presented the review of the exergy analysis and the thermo-economic analysis performance of the energy systems. It shows that thermo-economic analysis is an important tool for the determination of the cost for the system processes and its products for system improvement. Tsatsaronis and Pisa (1994) conducted an exergoeconomic evaluation of the CGAM problem (Valero et al., 1994). This is a predefined problem of the gas turbine engine. It shows that the exergoeconomic concept is a powerful tool in the determination of the cost sources and for the optimization of the complex system. Hence the exergoeconomic technique is a very important tool for thermal system designers in the determination of thermodynamic inefficiencies and costs in the thermal system (Tsatsaronis, 1996). Abusoglu and Kanoglu (2009a, 2009b) conducted a review of the different