Energy Conversion and Management 84 (2014) 524–532

Contents lists available at ScienceDirect

Energy Conversion and Management

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

Exergy analysis of a novel configuration of desiccant based evaporative air conditioning system

İrfan Uçkan [a,*], Tuncay Yılmaz [b], Ertaç Hürdoğan [c], Orhan Büyükalaca [c]

[a] Department of Mechanical Engineering, Yuzuncu Yil University, 65080 Van, Turkey
[b] Department of Mechanical Engineering, Osmaniye Korkut Ata University, 80000 Osmaniye, Turkey
[c] Department of Energy Systems Engineering, Osmaniye Korkut Ata University, 80000 Osmaniye, Turkey

ARTICLE INFO

Article history:
Received 26 December 2013
Accepted 1 May 2014
Available online 20 May 2014

Keywords:
Exergy analysis
Dehumidification
Evaporative cooling
Desiccant
Air conditioning

ABSTRACT

In this work, a process is developed for exergy analyses of a novel configuration of desiccant based an evaporative air conditioning system. The exergy transfer and destruction between the components of the system are defined for the average measured variables obtained from the experimental results. The exergy formulations are carried out to the experimental system using the data collected during a typical operation of the system. The exergy output, specific flow exergy, exergy destruction, exergy input and exergy efficiency are determined. Furthermore, the sustainability assessment and relative irreversibility of components are obtained. It is found that the exergy efficiency of the entire experimental unit is 40.7% at a reference temperature of 15 °C. It is also observed that the exergy efficiencies of the entire system varies between 56% and 25% for reference temperature of 0–30 °C, respectively. The effects of reference temperature on the performance of the studied system are investigated. Based on the investigation, it is seen that an exergy analysis can provide beneficial knowledge with respect to the theoretical upper limit of the system performance.

© 2014 Elsevier Ltd. All rights reserved.

1. Introduction

Desiccant air conditioning systems have been presented as interesting alternatives to conventional vapor compression systems owing to their advantages of utilizing low temperature energy. Generally, desiccant air conditioning systems are a composition of desiccant dehumidification, additional compression refrigeration, evaporative cooling and the regeneration of the desiccant [1]. In a desiccant based air conditioning system, outdoor air passes firstly through in solid desiccant dehumidifier that is main component of this system. After dehumidification, air that is dried can be firstly cooled by a sensible heat exchanger and for further cooling an evaporative cooler are used. Evaporative air cooling has been used for thousands of years in various forms for comfort cooling and is still in common use around the world because of its simplicity, low cost and effectiveness. On the other hand, evaporative cooling system cannot be used alone in humid climate due to raises the humidity of process air. So, this system should be combined with desiccant air conditioning system in hot and humid climate.

Evaporative cooling technologies were either utilized as direct, indirect or direct/indirect. A schematic diagram of two stage indirect–direct evaporative cooling system can be seen in Fig. 1. In evaporative cooling systems, air is drawn through evaporative cooler and its sensible heat energy evaporates water; the heat and mass transfer between the air and water decreases the air dry bulb temperature and increases the humidity at a constant wet-bulb temperature. Main components of basic evaporative cooling system occur from pumps (P), fans (F) and evaporative cooler that can be direct (DEC) or indirect (IEC).

To analyze, design and improve the solid desiccant air conditioning systems a number of works are given in the literature. Some of these works are focus on the optimization and analysis of operating parameters for the whole system [2,3]. Bourdoukan et al. [4] studied a desiccant air handling unit powered by vacuum-tube solar collectors and they first worked the performance of the components under various operating conditions. Then overall performance of the installation evaluated by authors.

Desiccant wheel is one of important components in desiccant air conditioning systems and many investigations have been performed on it [5–7]. Jia et al. [8] carried out experiments on a hybrid desiccant air conditioning system. The system is a combination of two units that are a solid desiccant wheel and a vapor compression air conditioning system. They found that the system reduces 37.5% electricity powers when the process air temperature and relative humidity are held at 30 °C and 55%, respectively.

* Corresponding author. Tel.: +90 432 2251728.
E-mail addresses: uckan65@hotmail.com, irfanuckan@yyu.edu.tr (İ. Uçkan).

http://dx.doi.org/10.1016/j.enconman.2014.05.006
0196-8904/© 2014 Elsevier Ltd. All rights reserved.

Nomenclatures

c_p	specific heat (kJ/kg K)
ex	specific exergy (kJ/kg)
$\dot{E}x$	exergy rate (kW)
f_i	exergetic factor
h	specific enthalpy (kJ/kg)
$I\dot{P}$	rate of improvement potential (kW)
$\dot{m}$	mass flow rate (kg/s)
$\dot{Q}_j$	the heat transfer rate at location j (kW)
s	specific entropy (kJ/kg K)
T_j	boundary temperature at location j (K)
W	rate of work (kW)

Greek symbol

ψ	specific flow exergy (kJ/kg),
ε	efficiency
δ	fuel depletion ratio
ξ	productivity lack
ω	specific humidity ratio (kg_{water}/kg_{air})

Subscripts

a	air
$dest$	destruction
f	fresh air
i	the ith device
in	input
out	output
R	regeneration air
v	vapor
w	waste air
0	dead reference state
1, 2, . . . , 17	state numbers

Superscripts

Ch	chemical energy
Ke	kinetic energy
Pe	potential energy
Ph	physical energy

Fatouh et al. [9] presented experimental performance data of a solid desiccant based hybrid air conditioning system. The system occurs a solid desiccant wheel combined with a R407C vapor compression air conditioning unit. They analyzed the effect of different air flow rates and regeneration temperatures on reactivation of the desiccant. Ruivo et al. [10] derived new correlations to calculate effectiveness parameters of a solid desiccant dehumidifier. Eicker et al. [11] studied experimental investigations on several commercially available and newly produced rotors. They found that the optimum rotation speed is lower for lithium chloride or compound rotors than that of silica gel rotors.

Exergy which is the maximum useful work possible during a process is now being increasingly recognized in the area of air conditioning system. To optimize and analyzes these types of energy systems, exergy analysis is one of the most effective methods. The detailed information about exergy analysis can be found in Refs. [12,13]. Hürdoğan et al. [14] investigated a desiccant air conditioning system that had a novel configuration and they defined the exergy transfer between the system components. Alpuche et al. [15] analyzed the effect of desiccant air conditioning systems on reaching thermal comfort conditions in the interior of a building. They carried out exergy analysis for the different design temperatures and relative humidity conditions. Kanoğlu et al. [16] established a desiccant cooling system and developed a method for the exergy and energy analyses. Taufiq et al. [17] defined the optimization and modeling analysis for cooling system in the building. La et al. [18] investigated the effects of each components of a desiccant cooling system. They derived appropriate methodology for thermodynamic assessment and developed a generalized model independent of the connection of components.

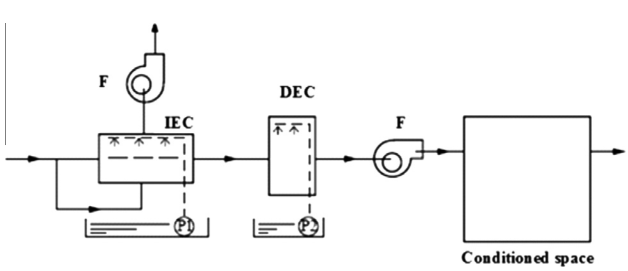

Fig. 1. A schematic diagram of two stage indirect–direct evaporative cooling system.

In the literature survey, many theoretical and experimental studies performed on the first law of desiccant air conditioning systems but very few studies were performed on the exergy analysis of these type systems.

The system described in this paper has a new configuration based on fabrication/assembly. The objective of this study is to perform exergy analyses of desiccant based evaporative air conditioning system [19] with a complex configuration which consists of evaporative coolers, rotary solid desiccant wheel, heat exchangers, electric heater unit, filters, pumps, control units, channels and fans. It is obvious that without detailed calculations it is not possible to predict energy consumption, so, exergy analysis of this type system should be done. In order to gain a more detailed insight to the origin of the energy analysis in this system, exergy analysis of each component has been calculated by means of energy and exergy balance. The effects of the individual irreversible processes in each component on the thermodynamic performance of the system are also analyzed. Moreover, specific flow exergy, exergy efficiency sustainability assessment and relative irreversibility of components are obtained.

2. System description

2.1. Experimental setup and operation

Fig. 2 shows experimentally investigated desiccant air conditioning system that has a novel configuration which consists of dehumidification, heat and cool recovery and evaporative cooling. Experimental setup includes two direct evaporative coolers, one rotary solid desiccant wheel, three heat exchangers, electric heater unit, filters, pumps, control units, channels and fans.

Based on the literature survey, it is seen that waste air from conditioned space is generally used for regeneration in the desiccant conditioning systems. The desiccant based air conditioning design needs new configuration for optimizing the operation of the system. In this study, at the beginning of the system design, an analysis is performed in order to maximize the performance of the system. It is found that outdoor air must be used for regeneration air to decrease consumption of the regeneration heat and

Download English Version:

https://daneshyari.com/en/article/763854

Download Persian Version:

https://daneshyari.com/article/763854

Daneshyari.com