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ScienceDirect

Energy Procedia 110 (2017) 434 – 439

Energy Procedia

1st International Conference on Energy and Power, ICEP2016, 14-16 December 2016, RMIT University, Melbourne, Australia

Performance evaluation of solid desiccant wheel regenerated by waste heat or renewable energy

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Abstract

To remove moisture, solid desiccant wheel technology presents an energy-efficient alternative to traditional systems especially when solar energy and waste heat come into play. Solid desiccant wheels can be coupled with other systems to provide desired air quality. In order to solve the problem of high energy consumption for regeneration of desiccant wheels, systems involving desiccant wheels use solar thermal energy or waste heat to regenerate desiccant material so dehumidification process is done by this technology while required energy to dehumidify air is provided by waste heat or renewable energy. The main component in these systems is desiccant wheel which should operate efficiently. In this study, performance of solid desiccant wheel is evaluated and affecting factors consisting of air humidity ratio, regeneration process and air process temperatures, mass flow rates, and wheel revolution are investigated. Software provided by Novel Aire Company is used to calculate outlet air conditions. Using the software, the performance of a rotary dehumidifier is studied based on effectiveness parameters including moisture removal capacity (MRC), sensible coefficient of performance (COPSen), latent coefficient of performance (COPLat) and total coefficient of performance (COP Total). In addition, affecting factors change as described: inlet air temperature between 15 °C to 40 °C, regeneration temperature between 65 °C to 110 °C, humidity ratio between 10 to 20 g/kg, air flow rates between 0.72 Kg/s to 1.28 m/s, and rotational speed of wheel between 10 to 40 RPH.

Peer-review under responsibility of the organizing committee of the 1st International Conference on Energy and Power.

Keywords: Desiccant wheel; dehumidification; waste heat; air compressor; rotary dehumidifier; renewable energy; effectiveness

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Peer-review under responsibility of the organizing committee of the 1st International Conference on Energy and Power.
doi:10.1016/j.egypro.2017.03.165

1. Introduction

To decrease energy consumption and also to displace fossil fuels with green energies, we need technologies energy-efficient and well-matched with renewable energy resources. Dehumidification process is one of the energy-consuming processes with which we are dealing in different ways, ranging from drying products to providing desired air quality for conditioned spaces. Three ways to remove moisture from air are applied: heating and ventilation, condensation and adsorption. Adsorption dehumidification by solid desiccant wheels is an energy-efficient way to remove moisture from air especially when waste heat and solar energy come into play so this technology can be well integrated with other systems like solar collectors. The key component in these integrated systems is solid desiccant wheel of which its appropriate performance affects whole system efficiency then this study focuses on the evaluation of solid desiccant wheel performance. Data required for this study is obtained from software provided by some Novel Aire company. Using this software, implications of all affecting parameters on desiccant wheel performance like supply air inlet and regeneration air inlet temperatures, humidity ratios and mass flow rates as well as wheel revolution are studied. Subsequently outlet air conditions are obtained and outcomes are investigated based on desiccant wheel effectiveness. Since mass and heat transfer processes occur during dehumidification process in desiccant wheels, combination of these two processes is taken into consideration to define desiccant wheel's effectiveness [1]. Moisture removal capacity (MRC), sensible coefficient of performance ($COP_{Sensible}$), latent coefficient of performance (COP_{Latent}) and, total coefficient of performance (COP_{Total}) are various parameters applied in this study to investigate desiccant wheel performance [1,2]. The characteristic distinguishing this study from other researches is that all effectiveness factors as well as a wide data bank for different wheel are considered to study. In addition, all affecting parameters are included in this research. Experimental investigations have been done using test facilities constructed by other researches. Mandegari et al did some experiments in hot dry and hot humid conditions to analyze desiccant wheel performance used in a cooling system. Based on the desiccant wheel's effectiveness, the authors found out enthalpy of the outlet process air goes up considerably and it leads to decrease adiabatic efficiency and subsequently an optimum value in some situations was obtained [1]. In [2], Napoleon et al experimented a desiccant wheel separately and coupled with a heat wheel and evaluated its performance based on the moisture removal and coefficient of performance. Finally they realized that desiccant wheel performance is analyzed better if all COPs are considered as other criteria to study results. In [3], a desiccant wheel regenerated by low thermal heat energy recovered from a micro generator has been evaluated based on a function of inlet temperatures, humidity ratios and flow rates. Consequently the authors realized that regeneration temperature and the supply air humidity ratio influence the desiccant wheel performance more than the supply air temperature. Additionally, Ursla et al conducted an experimental investigation on different desiccant wheels and their results showed that high regeneration temperature is positively correlated with dehumidification potential; however it increases enthalpy change of the process air. As well, higher humidity ratio in the ambient air leads to raise dehumidification capacity while dehumidification efficiency is not much affected [4]. In [5], sensible effectiveness and moisture removal of a desiccant wheel were considered as factors to study its performance. Effects of Wheel speed and regeneration temperature were analyzed and outcomes showed the optimum rotational speed so that lower speeds present better results than the higher ones. Avadhesh et al used software provided by manufacturers to study performance of a desiccant wheel based on moisture removal in the process air. As well, effects of air flow rate on regeneration and process air in different air conditions were evaluated [6]. In [7], Ge et al studied two-stage desiccant cooling system based on moisture removal and thermal COP. They found that increase in inlet air moisture causes a raise in moisture removal capacity and thermal COP.

Nomenclature

MRC	Moisture removal capacity
$COP_{sensible}$	Sensible coefficient of performance
COP_{latent}	Latent coefficient of performance
COP_{Total}	Total coefficient of performance
$\dot{m}$	Mass flow rate
h	Enthalpy
h_{Evap}	Water evaporation enthalpy