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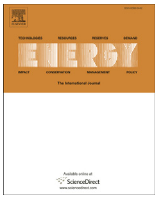

# Performance of a desiccant wheel cycle utilizing new zeolite material: Experimental investigation

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ABSTRACT

Removal of moisture from the air represents a considerable portion of the air conditioning load in hot and humid regions. It is a common practice to run air conditioning systems at temperatures lower than the moist air dew point temperature in order to accomplish dehumidification. Desiccant air conditioners offer a solution to meet the humidity and temperature requirements of buildings via decoupling latent and sensible loads. In this work, the performance of a new desiccant material is investigated experimentally. This desiccant material has a unique S-shape isotherm and can be regenerated using a low temperature heat source. The effects of the process air stream's temperature and humidity, the regeneration temperature, the ventilation mass flow rate, and the desiccant wheel's rotational speed on the cycle performance are investigated. ARI-humid conditions are used as a baseline. The moisture mass balance is maintained within 5% for all conducted tests. The results are presented in terms of the moisture removal rate and latent $COP_{lat}$ (coefficient of performance). The results show a desiccant wheel's $COP_{lat}$ higher than unity when it is coupled with an enthalpy wheel.

## 1. Introduction

The purpose of a solid desiccant cycle is to reduce the moisture content of the ambient fresh air. A typical approach for using solid desiccants for dehumidifying air streams is to impregnate them into a light-weight honeycomb or corrugated matrix that is formed into a wheel. The wheel is usually divided into two sections. The process air flows through one section of the wheel to be dehumidified, while a reactivation airstream passes through the other section to regenerate the wheel. The desiccant wheel rotates slowly between the process and the regeneration airstreams in order to make the process continuous.

There is a growing interest in desiccant wheel cycles since it is compact, less subject to corrosion, and can be operated using low temperature heat source, e.g. solar energy or waste heat. Extensive studies have been carried out on developing desiccant materials [1–6] and studying the performance of desiccant wheels numerically [7–11] and experimentally [12–15]. Many researches use a silica-gel desiccant wheel coupled with a sensible heat exchanger and evaporative coolers [16–18] which others compare and propose different system designs which are driven by solar energy [19–24].

In this work, a new type of desiccant material is implemented. It is named Functional Adsorbent Material Zeolite 01(FAM-Z01) with 7.3 Å pore size. This material has a unique S-shaped isotherm and can be regenerated using a low temperature heat source. A comprehensive experimental study on the performance of the desiccant wheel coupled with an enthalpy wheel is carried out. The system performance at different operating conditions has been investigated. Prior to analyzing the data, the validity of the recorded data is checked by ensuring energy and mass balance across the desiccant wheel. It has been noticed that this important step is usually ignored when conducting experiments on desiccant wheels. The experiment is conducted in compliance with ASHEAE 139 standards [25] and the results are presented in terms of the desiccant wheel capacity and its coefficient of performance. It is very important to follow the available standards in testing and rating the performance of a desiccant wheel. It has been noticed that this is rarely done in the pertaining literature. The available experimental data of various desiccant materials is not comparable, unless they are tested at the same operating conditions. Therefore, following the available standards would make it easier to compare the performance of different desiccant materials and select the

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### Nomenclature

*Abbreviations*

| | |
|---|---|
| MRC | moisture removal capacity |
| ASHRAE | American society of heating, refrigerating and air conditioning engineers |
| COP | coefficient of performance |
| DW | desiccant wheel |
| DWC | desiccant wheel cycle |
| EW | enthalpy wheel |
| FS | full scale |
| MRC | moisture removal capacity $kg_w$-$hr^{-1}$ |
| MRR | moisture rejected rate $kg_w$-$hr^{-1}$ |
| RD | reading |
| RPH | revolution per hour |
| W-A-HX | water–air heat exchanger |

*Parameters*

| | |
|---|---|
| h | moist air enthalpy kJ-$kg_a^{-1}$ |
| $h_{fg}$ | latent heat of water kJ-$kg_w^{-1}$ |
| $\dot{m}$ | mass flow rate $kg_a$-$hr^{-1}$ |
| Q | heat transfer rate kW |
| RH | relative humidity % |
| $R_{speed}$ | rotational speed RPH |
| T | temperature °C |
| w | humidity ratio $kg_w$-$kg_a^{-1}$ |
| $\varepsilon_{HW}$ | effectiveness of the enthalpy wheel |

*Subscripts*

| | |
|---|---|
| lat | latent |
| amb | ambient |
| reg | regeneration |
| min | minimum |

most appropriate desiccant wheel for the design in hand. In addition, very few researchers declare the uncertainty in the performance indices used to study the performance of desiccant wheels. In this study, the uncertainty in the calculated results is estimated based on the uncertainties in the primary measurements.

## 2. System description

The schematic of the desiccant wheel cycle is shown in Fig. 1. The cycle consists of a DW (desiccant wheel), an EW (enthalpy wheel), and a WAHX (water to air heat exchanger). The process air stream passes through the DW, where it is heated and dehumidified. Then, it passes through the EW, where it is precooled utilizing the exhaust side cold air inlet. In the exhaust duct, the regeneration air is heated in the WAHX to the required regeneration temperature, after it has been preheated using the EW. This would reduce the required regeneration heat input. After that, the regeneration air stream passes through the regeneration side of the DW and the moisture transfers from the DW to the air stream. Finally, the dried DW slowly rotates to the process air stream duct to adsorb the moisture from the process air.

The desiccant wheel utilizes Ferroaluminophosphate Zeolite material. This material has a unique isotherm shape when compared to conventional desiccant materials as can be seen in Fig. 2. Since these desiccant materials undertake the adsorption/desorption processes based on the difference in water vapor pressure between the desiccant material and the moist air, the S-shaped isotherm indicates that the desiccant water content can be altered by a small change in relative humidity. This also indicates that the desorption of water vapor from the desiccant material is easier and can be accomplished using a low temperature heat source. That is because the dehumidification air's relative humidity is not required to be very low, i.e. higher regeneration temperature, in order to desorb the water vapor from the desiccant material. The specifications of the DW used in the experiment are listed in Table 1 and the actual DW used is shown in Fig. 3.

The enthalpy wheel utilizes Molecular Sieve 3 Å material. It has a sensible effectiveness of 83%. The specifications of the EW are listed in Table 1. The actual wheel is depicted in Fig. 4.

The WAHX was modeled and sized using in-house software, Fig. 5 [26]. The dimensions of the heat exchanger selected are 305 mm (Height) × 356 mm (Width) × 89 mm (Thickness). The capacity at the operating conditions is estimated to be 2.1 kW.

## 3. Experiment apparatus

Fig. 6 shows the experimental setup used to investigate the performance of the DWC (desiccant wheel cycle). The fans have 3-phase motors which are controlled using variable frequency drivers. The volumetric flow rate is found using 76 mm nozzles, which are installed according to ASHRAE standards 41.2 [27]. The air mixer is used to avoid air stream stratification. A hot water storage tank equipped with resistance heating elements is used to heat the exhaust air stream in the WAHX. The air duct, the DW, and the EW are insulated in order to minimize the heat loss to the environment. The supply air stream temperature and humidity ratio are controlled using a vapor compression cycle, a heater, a steam humidifier, and a desiccant wheel. The exhaust air stream inlet conditions, state 6, are fixed at a temperature of 25 °C and a humidity ratio of 10 $g_w$ $kg_a^{-1}$. Details of the instrumentations used are provided in Table 2. All the instruments used are calibrated prior to installation. The output signals of these instruments are

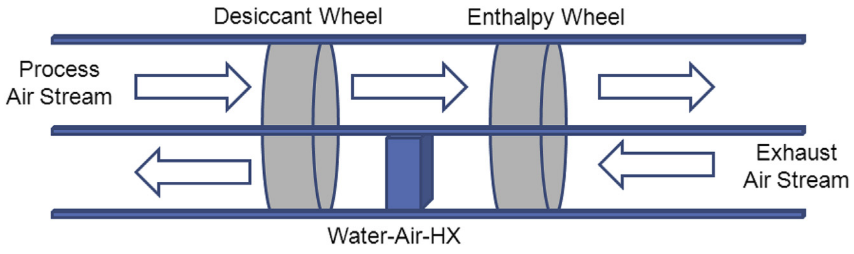

**Fig. 1.** Desiccant wheel cycle schematic.