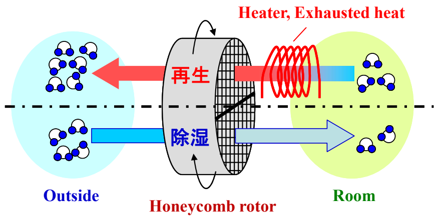
Dehumidification Behavior of Heat Exchanger Type Adsorber for Desiccant Humidity Control System

Introduction

Desiccant humidity control system

- **Humidity** can be controlled efficiently by using **thermal energy below 373 K**.
- Sensible and latent cooling loads can be controlled **independently**.



Conventional system

◎ **Simple system configuration**

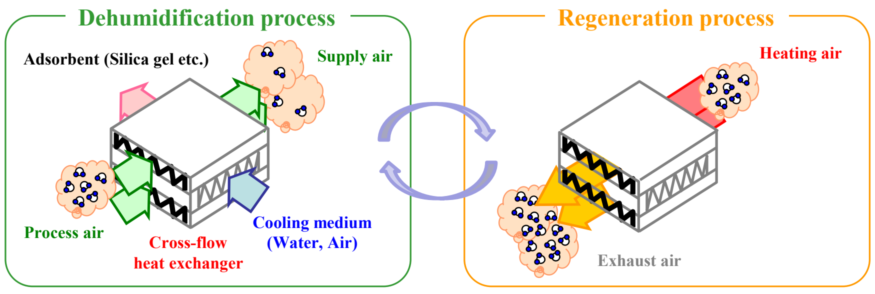
One rotor performs dehumidification/regeneration continuously.

△ **Lower water adsorptivity** of adsorbent in dehumidification

Excess temperature rise in regeneration

Temperature rise by water adsorption in dehumidification

Proposed novel system : Cross-flow Heat Exchanger Type Adsorber



◎ **Improvement of utilization ratio of adsorbent** during dehumidification process

◎ **Reduction of temperature rise of supply air**

Both **sensible heat of adsorber** and **heat of adsorption** is actively **removed** by flowing **cooling air**.

○ **Simpler system** than that with water coolant

△ **Batch system**

Two adsorbers are needed to produce dehumidified air continuously.

In this study

- **A lab-scale experimental set-up using cross-flow heat exchanger coated with ALPO zeolite was made.**
- **Dehumidification experiment was conducted at various cooling air velocities and regeneration temp.**

Experimental

～ Adsorbent & Cross-flow heat exchanger type adsorber ～

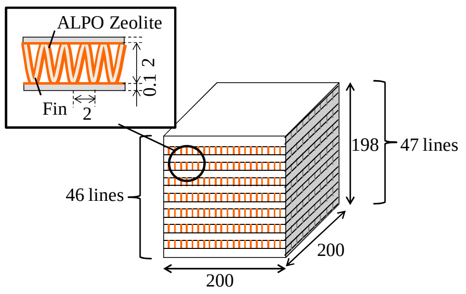


Fig. Schematic diagram of cross-flow heat exchanger type adsorber

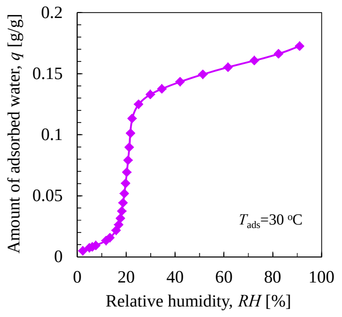
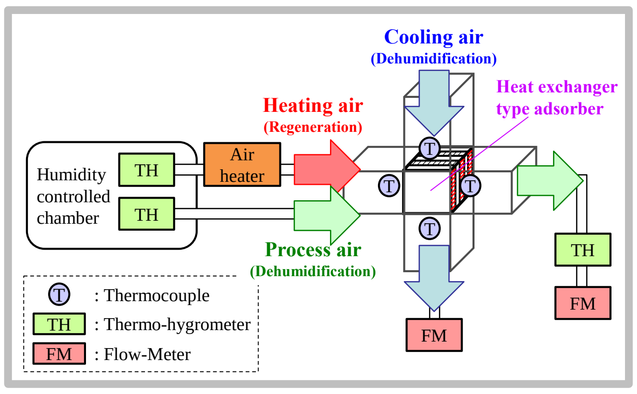


Fig. Water adsorption isotherm on ALPO zeolite

～ Apparatus ～



～ Procedure ～

Temperature and humidity controlling in the chamber

Regeneration process with ***Heating air***

Dehumidification process with ***Process air*** & ***Cooling air***

Measurement of time-change in humidity and temperature

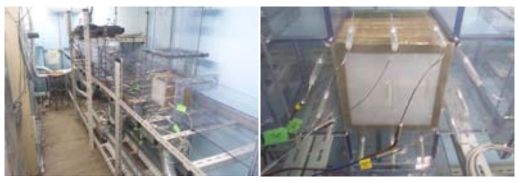


Fig. Experimental apparatus

Table Experimental conditions

	Dehumidification		Regeneration
	PA	CA	HA
Temperature, T [°C]	30	30	**45-70**
Air velocity, u [m/s]	1.0	**0, 1.0-3.0**	1
Humidity, AH [g/kg-DA]	16	16	16
(Relative humidity)	60	60	12.8

PA: Process air, CA: Cooling air, HA: Heating air

Results & Discussion

Dehumidification behavior of heat exchanger type adsorber

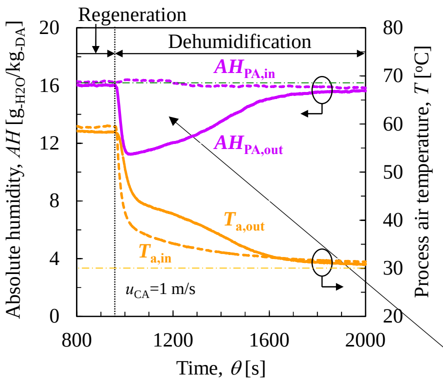


Fig. Time change in inlet/outlet absolute humidity and air temperature of the process air

◆ ***Outlet absolute humidity***

✓ Decrease rapidly at the beginning of dehumidification.

✓ $AH_{PA,out}$ gradually recovered to $AH_{PA,in}$.

✓ **Dehumidified air can be supplied.**

◆ ***Outlet process air temperature***

✓ Decrease gradually to $T_{a,in}$=30 °C

✓ **Temp. difference between inlet/outlet is caused by generation of adsorption.**

Amount of dehumidification

$$q = \int m(AH_{in} - AH_{out})d\theta$$

m: mass flow rate [kg-DA/s], θ: time [s]

AH: absolute humidity [g-H_2O/kg-DA]

Advantage of ALPO zeolite for low-temperature regeneration

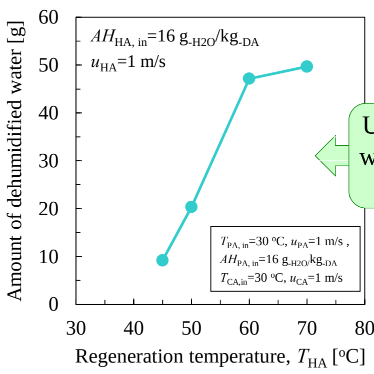
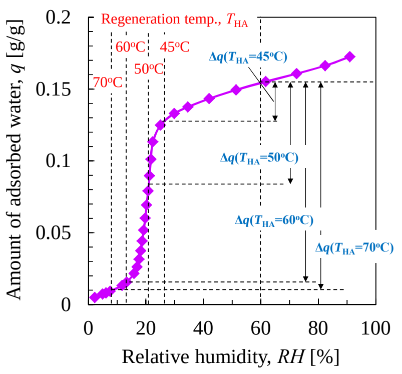


Fig. Effect of regeneration temperature on amount of dehumidified water

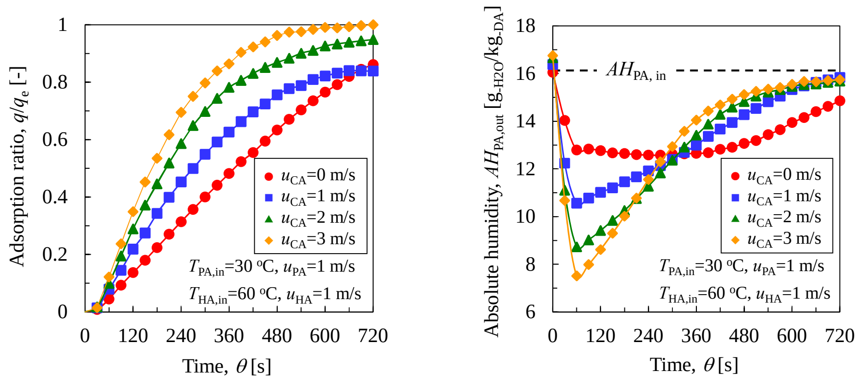
Unique ***S-shape*** water adsorption isotherm



✓ Adsorber with ALPO zeolite kept a high amount of dehumidified water even at **regeneration temp. of 60 °C.**

ALPO zeolite is effective for low-temp. regeneration.

Effect of cooling air velocity on dehumidification performance



(a) Adsorption ratio

(b) Outlet absolute humidity of process air

Fig. Time changes in adsorption ratio and absolute humidity at various cooling air velocities

◆ ***Adsorption rate***

✓ **Cooling air velocity ↑ ⇒ Adsorption rate ↑**

e.g. u_{CA}=0 m/s: q/q_e=0.48 at 360 s ⇔ u_{CA}=3 m/s: q/q_e=0.86 at 360 s

↑

Heat transfer between adsorbent and cooling air ↑

Cooling of the adsorber was effective to promote adsorption rate.

◆ ***Outlet absolute humidity***

✓ **Cooling air velocity ↑ ⇒ Lowest absolute humidity ↓**

e.g. u_{CA}=0 m/s: $AH_{PA,out}$=13 g/kg-DA ⇔ u_{CA}=3 m/s: $AH_{PA,out}$=7.5 g/kg-DA

Hypothesis:

For comfortable indoor air quality,
dehumidified air at 25 °C and RH=50 % would be supplied in a room.
= Lowest absolute humidity have to reach 10 g/kg-DA.
⇒ **Air cooling over u_{CA}=1 m/s is required** for practical use.

Cross-flow heat exchanger type adsorber with ALPO zeolite has a potential to supply dehumidified air at a lower AH with high utilization ratio of adsorbent.

Conclusion

- ◆ Air cooling was effective to enhance water adsorption rate (=dehumidification rate) by removing both sensible heat of adsorber and heat of adsorption.
- ◆ Adsorber with ALPO zeolite kept a high amount of dehumidified water even at regeneration temp. of 60 °C.
- ◆ As increasing cooling air velocities, an initial adsorption rate increased and the lowest absolute humidity decreased during dehumidification process.
- ◆ Dehumidified air at absolute humidity of 10 g/kg-DA, which is a target of process air for supplying into the room, could be obtained by flowing cooling air at its velocity over 1 m/s.

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