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NEW ADSORPTIVE HONEYCOMB DEHUMIDIFIER ROTORS USING ION EXCHANGE RESIN

(Odor Prevention in Desiccant Air Conditioning)

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ABSTRACT

A dehumidifying honeycomb rotor impregnated with ion exchange resin was developed to solve the odor transfer problem encountered in honeycomb dehumidifiers operating in a total heat exchange mode. The dehumidifying efficiency was examined and compared with the SSCR-U metal silicate rotor to confirm that the ion exchange resin rotor has a high performance sufficient to work in the desiccant air-conditioning system in spite of a little less efficiency than the metal silicate rotor.

INTRODUCTION

A desiccant air-conditioning has been attracting attention as a potential system to utilize waste heat efficiently in the co-generation combined with various private power generators because it is activated with low level thermal energy such as solar heat or waste heat.

The whole system of desiccant air-conditioning works mainly in summer for cooling but just a honeycomb dehumidifier is operated in other seasons, too, for the total heat exchange. In this cases the odor substance adsorbed from polluted return air happens to be supplied back to the room by desorption with fresh outdoor air. This odor transfer problem was discussed in detail for the total heat exchangers and solved by the substitute with ion exchange resin for adsorbent[2,3]. In the present study the same method to prevent odor transfer was applied to the dehumidifier rotor and the dehumidifying performance of a rotor manufactured with ion exchange resin has been examined for all-season running of the desiccant air conditioning system.

DESICCANT AIR CONDITIONING AND TOTAL HEAT EXCHANGE USE

In a typical desiccant air-conditioning system[1,4] as shown in Fig.1, moisture in the outdoor air is first removed by a honeycomb dehumidifier (1→2). The adsorption heat generated is removed by a sensible heat exchanger (2→3). Further the air is cooled by an evaporative cooler and then supplied to a room(3→4). The adsorbent rotor is regenerated by a suitable heat source and the moisture dedsorbed is exhausted out of the system(7→8→9).

In winter and the intermediate seasons, honeycomb dehumidifiers may be used as total heat exchangers by increasing the rotation speed up to several rpm to recover both sensible and latent heats and to upgrade the total utilization of the desiccant air-conditioning. Unexpected generation of offensive odor from a dehumidifying rotor happens along with the moisture transfer as follows. When the outer air humidity increases rapidly in early spring or in the rainy season, the adsorbed amount of water vapor on the adsorbent increases and odor substance having been adsorbed is purged and got back to the room by the so-called substitution adsorption.

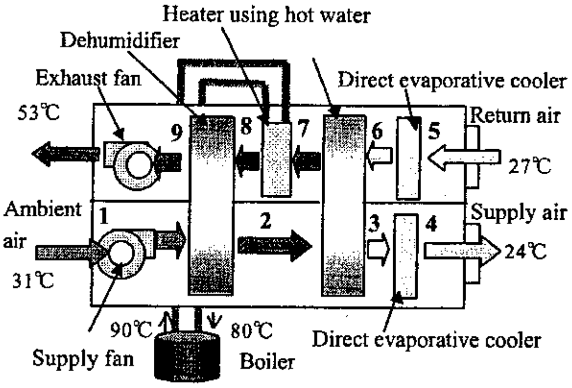

Fig.1 A typical system of desiccant air-conditioning

Silanol radical(Si-OH) on porous silica gel has a very strong affinity to water vapor and offensive odors as well. Water-soluble odors dissolve in water adsorbed by capillary condensation. Therefore the odor transfer cannot be avoided with porous adsorbents like silica gel. A strong acid cation exchange resin used in the present study has sulfonic acid radicals($-SO_3H$) as fixed ions and sodium(Na^+) and others as counter ions. Hygroscopicity in ion exchange resin is generated by a difference between external water vapor pressure and internal pressure balanced to hydration/osmotic pressure.

Table 1 Comparison of specifications of rotors

	Ion ex. resin rotor	SSCR-U
Application	Air condition	Industry
Matrix	Ceramic fiber	Ceramic fiber
Binder	Inorganic	Inorganic
Adsorbent type	Ion exchange resin	Metal silicate
Carrying methods	Carrying by impregnating	Carrying by Synthesis reaction
Honeycomb size	AS−31	AS−31
Channel pitch [mm]	3.4	3.4
Channel height [mm]	1.8	1.8
Number of cells [$1/m^2$]	3270	3270
Reactivation temperature [℃]	~100	~140
Heat resistance [℃]	120	200
Flammability	Flame resistant	Incombustible
Burned or Not	Burned	Burned
Bulk density [kg/m^3]	221.3	207.8
Adsorbent content [wt%]	48.1	44.53
Rotation speed [rph](at 2m/s)	25.7	20

The inside of the resin is kept at a pressure considerably higher than in the electrolyte solution with an open surface. Due to this internal pressure, even water-soluble odor ingredients hardly dissolve into the water inside the resin and thus odors are hardly adsorbed/accumulated.

DEHUMIDIFICATION PERFORMANCE

Dehumidification Test

The dehumidification performance was examined in a small test device with rotors of 300mm in effective diameter. Table 1 shows specifications of the rotors used. The SSCR-U rotor is an improved version of the SSCR series of metal silicates adsorbent. The ion-exchange resin rotor(IER rotor) was manufactured by impregnating with ion-exchange resins by a dipping method. A mirror-type dew point meter was used to obtain absolute humidity from the dew point temperature. Thermocouples were used to measure each temperature.

Figure 2 shows the amount adsorbed of water on the rotor honeycombs. The IER rotor has less amount adsorbed than that of the SSCR-U rotor in low humidity air, but the amount adsorbed increases suddenly at high humidity and exceeds that of the SSCR-U metal silicate rotor in the atmosphere of relative humidity higher than 75%.

Dehumidification Performance

The IER rotor has less efficiency by about 20% in dehumidified quantity of ΔX as shown in Fig.3 in comparison with the SSCR-U rotor of highest efficiency among the metal silicate series, but has a wide range of application to the desiccant air-conditioning with an sufficient efficiency. Referring to Fig.4, the air temperatures at the outlet of the dehumidifier is about 3℃ higher for the IER rotor in a low humidity range than that of the SSCR-U rotor, but the difference in temperature becomes less in a high humidity range and disappears at about 20g/kg of humidity of feed air.

Figure 5 shows calculation/comparison of a specific increase in process air enthalpy per dehumidified quantity $\Delta I/\Delta X=(I_{P2}-I_{P1})/(X_{P1}-X_{P2})$. The specific increase in enthalpy is contributed by sensible heat transferred from the regeneration zone by a regenerative heat transfer and by latent heat effect due to an enthalpy difference between heats of adsorption and vaporization. In the IER rotor, the specific enthalpy increase is higher than that in the SSCR-U rotor. In comparing the amount adsorbed between two types of rotors as shown in Fig.4, the amount adsorbed is less in the IER rotor at the relative humidity of 50% or less over which range the dehumidifier rotor works at highest performance. To compensate less amount adsorbed, the IER rotor was forced to rotate at 25% higher speed as shown in Table 1, resulting in the corresponding increase in sensible heat transferred from the regeneration zone.

CONCLUSIONS

Dehumidification performance of the dehumidifier rotor manufactured using ion exchange resin was examined and the dehumidification performance was confirmed to be sufficient to use as a rotor for the desiccant air-conditioning system. With this new dehumidifier rotor free from odor problems, the desiccant air-conditioning system serves as an air cooler in summer and as a total heat exchanger in winter and intermediate seasons. As a result of improvement in the total utilization the market expansion of the desiccant air conditioning is expected in co-generation with various private power generators.

REFERENCES

[1] Kuma, T., Hirose, T., Goto, M. and Kodama, A., ASME Journal of Solar Energy Engineering; **120**, 45-50(1998).

[2] Okano, H., Kuramitsu, R. and Hirose, T., 5th International Symposium on Separation Technology Between Korea and Japan, 618-621 (1999).

[3] Okano, H., Tanaka, H., Hirose, T., Funato, H. and Ishihara, S., ASHRAE Transactions **107**,No.2, 66-71 (2001).

[4] Okano, H., Jin, W., Hirose, T., Kuramitsu, R., Taguri, E. and Nawata, H., Fundamentals of Adsorption, 7, 926-933 (2001)

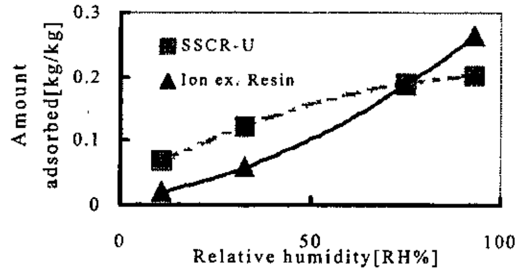

Fig.2 Isotherms of water vapor adsorption

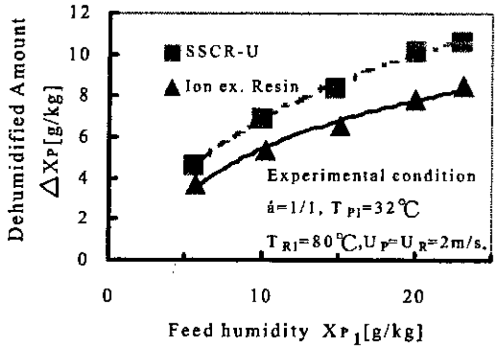

Fig.3 Variation of dehumidified amount with feed humidity

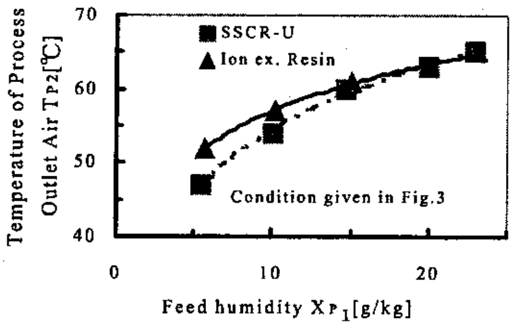

Fig.4 Variation of temperature of process outlet air with feed humidity

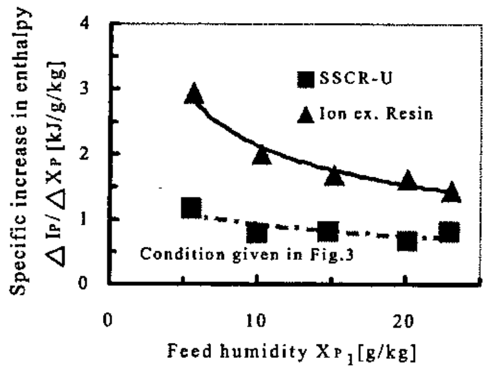

Fig.5 Variation of specific in crease in enthalpy with feed humidity