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Properties of Advanced Adsorbent for Solid Desiccant Cooling*

Cui Qun** Chen Haijun Tao Gang Yao Huqing

(College of Chemical Engineering, Nanjing University of Technology, Nanjing 210009, China)

Abstract: Characteristics of 13x molecular sieve, silica gel and DH-5 and DH-7 prepared by authors, were investigated for the solid desiccant cooling system. The adsorption isotherms of DH-5 and DH-7 were experimentally determined. The performance parameters of adsorption capacity, air humidity, regeneration temperature and cooling volume were tested and discussed in detail. The results show that the properties of new adsorbents DH-5 and DH-7 on desiccant cooling are much better than those of common desiccants. The maximum adsorption volumes of water on DH-5 and DH-7 are 0.72?kg/kg and 0.73?kg/kg, respectively. The desiccant cooling volumes of DH-7and DH-5 are 2.2 and 1.3 times larger than those of silica gel and 13x(molecular sieve), respectively, after regeneration at 100?℃. The cooling volume per mass unit of DH-5 is 1.9 times larger that of 13x.

Key words: desiccant cooling; adsorbent; humidity; adsorption capacity

The desiccant cooling, as a kind of refrigeration method, using surrounding air as working media, cools air by dehumidifying, heat exchanging, increasing humidity and evaporating to dryness. In a desiccant cooling process, Fluorocarbons are not required; moreover, solar energy and low-grade heat source such as waste heat in industry can be used. So it is studied widely now in the U.S., Japan and Europe[1,2], as well as in China[3,4] recently.

The studies of solid desiccant cooling are usually focused on dehumidifier structure, dehumidifier type and the running mode of dehumidifying system. All the studies mentioned above depend on the type and property of desiccant. The commonly used desiccants in desiccant cooling system are lithium chloride and silica gel. Silica gel is a desiccant with high performance, but it can be destroyed after adsorbing a great deal of water and it is not a heat-resistant material. Lithium chloride can adsorb much water, but chemical adsorption will affect the refrigeration volume and lithium chloride is corrosive to equipment. Many desiccants are prepared and selected in this work.

1 Experiment

1.1 Principle

In the desiccant cooling system, moisture in air is adsorbed by desiccant. Air is dehumidified and its temperature increases. Then heat exchanger cools down air and adiabatic evaporation occurs in adiabatic evaporator. Air is then sent into the system, which needs low temperature situation and moderate humidity. So the refrigeration process is accomplished. The air discharged from consumer system is cooled by evaporation. It is sent to a sensible heat exchanger to exchange heat with dry air in the outlet of adsorber. Then the desiccant should be regenerated in the adsorber.

1.2 Adsorption isotherm

The adsorption isotherms of adsorbent DH-5 and DH-7 are determined by using high vacuum weight method. The experiment is carried out in a vacuum adsorption apparatus (See Fig.1), proposed by authors.

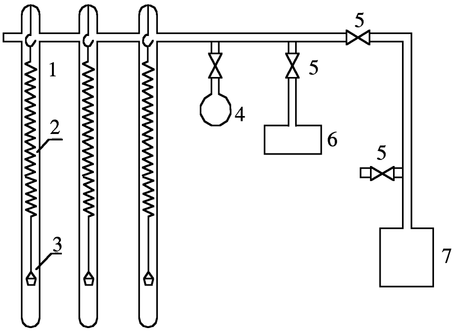

Fig. 1 Measurement device of adsorption isotherm

1. Adsorption tube; 2. Quartz spring; 3. Sample basket; 4. Reagent bottle; 5. Valve; 6. Thin-film vacuum manometer; 7. Vacuum system

The adsorbent sample is activated at 450?℃ for 2? h in a Maffe furnace. Then the adsorbent is put into the

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** Born in 1957, female, associate professor.

basket and the whole system is vacuumized. When the pressure and the temperature are 0.1?Pa and 300?℃, respectively, keep the state for 3?h. Some sample to be adsorbed is steamed in, and the length difference of quartz spring before and after adsorption is measured by cathetometer. The equilibrium adsorption quantities of adsorbent in different pressure are measured. Accuracy of cathetometer is 0.02?mm, and sensitivity of quartz spring is 37 – 40?cm/g.

1.3 Experimental device

In order to select desiccant, desiccant cooling experimental device was built as shown in Fig.2. Air from the air compressor is sent to a buffer. After measured by rotary flowmeter, it is sent to the adsorber and the cooler where moisture is adsorbed and the air is cooled. The temperature of air decreases and its humidity increases at the same time in adiabatic evaporator. The moist air is sent to the consumer.

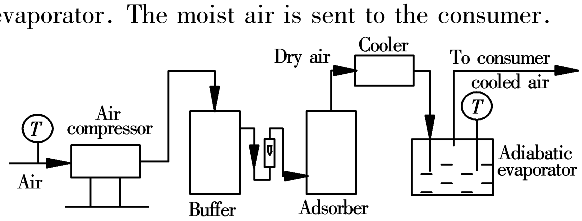

Fig.2 Experimental device of desiccant cooling

The temperature of air is measured by a dry bulb and wet bulb thermometer. The temperature of water in adiabatic evaporator is measured by a precise thermometer. A certain amount of desiccant is weighted and put into the oven. It is heated at a certain temperature for 2 – 4?h and sealed in thermal state for stand-by. The total dynamic adsorption volume is measured by weighting. The evaporating volume in refrigeration process is obtained by measuring the water volume changed in the evaporator.

2 Results and Discussion

2.1 Equilibrium adsorption capacity

Fig.3 and Fig.4 show the equilibrium adsorption volumes of DH-5 and DH-7 increases with the ascending of the aqueous vapor pressure. The maximum equilibrium adsorption volume can reach 0.72?kg/kg and 0.73?kg/kg, respectively, which is far greater than the adsorption volume of common adsorbents, e.g., over two times greater than that of the molecular sieve. Even under the low aqueous vapour pressure(P/P_s = 0.1, P_s is saturation prressure), DH-5 and DH-7 can still have large equilibrium adsorption volume (q > 0.1?kg/kg), which is greater

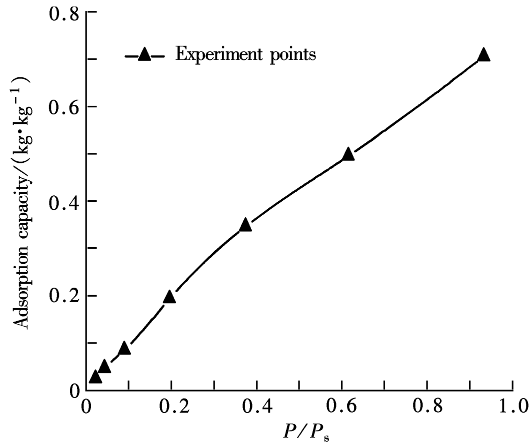

Fig.3 Adsorption isotherm of DH-5 adsorbent-H_2O

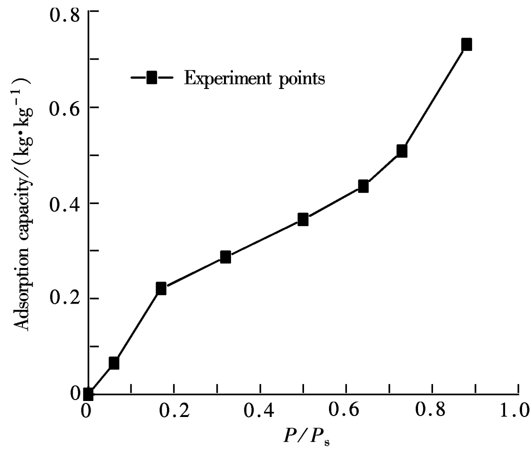

Fig.4 Adsorption isotherm of DH-7 adsorbent-H_2O

than that of silica gel. Thus, DH-5 and DH-7 have good abilities of absorbing water. Its dehydration ability is better than that of molecular sieve used in the dehumidy process of relativly lower relative humidity and its dehydration quality is higher than that of 13x, under higher relative humidity.

Such adsorbent improves the dehydration capability of absorber and increases the refrigeration quality of dehumidity air-condition system.

2.2 Dynamic curves of desiccant cooling

The dynamic performance of silica gel, DH-5 and DH-7 is tested at regeneration temperature of 100?℃. The relationship between time and temperature of water in evaporator is shown in Fig.5. The effect of sensible heat exchanging between water and air in evaporator is neglected for convenience of analysis. The refrigeration volumes of desiccant cooling process are calculated by the evaporating volumes in evaporator and the latent heat of water at corresponding temperature. The effect of desiccant cooling is measured by refrigeration volume of different desiccants.

As shown in Fig.5, all the properties of silica

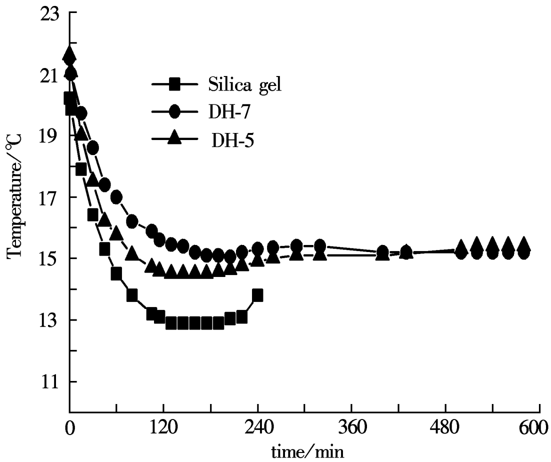

Fig.5 Temperature curve of evaporator

gel, DH-5 and DH-7 can make the temperature of water in evaporator decrease 7 – 8?℃ at low regeneration temperature (100?℃). DH-5 and DH-7 can make the water in evaporator sustain lower temperature for 7-8?h, but only for 1.5?h silica gel does. This shows that DH-5 and DH-7 have larger dehydration capacity. The total refrigeration volume of DH-7 is two times greater than that of silica gel, the refrigeration volume is calculated by the evaporating volume in evaporator. So DH-5 and DH-7 are dehumidifying desiccants with good performance. This type of desiccant is suitable to desiccant cooling system, at which solar energy and other low-grade heat sources can be used.

2.3 Effect of regeneration temperature on refrigeration volume

In order to find the desiccant with good performance of desiccant cooling at high regeneration temperature, the performance parameters of desiccant cooling system of DH-5 and 13x are tested at different regeneration temperature and air relative humidity. Results are shown in Tab.1.

Tab.1 Desiccant cooling performance of DH-5 and 13x at different regeneration temperature

Regeneration temperature/℃	Air relative humidity/%	Refrigeration volume of DH-5 /(kJ · kg^{-1})	Refrigeration volume of 13x /(kJ · kg^{-1})
300	75	542	516
250	72	682	459
200	88	511	411
150	79	478	
100	63	1?107	

From Tab.1 we can see that the refrigeration volume of DH-5 per desiccant mass is not improved obviously with increasing regeneration temperature. This shows that DH-5 fits the need of desiccant cooling at 100?℃. Although improving regeneration temperature cannot increase refrigeration volume, it has no effect on desiccant cooling performance of DH-5. That is to say that DH-5 can be used in wide temperature range, such as desiccant cooling system using waste gas from car (300 – 500?℃). Tab.1 also shows that the refrigeration volume of desiccant cooling system is affected by air relative humidity.

2.4 Effect of air relative humidity on refrigeration volume

The experiment shows that the performance parameter of desiccant cooling is sensible to work conditions of surrounding. In order to research the effect of air relative humidity on refrigeration of desiccant, the desiccant cooling performance parameters of 13x, DH-5 and DH-7 at different relative humidity conditions were tested. The relationship between refrigeration volume and air relative humidity is shown in Fig.6.

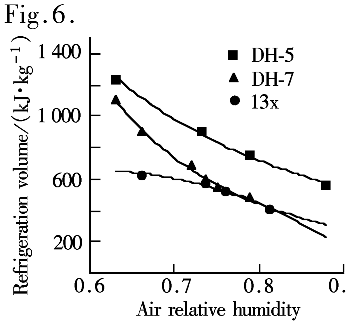

Fig.6 Relationship of refrigeration volume and air relative humidity

The refrigeration volumes of 13x, DH-5 and DH-7 increase slowly if air relative humidity decreases. The moisture in air decreases relatively if the air relative humidity decreases. So the adsorbed water decreases and the saturation time of desiccant increases. This causes the refrigeration volumes of desiccant cooling per desiccant mass increase. The refrigeration volumes of DH-5 and DH-7 increase obviously if the air relative humidity decreases and the increasing range is larger than that of 13x. This shows that DH-5 and DH-7 have large adsorption capacities even with small mass transfer driving force. It seems that DH-5 and DH-7 are desiccants with high performance for desiccant cooling. They have good prospect.

3 Conclusion

Proposed DH-5 and DH-7 have good dehydration capability and well performance of desiccant cooling. DH-5 can be used in a wide range of heat source temperature. The desiccant cooling performance of DH-5 is superior to silica gel at low regeneration temperature (100?℃). Its desiccant cooling volume is larger than 13x at high regeneration temperature (200 – 300?℃). DH-5 and DH-7 have better desiccant cooling capacity in low air relative humidity. They are promising desiccants for desiccant cooling.

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除湿制冷用优良吸附剂的特性研究

崔 群　陈海军　陶 刚　姚虎卿

(南京工业大学化工学院,南京 210009)

摘　要　对自制吸附剂(DH-50,DH-70),硅胶和 13x 的除湿制冷性能进行了实验研究.测定了 DH-5 和 DH-7 吸附剂的吸附等温线;对 DH-5,DH-7,硅胶和 13x 用于除湿制冷过程的动态特性进行了研究;讨论了吸附量、空气湿度、再生温度和单位质量吸附剂的制冷量对固体除湿过程的影响.结果表明:DH-5 和 DH-7 的除湿制冷性能明显优于常规吸附剂(硅胶和 13x).DH-5 和 DH-7 吸附剂的最大平衡吸附量分别为 0.72? kg/kg 和 0.73? kg/kg;在 100?℃条件下再生,DH-7 吸附剂的除湿制冷量是硅胶的 2.2 倍,单位质量吸附剂的制冷量是硅胶 1.9 倍;在较高再生温度(200～250?℃)下,DH-5 吸附剂的除湿制冷量是 13x 的 1.3 倍,单位质量 DH-7 吸附剂的制冷功率是 13x 的 2.2 倍.

关键词　除湿制冷, 吸附剂, 湿度, 吸附量

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