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Adsorption Isotherms and Kinetics of Ethanol onto Powder and Consolidated Activated Carbon

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Abstract

Adsorption cooling systems (ACS) are a feasible alternative to vapor compression cooling systems as they use natural or low GWP refrigerants and can be driven by low temperature waste heat or solar energy. Consolidated adsorbents are one way to reduce the volume and improve the performance of ACS. In this study, we measured and compared the adsorption characteristics of ethanol onto powder and consolidated activated carbon (AC). The consolidated adsorbent was made of 80% AC powder and 20% binder of type Polyvinylpyrrolidone (PVP). The adsorption isotherms and kinetics were measured using a constructed constant volume variable pressure (CVVP) apparatus. The equilibrium adsorption uptake of ethanol per unit mass of adsorbent agreed fairly with that measured by thermogravimetric analyzer (TGA). We found that the adsorbed mass in consolidated material (powder + binder) were lower of 20% comparing to powder AC. Also, the adsorption rate in powder sample was faster than that of consolidated sample as consolidation decreased the permeability. The measured adsorption characteristics will be helpful in designing more compact and efficient adsorption cooling system.

1. Introduction

Adsorption cooling systems (ACS) have numerous advantages over vapor compression systems in air-conditioning and refrigeration applications. Low grade waste heat such as heat dissipated from car engines, industries or solar energy can be used to drive ACS [1]. Moreover, refrigerants used in these systems are natural therefore they do not cause Ozone layer depletion and their global warming potential is zero or negligible. Some examples of such refrigerants are: water [2], methanol, ethanol [3], ammonia, CO_2[4], R1234ze [5]. In this study, a small sized, cost effective CVVP system was designed and constructed to characterize ethanol adsorption onto consolidated activated carbon. The data of CVVP apparatus agreed fairly with that of thermogravimetric apparatus for ethanol adsorption onto ACP. The consolidated adsorbent is composed of 80% activated carbon powder (ACP) of type Maxsorb III and 20% binder.

2. Experiment

Adsorbent was dried for several hours at 120°C before the measurement. Then the adsorbent is placed inside the adsorption chamber and regenerated with vacuum pump at 80°C for several hours. After that the adsorption temperature is set

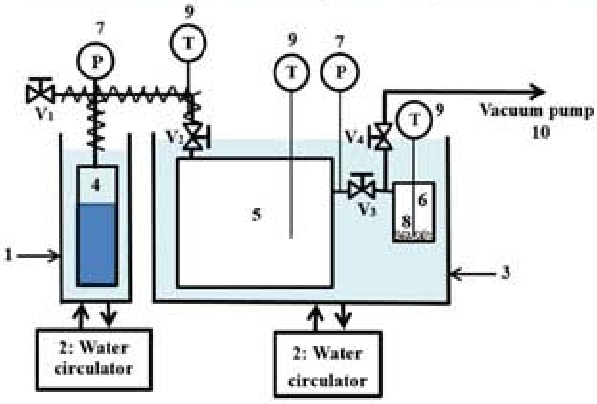

Fig. 1: Schematic of Constant Volume Variable Pressure (CVVP) experimental apparatus

with water bath-II. The charging cylinder is connected to saturated ethanol cylinder and charging pressure is regulated by controlling the temperature of water bath-I. Charging pressure and temperature were recorded after achieving equilibrium condition. The charging cylinder is connected to adsorption chamber and instant pressure and temperature variations in charging and adsorption cylinders were recorded using data logger.

3. Results and discussion

The experiment have been carried at 30°C adsorption temperature with AC powder. As shown in Fig. 2, the uptake points from CVVP fairly agrees with TGA data.

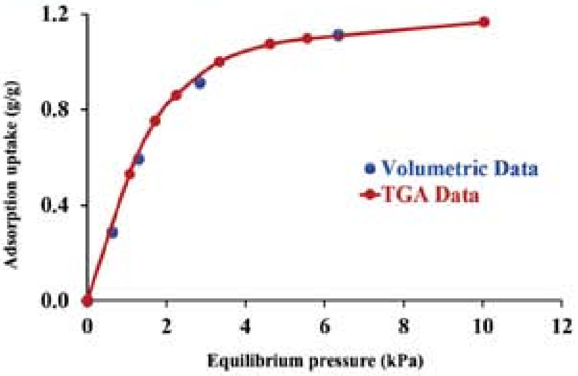

Fig. 2: Comparison of adsorption uptake (g/g) with Thermogravimetric Analysis (TGA) for AC powder

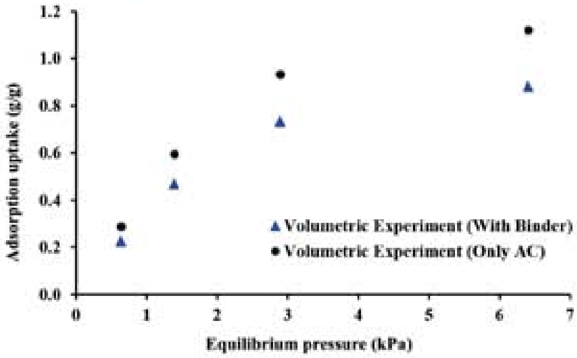

Fig. 3: Equilibrium adsorption uptake of ethanol onto powder (points) and consolidated (blue triangles) activated carbon measured with CVVP apparatus

Consolidated AC sample adsorption isotherm is shown in Fig. 3. The binder itself has no porous property and do not contribute to the adsorption. Thus, adsorption uptake (g/g) points in Fig. 3 were lower of 20% than that of AC powder. According to Fig. 4, adsorption rate is much faster for AC powder whereas, for the consolidated sample, the kinetic is very slow and takes about 30 minutes to reach equilibrium. Temperature profile during adsorption is shown in Fig. 5. At the beginning, the adsorption temperature rises about 9°C for the powder sample whereas, for the consolidated sample, temperature increment is about 31°C.

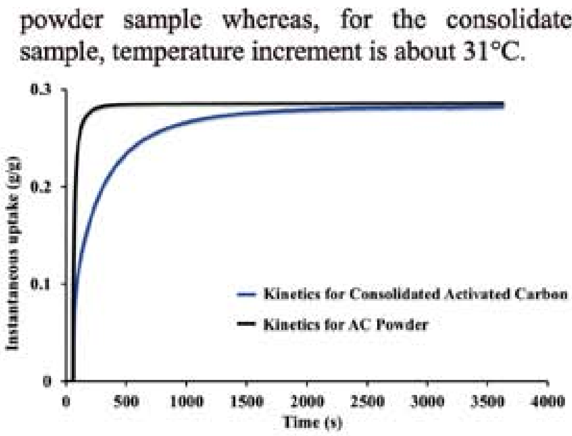

Fig. 4: Adsorption kinetics comparison - AC Powder vs. consolidated sample

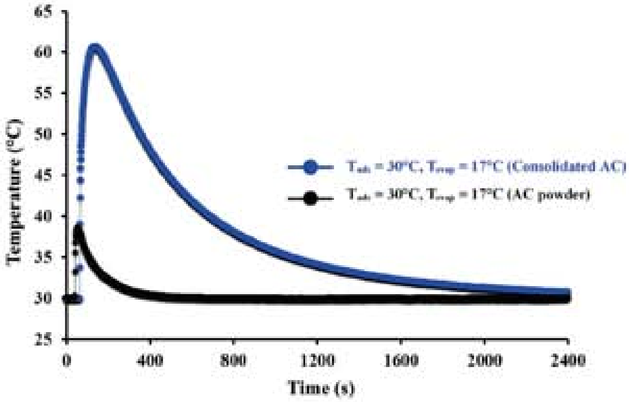

Fig. 5: Adsorbent temperature comparison – AC powder vs. consolidated sample

4. Conclusions

A CVVP apparatus have been designed and constructed to characterize adsorption of ethanol. Accuracy of the CVVP apparatus was verified first by comparing AC powder isotherm data with TGA. Consolidated sample have been prepared and adsorption isotherm, kinetics and temperature profile of the prepared composite sample have been measured using the CVVP apparatus. Adsorbed refrigerant amount is approximately 20% lower for consolidated sample than the powder one. However, adsorption kinetics have been decreased due to the consolidation.

5. References

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