Capture Carbon Dioxide in Flue Gas by Pressure Swing Adsorption Technology

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Introduction

The concentration of carbon dioxide in the atmosphere has gradually increased. According to the report by NOAA in February 2021, the average CO_2 concentration in the atmosphere has risen to 416.67 ppm. In order to slow down the greenhouse effect and global warming, many countries have begun developing CO_2 capture technologies. The most promising commercial application of CO_2 capturing is chemical solvent absorption, but its energy consumption is high. Therefore, this study uses solid adsorbents to capture CO_2 in flue gas of coal power plants by pressure swing adsorption process, attempting to capture CO_2 dioxide in a way of solvent-free and low energy consumption.

Experimental Results

This research started with the screening of solid adsorbents in the laboratory, the CO_2 adsorption isotherm experiments were run by a small amount of different molecular sieves (the test equipment is shown in Fig.1). The parameters of Langmuir were obtained from the experiment data and used to calculate the working capacity of carbon dioxide for per unit adsorbent (the results are shown in Fig.2). The results indicated that the performances of those molecular sieves were similar at 45 ℃, but molecular sieve C performed slightly better than the others at 25 and 70℃, as well as the maximum adsorption capacity. Finally, the molecular sieve C was selected to be the adsorbent to capture CO_2 in the flue gas of coal power plants.

The carbon dioxide capturing test platforms are installed in containers (Fig.3). When necessary, the containers may be transported to the any power plant for carbon capture experiment. In this study , we captured CO_2 with the 3-Bed-9-Step VPSA (Vacuum Pressure Swing Adsorption) CO_2 separation process with molecular sieve C (the process diagram is shown in Fig.4, the 3-Bed equipment is shown in Fig.5). First, we applied the compressed gas cylinders to simulate the flue gas of power plant to carry out 3-Bed-9-Step VPSA CO_2 separation process. The results are shown in Fig.6, which confirms that the feed carbon dioxide concentration is stable at 12.9±0.1%, and the CO_2 concentration after separation can reach 95.4±0.8% after 5^{th} cycles-preliminarily confirms that the operation process is normal. Hereafter, the VPSA CO_2 separation process carried out with the flue gas of power plants. The results are shown in Fig.7, which shows the CO_2 concentration after separation can reach 92.53% after 7^{th} cycles, and the average concentration is 93.70±0.81%. The results confirmed that VPSA CO_2 separation process can successfully separate the flue gas of power plants.

The 100-hour long-term carbon dioxide separation from the flue gas test was carried after confirming that the process and equipment are in line with the designed performance. After analysis, the experiment data indicated： 1. the concentration of CO_2 in the feed flue gas was 11.32~13.16 % with a concentration fluctuation of about 1.8%, 2. the CO_2 concentration after separation can stably reach 90% after 6^{th} cycles, 3.the highest concentration can reach 94.83%, 4. the average CO_2 concentration after separation can stably reach 91.66±0.64 %, and 5. the process reached a cyclic steady state after 56^{th} cycles. The CO_2 concentration after separation would increase when the concentration of CO_2 in the feed flue gas was raised (Fig.8), and the energy consumption of the vacuum pump of VPSA process was estimated 1.39 GJ/ton CO_2. This study confirmed that the VPSA process can lastingly and stably separate the CO_2 in flue gas.

Future

The prototype of VPSA process is the first facility of TPC which separates CO_2 from flue gas by solid adsorbents. The VPSA process can be improved by upgrading several components such as temperature balancing control, VPSA main process control, electrical system control, and recording and controlling equipment. The upgrade will increase the efficiency and stableness of CO_2 capturing process from the flue gas of coal power plants, and the overall performance of the VPSA process may be thus improved, too.

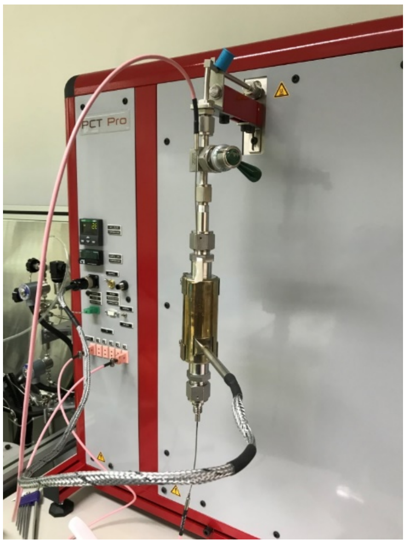

Fig.1 Equipment for measuring carbon dioxide adsorption capacity of solid adsorbent.

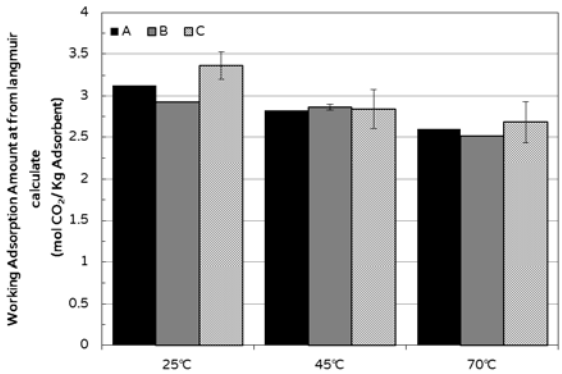

Fig.2 Comparison of the working capacity of CO_2 for various molecular sieves.

Fig.3 Containers of VPSA facility (two 20-foot yellow and blue containers).

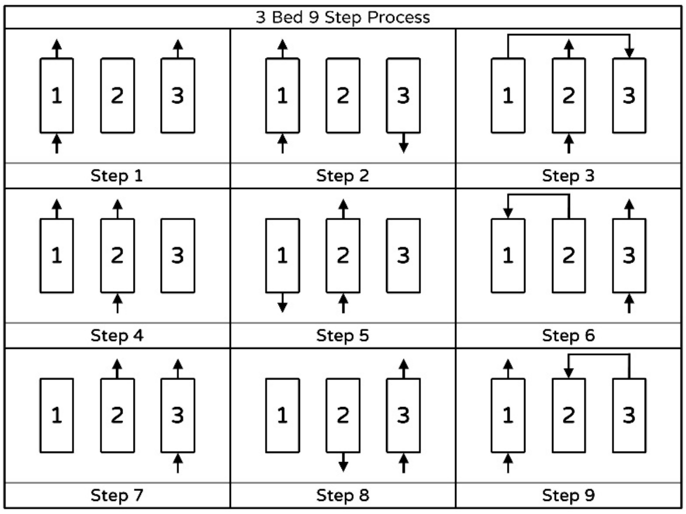

Fig.4 Process diagram of 3-Bed-9-Step VPSA CO_2 separation.

Fig.5 The main facility of 3-bed pressure swing adsorption CO_2 separation.

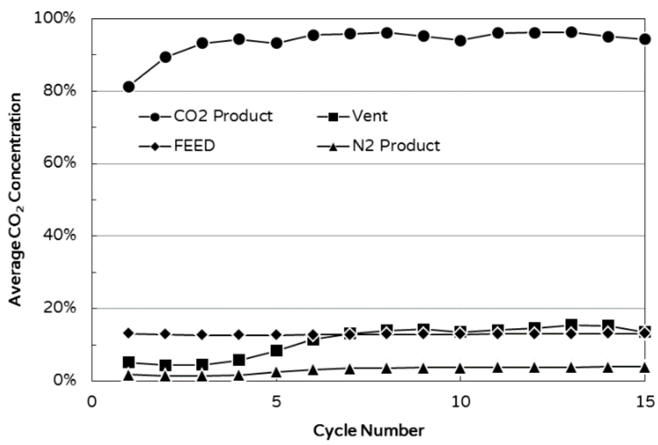

Fig.6 Average concentration of CO_2 in each cycle (feed simulate the flue gas by mixing compressed gas cylinders)

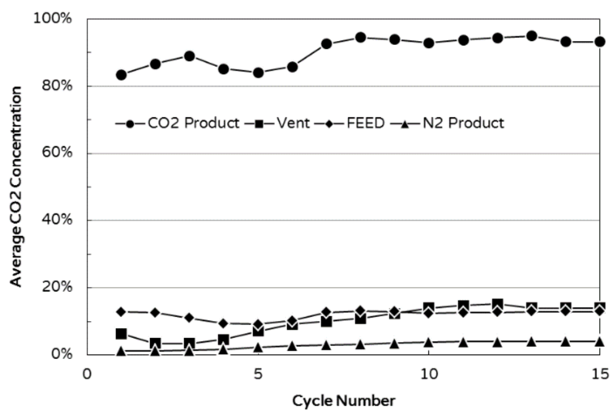

Fig.7 Average concentration of CO_2 in each cycle (feed the flue gas)

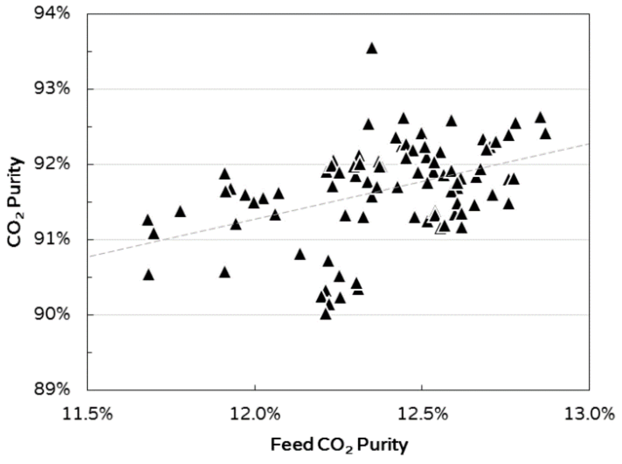

Fig.8 The concentration of carbon dioxide after separation vs. the concentration of carbon dioxide in feed flue gas.