Technology

Development of CO_2 capture technology using amine adsorbents
- Adsorption characteristics when steam regeneration -

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1. Introduction

In order to achieve the government's goal of virtually zero CO_2 emissions by FY2050, it is important to capture CO_2 at high yield not only from large-scale CO_2 emission sources such as thermal power plants, but also from dispersed small- and medium-scale CO_2 emission sources (50 tons or less per day). In addition, to develop CO_2 capture as a business, its cost reduction is desirable. We have commercialized a CO_2 capture PSA (Pressure Swing Adsorption) system with a capacity of 10 tons per day, targeting small- and medium-scale CO_2 emission sources in April 2023 [1], and are currently conducting joint research with Hiroshima University to develop a lower-cost and higher-yield CO_2 capture system.

CO_2 capture using aqueous amine solutions, which are often used for large-scale capture, requires energy equivalent to the latent heat of evaporation of water in addition to CO_2 desorption. On the other hand, CO_2 capture using amine adsorbent does not involve a solvent, so the energy equivalent to the latent heat of evaporation of water is not required. Furthermore, by applying a process to desorb the adsorbed CO_2 with low-grade, inexpensive steam, PSA that can capture CO_2 at a concentration of 98% or higher with high yield and at low cost can be realized. In order to achieve this, we have been evaluating the CO_2 adsorption behavior of amine adsorbents regenerated with steam [2),3),4)] and are aiming at CO_2 capture from flue gas containing CO_2 emitted from lime furnaces, etc. by using amine adsorbents (adsorbents with amines supported on porous supports). This report introduces the methods used to evaluate amine adsorbents and to study equipment operating conditions.

2. Evaluation test method and test conditions

Table 1 shows the evaluation test conditions and Figure 1 shows the evaluation test equipment.

This test evaluated the CO_2 adsorption behavior during the adsorption process by supplying humidified N_2 gas containing CO_2 to the adsorption column and analyzing the CO_2 concentration in the gas flowing out of the secondary side of the adsorption column.

Table 1 Evaluation test conditions

	Condition 1	Condition 2	Condition 3
Adsorption gas		N_2 + CO_2 gas	
Adsorption Temperature		110℃	
Regeneration temperature		110℃	
Adsorbent amount		36 g	
Packed bed height		0.14 m	
Regeneration method	Dry N_2	Steam	Steam + N_2

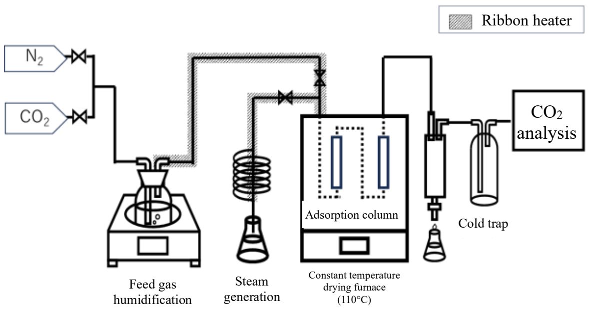

Figure 1 Evaluation test equipment

3. Evaluation results of adsorption characteristics of adsorbent regenerated with steam

Figure 2 shows the analysis results of CO_2 concentration during the adsorption process.

Under Conditions 1 and 3, the concentration of CO_2 flowing out of the adsorption column increased at 2 min, whereas under Condition 2, it started to increase at 3 min. This means that the adsorption column using the amine adsorbent regenerated with steam started to release CO_2 at a later point in time. In addtition, under Conditions 1 and 3, after the CO_2 release started, the relative CO_2 concentration increased rapidly to around 0.8 and then slowly, and adsorption equilibrium (relative CO_2 concentration = 1.0) was reached at 40 min. In contrast, under Condition 2, the concentration of flowing-out CO_2 increased gradually immediately after the start of CO_2 release and adsorption equilibrium was reached at 18 min.

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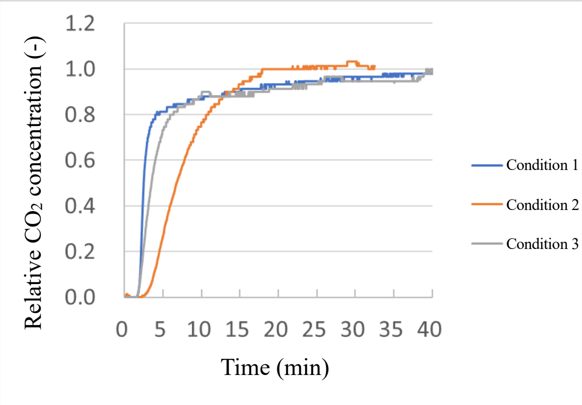

Figure 2 Result of CO_2 concentration analysis result during adsorption process

One of the reasons for the difference in CO_2 adsorption behavior is probably the influence of the CO_2 adsorption properties of the supported amine.

Typical reaction equations of amine and CO_2 are shown in Equations (1) and (2) [5].

$$2R_1R_2NH + CO_2 \rightarrow R_1R_2NCO_2^- + R_1R_2NH_2^+ \quad (1)$$
$$R_1R_2NH + CO_2 + H_2O \rightarrow HCO_3^- + R_1R_2NH_2^+ \quad (2)$$

(Rn: alkyl group, etc.)

The reaction of Equation (1) proceeds without the presence of water, but the reaction of Equation (2) requires the presence of water. Under Condition 1, since the adsorbent is regenerated with dry N_2, the adsorbent is dry and water is not present at the beginning of the adsorption process. Therefore, the reaction of Equation (2) does not proceed at the beginning of the adsorption process, and the reaction of Equation (1) proceeds preferentially. Subsequently, as the water in the feed gas is adsorbed, the reaction in Equation (2) proceeds. Therefore, it takes time to reach adsorption equilibrium.

Under Condition 2, the adsorbent has adsorbed water due to the regeneration with steam. As a result, the reaction between Equations (1) and (2) proceeds from the beginning of the adsorption process, and the amount of CO_2 adsorbed at that time is larger than under Condition 1. This causes the CO_2 release to start later. In addition, since the reaction starts from the beginning of the adsorption process, the adsorption equilibrium is reached earlier.

Under Condition 3, regeneration with steam is followed by purging with N_2, by which water is desorbed, the same trend as in Condition 1 is observed.

As described above, we found that the CO_2 adsorption behavior of amine adsorbent differs when regenerated with dry N_2 and when regenerated with steam. In addition, since this evaluation method was able to reproduce the reaction of the supported amine in the presence of water, we concluded that the process using steam and the evaluation of the adsorbent were feasible.

4. Conclusion

By utilizing the evaluation method as shown in this paper, we aim to develop a CO_2 capture system for CO_2 capture applications for small- and medium-scale CO_2 emission sources that can achieve gas costs equivalent to their current market price through further investigation of a practical process using adsorbents and steam.

5. Acknowledgements

We would like to express our deepest gratitude to Professor Ichikawa, Associate Professor Tsunoji, Specially Appointed Professor Mochizuki, and Researcher Okamura of the Graduate School of Advanced Science and Engineering, Hiroshima University, for their cooperation, support, and guidance in the research presented in this report.

This paper introduced some of the results obtained through joint research conducted by Associate Professor Tsunoji under the Intensive Support Program for Young Promising Researchers (JPNP20004) funded by the New Energy and Industrial Technology Development Organization (NEDO).

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