CO_2 ADSORPTION WITH ATTRITION OF DRY SORBENTS IN A FLUIDIZED BED

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Introduction

A number of techniques have been used for separation of carbon dioxide, one of the main greenhouse gases, from flue gas streams. Of these techniques chemical absorption and fixed bed process are commercially operated. The chemical absorption process can control carbon dioxide with high removal efficiency, but it is a very energy intensive process for carbon dioxide removal and has a problem with corrosion. In addition, fixed bed process is simple to operate, but it also requires much energy for carbon dioxide control, and can not treat high volumes of flue gases. Therefore, new technology is required to decrease the cost for carbon dioxide control and to treat high volumes of flue gases.

A fluidized bed is known as a proper process to control high volumes of flue gases, and dry sorbents can be used to cut down the cost for control, so the use of dry sorbents in a fluidized bed is considered as a proper process to remove carbon dioxide economically[1)]. However, research is required for developments of the fluidized bed process with dry sorbents which have low attrition and high adsorption capacity for carbon dioxide.

Therefore, in this study, activated carbon, activated alumina, molecular sieve 5A, and molecular sieve 13X, which have been used in fixed bed process, are used as dry sorbents to control carbon dioxide in a fluidized bed. In addition, the characteristics of CO_2 adsorption and attrition of the dry sorbents are investigated. The objective of this study is to provide basic data for process development.

Experimental

Apparatus and procedure for attrition experiment. Three-hole air jets used by Gwyn on the basis of a research of Forsythe and Hertwig[2)] were used to investigate attrition of dry sorbent with fluidization.

Air came from a compressor (Hanshin piston), moisture and particles in the air are removed, passing a trap, and mass flow controller (5850E, Brooks Co.) controlled air flow rate. The dry sorbents after the attrition were collected, and the particle sizes of them were measured by sieves of 60, 80, and 140 mesh size.

Apparatus and procedure for adsorption experiment. An experimental fluidized bed reactor has a 6cm diameter and 95cm height, and the air box of the reactor has a 10cm height. The distribution plate was made to 3.11% fractional opening and 3mm thickness, considering pressure drop in the bed. The cyclone was made by standard proportion. This reactor was made from acryl.

Air flow rate was controlled by a flow meter, CO_2 (99.9%) flow rate was controlled by mass flow controller (5850E, Brooks Co.), and then 10% CO_2 inlet concentration was maintained by mixing in a mixing chamber. CO_2 outlet concentration was also measured by CO_2 analyzer (Landfill Gas Analyzer), and the pressure in the reactor was measured by pressure sensors and analyzed by a computer program.

Results and Discussion

The particle sizes of activated carbon were measured after the fluidization for 0, 10, 20, and 30 hours at 10L/min gas flow rate to investigate the attrition characteristics with fluidization time. At each time point, the weight of particles remaining in 60 mesh sieves was 44.10g, 42.05g, and 41.07g, and the weight of carryover particles was 3.69g, 5.32g, and 5.90g, so the attrition of dry sorbents was considered to occur in the beginning of fluidization. Furthermore, carryover particles were considered as the standard to estimate attrition of dry sorbents because their particle sizes were less than 140 mesh size.

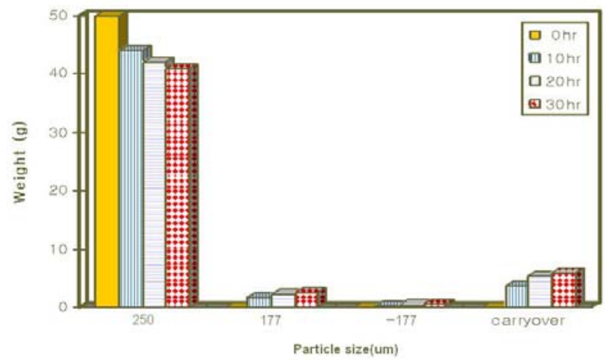

Figure 1. Particle size distribution of activated carbon with time at 10L/min gas flow rate.

Gas velocity is an important operating condition in the fluidized bed process, and it can highly affect the attrition of dry sorbents. Therefore, this study measured the weight remaining in the bed with fluidization time for a gas velocity of 20.59 cm/s, 25.74 cm/s, and 30.89 cm/s to estimate the attrition of dry sorbent with gas velocity. As shown in Fig. 2, attrition mainly occurred in the early stage of fluidization. The attrition rate decreased with time, and the regression equations fit natural log functions. In addition, Fig. 2 showed that the attrition of dry sorbents is highly affected by air velocity in the fluidized bed process.

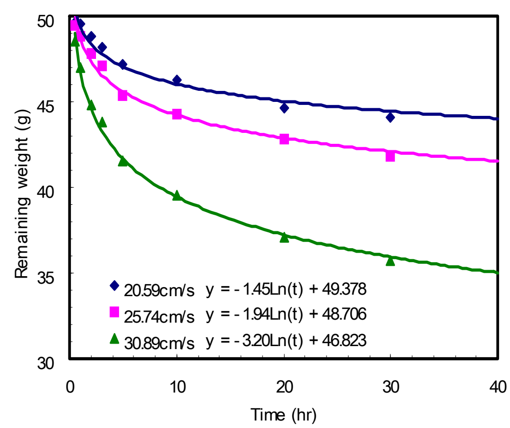

Figure 2. The remaining weight with time for attrition of 40/60mesh activated carbon.

Fig. 3 shows the remaining weight of dry sorbents with time. For every dry sorbent, attrition mainly still occurs in the early stage of fluidization. Moreover, using AI (Attrition Index) on the basis of the weight after 5 hours, the AI of molecular sieve 5A and molecular sieve 13X presented 2.1~4.0-fold higher than the AI of activated carbon and activated alumina. Therefore, the use of them in a fluidized bed can cause high maintenance cost for dry sorbent and problems in the operation of a process.

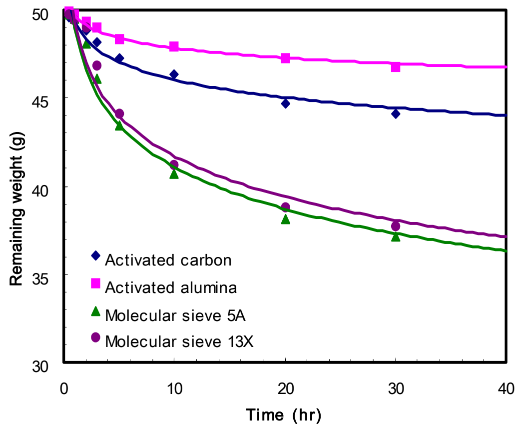

Figure 3. The remaining weight with time for attrition of dry sorbents.

Fig. 4 and Fig. 5 are CO_2 adsorption breakthrough curves and adsorption capacity with dry sorbents. These adsorption experiments were carried out in the operating conditions with an aspect ratio of 2 (L/D) and 12 cm/s gas velocity. The breakthrough points defined as the points in the 5% of inlet concentration were 1.65 minutes for molecular sieve 5A and 1.46 minutes for molecular sieve 13X, and those values were 2.47~3.0-fold higher than activated carbon and activated alumina.

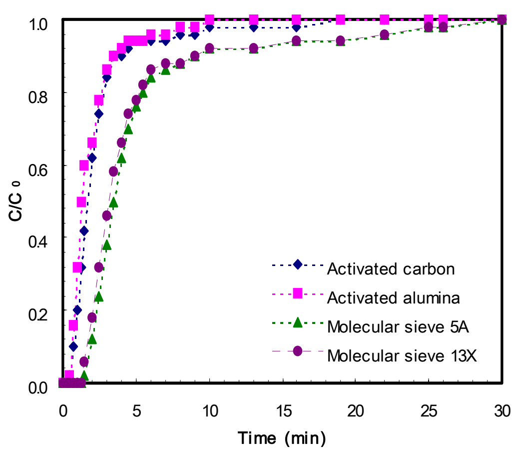

Figure 4. CO_2 adsorption breakthrough curves with dry sorbents in fluidized bed.

Furthermore, as shown in Fig. 5, the adsorption capacities, calculated from the area above the curves in Fig. 4, were 2.35mmol/g for molecular sieve 5A, and 2.23mmol/g for molecular sieve 13X, and those values were 1.5~2.7-fold higher than activated carbon and activated alumina. The relatively high value of the adsorption capacity for activated carbon results from relatively high apparent density.

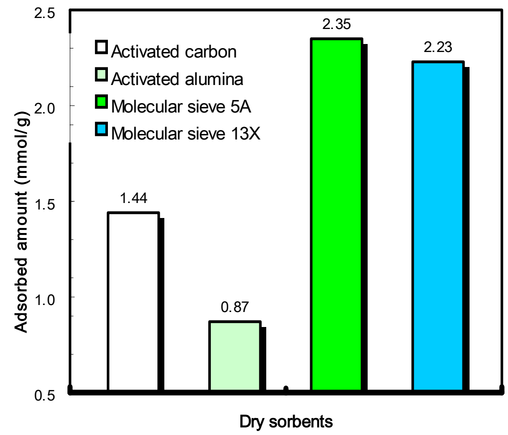

Figure 5. The adsorbed amount of CO_2 with dry sorbents in fluidized bed.

Conclusions

In the fluidized bed process, attrition caused dry sorbent to be carryover. This mainly occurred in the early stage of fluidization and was highly affected by gas velocity. Molecular sieve 5A and molecular sieve 13X presented 2.1~4.0-fold higher attrition than activated carbon and activated alumina, so they possibly cause high maintenance cost for dry sorbent and problems in the operation of fluidized bed process.

On the other hand, the adsorption capacities of molecular sieve 5A and molecular sieve 13X were 2.35mmol/g and 2.23mmol/g, and these values were 1.5~2.7-fold higher than the other sorbents.

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References

(1) Hoffman, J. S.; Pennline, H. W.; "Study of regenerable sorbents for CO_2 capture," *J. Energy. & Environ. Res.*, **2001**, 1(1), pp. 90～100.

(2) Forsythe, W. L. and Hertwig, W. R., "Attrition characteristics of fluid cracking catalyst," *Ind. Eng. Chem.*,**1949**, 41, pp. 1200～1206.

(3) Cook, J. L.; Khang, S. J.; Lee, S. K.; and Keener, T. C.; "Attrition and changes in particle size distribution of lime sorbents in a circulating fluidized bed absorber," *Powder Technology*, **1996**, 89, pp. 1～8.

(4) Oh, K. J; Lee, S. S; Choi, W. J; Kim, M. C; "CO_2 adsorption characteristics of dry sorbent in fluidized bed.", *Carbon Dioxide Reduction & Sequestration Workshop*, **2003,** pp. 399