

Feasibility Study of Applying a Honeycomb Structure for Direct Air Capture on Vehicles

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Direct Air Capture (DAC) is attracting attention as a carbon dioxide removal technology for compensating residual CO₂ emissions from hard-to-abate sectors such as aviation and shipping. However, because the atmospheric CO₂ concentration is only approximately 400 ppm, a large volume of air must be processed, and the electricity consumption of blowers for air supply remains a major challenge.

In this study, a vehicle-mounted DAC system utilizing airflow generated during vehicle operation was investigated as a blower-free DAC concept. A honeycomb sorbent consisting of an ion-exchange resin (LEWATIT® VP OC 1065) supported on a cordierite honeycomb substrate was evaluated. Fluid simulations were first conducted to estimate the inlet gas velocity within the honeycomb under different vehicle speeds and honeycomb lengths. The results showed that inlet gas velocity increased with increasing vehicle speed, while it decreased with increasing honeycomb length.

Adsorption experiments were performed using ambient air containing approximately 400 ppm CO₂ at 25°C and 70% RH. Adsorption performance was evaluated from breakthrough curves, and the adsorption rate was quantified by t_{80} , defined as the time required to reach 80% of the final cumulative adsorption amount. When the honeycomb length was fixed at 125 mm, increasing the gas velocity from 0.20 to 0.68 m s⁻¹ accelerated breakthrough and reduced t_{80} from 96 min to 51 min. In contrast, when the gas velocity was fixed at 0.20 m s⁻¹, increasing the honeycomb length from 25 to 125 mm extended breakthrough time and increased t_{80} from 37 min to 95 min. These results indicate that higher gas velocities accelerate sorbent saturation, whereas longer honeycombs increase adsorption capacity owing to the greater amount of supported sorbent.

To evaluate the effects of gas velocity and honeycomb length using a unified parameter, the adsorption behavior was analyzed using Space Velocity (SV). The experimental results obtained under different operating conditions were successfully correlated by SV, and a strong relationship was observed between SV and t_{80} ($R^2 = 0.9913$). Furthermore, t_{80} decreased with increasing SV, indicating that sorbent saturation is strongly governed by the air throughput relative to the honeycomb volume.

These findings suggest that, within the experimental range investigated, the saturation time of honeycomb sorbents in vehicle-mounted DAC systems can be estimated from the inlet gas velocity and SV calculated from vehicle speed and honeycomb dimensions. Therefore, SV has the potential to serve as a useful design parameter for predicting adsorption duration and regeneration intervals in practical vehicle-mounted DAC applications.

