Measurements and Simulations on Lab Scale CO_2 Capture Vacuum Pressure Swing Adsorption Pilot Unit using MOF

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Abstract:
Nowadays, power generation and carbon-intensive industries (cement plants, steel plants…) are responsible for around 50% of anthropogenic CO_2 emissions to our atmosphere that mainly contributes to global warming. So, the reduction of CO_2 emissions from industries is crucial. Since several decades, CO_2 capture techniques were investigated to envisage CO_2 storage and chemical reuse. Absorption-regeneration amine-based process, the benchmark solution, suffers from high energy penalties that leads adsorption process a promising alternative thanks to improvement of process design and development of new materials. Among these materials, MOFs appears as very promising materials for both gas separation and purification. However, the performances of these hybrid materials in carbon capture technologies have not been fully evaluated and fine-tuning is still needed for adsorption processes at large scale in real industrial conditions which is the purpose of H2020-MOF4AIR project (https://www.mof4air.eu/).
In this study, several MOFs have been studied to be used in a Vacuum Pressure Swing Adsorption (VPSA) process. MIL-160 (Al)[1,2] have been selected due to it is capacity to keep properties in real conditions (presence of impurities). It was upscaled at 200g-scale and shaped in 2mm-pellets with 3% of PVB by wet granulation. The adsorption performances have been evaluated by pure component adsorption isotherms and breakthrough curves measurements. From these data, a complete simulation of VPSA process using the Linear Driving Force (LDF) model and IAST was performed on Aspen Adsorption® software to evaluate the performances of a VPSA process with MIL-160(Al). A 2-stage VPSA process with 2 columns (Skarstrom cycle with 6 steps including pressure equalization)[3] and a 1-stage VPSA process with 3 columns (with 9 steps including rinse and purge)[4] have been investigated and optimized in order to reach the target of such a process: CO_2 purity of 95% and recovery of 90%. After a first optimization of both processes based on a design of experiments (adsorption time, purge time, purge flowrate, column volume, L/D ratio), the targets are reached for 2-stage VPSA process and close (94% of purity and 91% of recovery) for 1-stage VPSA process that confirms the promising potential of this adsorbent. These simulations allow the design a 3-column VPSA lab scale pilot to treat a CO_2/N_2 (15/85) flow of $1 m^3/h$ with column of 1.1 liters (L/D ratio of 4.3). Moreover, the preliminary measurements carried out with lab-scale pilot confirm the results determined by simulation.

References:

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