# DEVELOPMENT OF ADSORPTION-BASED POST-COMBUSTION $CO_2$ CAPTURE PROCESSES

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## Work-In-Progress Abstract

$CO_2$ capture and Storage (CCS) is being demonstrated worldwide across all sectors at large scale. However, the total capacity of current operating projects, 31 Mt $y^{-1}$, needs to be upscaled to reach a cumulative capacity of 135 Gt by 2050 and of 790 Gt by 2100, to have a 50% chance of holding the global warming to below 1.5 °C by 2100.

Post-combustion $CO_2$ capture processes based on amine absorption are the most mature. However, these have a series of drawbacks, like degradation and corrosion problems, toxic emissions, solvent make-up, and energy intensity. Emerging technologies present a lesser development stage but scope to reduce the energy penalty of the capture process. This is the case of adsorption, which avoids the need of a solvent, and has no associated emissions, being benign to the environment.

Adsorption-based separation processes design depends strongly on the conditions and composition of the gas stream that needs to be separated, on the specification of the products, and on the adsorbent selected. Different adsorption technologies have been considered so far for post-combustion $CO_2$ capture, including fixed bed, moving bed, rotary adsorption beds, and fluidized beds, and different types of adsorbents: carbons, zeolites, MOFs, supported amines, and carbonates. Moreover, the processes also differ in the method of regeneration, with the most common being pressure swing adsorption (PSA), temperature swing adsorption (TSA), concentration swing adsorption (CSA) and a combination of these.

In this work, a fixed-bed process has been designed to capture at least 85% of the $CO_2$ produced by a supercritical coal fired power plant of 800 MWe with a purity of at least 95% (dry basis). The adsorbent considered in the present work is a carbon honeycomb monolith that presents lower pressure drop, higher thermal conductivity, and lower attrition than conventional carbon packed beds. Carbon materials have the advantages of availability, low cost, high stability in the presence of flue gas components, and easy regeneration, although they do show moderate adsorption capacity towards $CO_2$. In the proposed process, the adsorbent is regenerated by steam stripping, which is a combination of TSA and CSA. The steam is generated in situ from the condensate knocked out from the $CO_2$ product and from the flue gas. Indirect heating and cooling is carried out by means of a thermal fluid that circulates axially to the monoliths, which entails reducing the cycle time and thus maximizing productivity. Moreover, the circulation of the thermal fluid between the different units of the process entails conserving thermal energy within the process.

The process performance has been analyzed through dynamic simulation. A dynamic fixed bed adsorption model was built in Aspen Adsorption based on the conservation equations for mass, energy and momentum, resulting in a set of coupled partial differential equations distributed over the time and space domains. The model takes into account competitive adsorption between $N_2$, $CO_2$ and $H_2O$, which are the main flue gas components, making use of the Ideal Adsorbed Solution Theory (IAST). Simulations were run until cyclic steady state convergence criteria were met. Results show that it is possible to decarbonize the flue gas, capturing over 85% of the $CO_2$, and to deliver a product with a $CO_2$ purity above 95% (dry basis) with an energy consumption competitive with the benchmark technology. The energy consumption of the adsorption process depends largely on process design but also on the adsorption equilibrium and kinetics, which are given by the adsorbent characteristics.

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