RESEARCH NOTES

Sorbent Cost and Performance in CO$_2$ Capture Systems

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Power plants are prime candidates to apply CO$_2$ capture for final storage as a mitigation option for climate change. Many CO$_2$ capture concepts make use of a sorption−desorption cycle to separate CO$_2$ from flue gas or O$_2$ from air. These include commercial absorption processes, as well as processes using new sorbent formulations, adsorption, and high-temperature chemical looping cycles for CO$_2$ and O$_2$. All of these new processes must confront the large scale of carbon flows typical in a power plant. In this work, a common mass balance for all of these processes is used to define a parameter that highlights the minimum sorbent performance required to keep sorbent makeup costs at an acceptable level. A well-established reference system for which reliable commercial data exist (absorption with monoethanolamine, MEA) is used as a technoeconomic baseline to show that some of the sorbents being proposed in the open literature might need to be tested under laboratory conditions for tens of thousands of sorption−desorption cycles before they can be further considered as viable options for CO$_2$ capture from power plants.

Introduction

The capture of CO$_2$ from large stationary sources with storage in geological formations is being widely studied as a mitigation option to achieve deep cuts in CO$_2$ emissions from fossil fuels.[1] In the longer term, if biomass is used as the primary fuel, power plants implementing CO$_2$ capture and storage technologies could even become effective net sinks of CO$_2$ from the atmosphere.[2]

There are a wide range of concepts for CO$_2$ capture that make use of a sorption−desorption cycle to separate CO$_2$ from a flue gas (postcombustion capture) or from a fuel gas (precombustion capture). These include commercial processes using amines and physical sorbents, as well as new sorbent formulations for absorption, adsorption, and high-temperature chemical looping cycles for CO$_2$ and O$_2$. The general scheme for all of these processes can be represented in Figure 1 in terms of molar flows of CO$_2$ (F_{CO_2}), sorbent flowing in the capture−regeneration loop (F_R), and sorbent makeup flow (F_0). A similar scheme would be valid for the O$_2$ chemical looping cycles. A makeup flow of sorbent (F_0) is required to compensate for the natural decay of activity and/or sorbent losses during many sorption−desorption cycles. It must be emphasized that this decay is, to some extent, always unavoidable because of a wide range of chemical and physical interactions of the
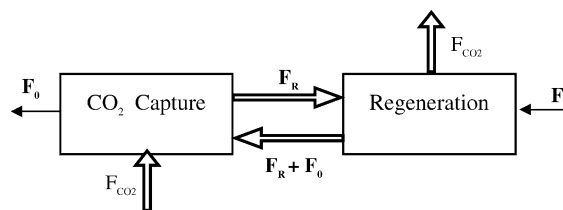

Figure 1. General scheme of a CO$_2$ capture system using a sorption−desorption cycle.

sorbent inside the reactors and transport lines and the sorbent losses associated with gases leaving the system.

CO$_2$ capture systems are in a class by themselves because the mass flows of sorbent circulating in a system such as Figure 1 are very large, at least large enough to match the large molar flow of CO$_2$ being processed in the power plant. For the sake of comparison, it is useful to compare this to the size and scale of the sorbent flows in a flue gas desulfurization unit. The CO$_2$ molar flow in the flue gases of a power plant is typically 2 orders of magnitude higher than the SO$_2$ molar flow, even when processing high-sulfur fuels. Therefore, extremely low values of F_0/F_R are required in order to keep the sorbent makeup cost (and any other costs related to the disposal of spent sorbent) within reasonable limits. This translates into very demanding conditions for the sorbent performance required in the sorption−desorption chemical loop, as will be discussed below. It is beyond the scope of this work to review the wide range of sorbents proposed for capturing CO$_2$ in power plants and their relative benefits arising from specific process conditions. Our aim is only to establish a common link between the expected cost of a sorbent and its expected performance in the sorption−desorption loop of Figure 1.

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