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CO_2 capture by pressure swing adsorption with novel solids sorbents

The reduction of CO_2 emissions to the atmosphere is one of the task in combating the warming of the atmosphere and consequently reducing the negative impacts of global change of the environment. Carbon capture and sequestration (CCS) is considered as one of the options for mitigating the greenhouse gas emission because other methods like: improvement of boiler efficiency, biomass co-combustion not allowed drastically reduce CO_2 emission. The CCS system includes 4 elements: capture and compression of carbon dioxide, transport, injection and storage. Therefore, there are applied and developed technologies for CO_2 capture to become more effective and low cost.

The easiest way to reduce CO_2 emission is post combustion capture from industrial process streams. Nowadays, new built high-efficiency power plant boilers should be capture ready, i.e. to have place to built up CO_2 capture unit. Important thing is also operating and capital costs as well as overall power plant efficiency penalty.

There are five techniques of CO_2 separation: chemical and physical absorption, adsorption, membrane separation and cryogenic separation. Each technology has their optimal fields to be applied to. Chemical absorption suits low concentration of carbon dioxide in flue gases. The physical absorption and membrane separation are suitable for capture of CO_2 from syngas (gas under high pressure). In case of the oxyfuel combustion where the CO_2 concentration is high the cryogenic capture is the optimal solution, and oxygen enriched combustion – adsorption technology. Each of mentioned technologies show advantages as well as disadvantages. Chemical absorption process requires large amounts of solvent – it should be periodically refilled, and thus this process is connected with high investment costs and energy consumption. The physical absorption and membrane separation involve high gas pressures. Additionally membrane techniques have inherent difficulty in achieving high degrees of gas separation while cryogenic ones require significant energy penalty.

Adsorption methods are quite attractive for CO_2 capture mechanism, despite their disadvantages: low capacity of sorbents and influence of contaminants like: SO_2, H_2O on the separation process. There are also advantages of this process: availability, flexibility, fully automated operation of the process and production of high purity product.

The separation can be carried out by pressure swing adsorption – PSA, vacuum-pressure swing adsorption – V-PSA, temperature swing adsorption – TSA, pressure-temperature swing

adsorption – PTSA or electric swing adsorption – ESA (required sorbents which are electrical conductivity) processes. The beds of the installation are filled with solid sorbents. The selectivity depend on difference in adsorption equilibrium or sorption rates and on the effectiveness (concentration and recovery) has significance: cycle configuration, adsorption time, adsorption and desorption pressure, temperature during the process as well as the kind of applied sorbent.

The effective sorbent should characterized: high CO_2 capacity and selectivity, lower regeneration energy and cost. Therefore, last time, there are lot of research to improve efficiency and inexpensiveness of adsorption materials. There are investigations on cation exchanged adsorbents (for instance NaZSM-5, Ba-ZSM-5) which characterize higher adsorption, especially at low partial pressures of CO_2 as well as adsorbents which offers sorption at elevated temperatures – hydrotalcite like compounds. There were also developed low-cost biomass-based adsorbents, like activated carbons, that characterizes comparable and even better capacities than commercial activated carbons. Adsorbents were also synthesized from fly ashes (method of fusion with sodium hydroxide prior to the hydrothermal reaction or the process based on two-stage method realized by dissolve Si source form fly ash and the addition of Al sorce to prepare initial gel which is crystallized under static condition during hydrothermal treatment). Fly ashes coming from fluidized-bed boiler and pulverized coal boiler combusted hard coal, brown coal and biomass were applied. The achieved sorbents: Na-A, Na-X, MCM-41 characterize comparable capacity to commercial ones. Next improvement in effectiveness of adsorbents were their modification by impregnation, for example: polyethyleneimine. This causes the increase the affinity between the adsorbent and CO_2 which enhanced the gas adsorption capacities.

The paper presents the results of carbon dioxide separation applying adsorption process as the one of post-combustion CO_2 capture method. The separation is carried out in the two-bed installation, whose beds were filled with coconut shell steam activated carbon. The parameters of the process like pressure and adsorption time were taken into account. The effectiveness of the process was determined by average concentration of CO_2 in low-pressure product and recovery of CO_2 from feed gas. In the near future, it is planned to carried out the separation on the semi-industrial mobile facility.