CO_2 CAPTURE FROM INDUSTRIAL SOURCES BY HIGH TEMPERATURE SORBENTS

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Key Words: Calcium looping, SEWGS, cement, steel mill, hydrogen

Among the emerging CO_2 capture technologies, systems based on high temperature (HT) regenerable sorbents had a significant development in recent years. In addition to power plants, HT sorbents technologies can be particularly promising for CO_2 capture in carbon intensive industrial processes such as cement plants, steel mills and hydrogen plants.

Calcium looping (CaL) is a combined post-combustion and oxyfuel combustion technology which uses calcium oxide (CaO) as CO_2 sorbent. In this process, CO_2 in combustion flue gases is absorbed in a carbonator reactor by forming calcium carbonate ($CaCO_3$) through the exothermic carbonation reaction. Carbonated sorbent is then regenerated to CaO through the reverse calcination reaction in a calciner, where reaction heat is provided by oxyfuel combustion. A CO_2 concentrated stream is therefore released from the calciner, which can be purified and compressed as in conventional oxyfuel product gas. Calcium looping is particularly promising for application in cement plants, because the raw materials used for the production of clinker (the energy intensive process in cement manufacturing) are rich of $CaCO_3$, which is also the starting material of the CaL CaO sorbent. Therefore, no additional material needs to be imported or is released as waste when CaL is integrated in a cement plant. Two main configurations can be assumed to integrate the CaL process into a cement burning line: (i) the tail-end configuration, where the CaL process is used as a post-combustion, end-of-pipe capture process and (ii) a highly integrated configuration, where the CaL reactors are integrated into the raw meal preheating tower of the clinker production process and the CaL oxyfuel calciner coincides with the raw meal pre-calciner.

Another class of processes where CaO is used as CO_2 sorbent is sorption enhanced reforming (SER) technologies, where CO_2 is absorbed within a steam methane reforming (SMR) reactor. The advantage of this class of processes is that the heat released by sorbent carbonation reaction matches very well with the steam methane reforming reaction. Moreover, the removal of the CO_2 reaction product allows a greater advancement of the reforming and water gas shift (WGS) reactions. As a result, with a SER reactor, a H_2 production and CO_2 separation are performed in a single adiabatic reactor operating at moderate temperature (~650°C) instead of a sequence of reactors for steam reforming (~900°C), WGS (200-400°C) and CO_2 separation (~30°C) operating in a wide temperature range as in conventional H_2 production processes.
In addition to material development, the main challenge in SER technologies is in the endothermic sorbent regeneration step. Several process schemes have been proposed for sorbent calcination, such as: (i) oxyfuel combustion, (ii) high temperature heat exchangers, (iii) direct contact heating with hot solids from a chemical looping combustion loop. Both fluidized bed and packed bed reactors are proposed for SER processes operating at different temperature and pressure range.

If a CO_2 sorbent is active at intermediate temperatures (~400°C), such as in the case of hydrotalcite-based sorbents, it can be adopted in sorption enhanced WGS (SEWGS) processes. As in the SER principle, the in-situ removal of CO_2 form the gas phase allows a higher advancement of the WGS reaction. Therefore, H_2-rich gas production and CO_2 separation can be performed in a single pressurized reactor. While this concept can be adopted in hydrogen production plants, a promising application is in steel mills, where most of the CO_2 emissions are associated to the combustion of the blast furnace gas (BFG) in the steel mill power plant. BFG is a byproduct of the pig iron production process and is a low calorific value fuel rich of CO, CO_2 and N_2. By processing BFG in a SEWGS reactor, a H_2-N_2 stream is produced, which can be burned at high efficiency in a low emission combined cycle.

CaL, SER and SEWGS processes illustrated above for CO2 capture in industry, are being developed in the three ongoing EU FP7 and H2020 projects Cemcap (G.A. 641185), Ascent (G.A 608512) and Stepwise (G.A. 640769). In this work, the potential of these processes in terms of CO2 capture efficiency and energy efficiency will be discussed and compared with benchmark technologies, based on process integration and simulation studies.