Capture and purification processes applied to CO_2 derived from cement industry

by Ir Sinda LARIBI, University of Mons (Belgium)

The present communication is focusing on the application of Carbon Capture (by means of a partial oxyfuel combustion capture process) and flue gas purification (by means of a full oxyfuel combustion capture process) in the cement industry.
Partial oxyfuel combustion capture ($y_{CO2,in}$ = 20-60 vol.%) is an intermediate process that could apply a conventional post combustion capture to flue gases deriving from O_2-enriched combustion. It proposes an optimized operation leading to further reductions of the overall en ergy consumption of the process. In this work, firstly, performances of several solvents were evaluated thanks to screening tests carried out both at lab and micro-pilot scales and considering high CO_2 contents in the gas to treat. Secondly, experimental tests and Aspen Hysys^{TM} simulations have highlighted the interest of the partial oxyfuel combustion capture in terms of regeneration energy.
In the case of full oxyfuel combustion capture ($y_{CO2,in}$ = 70-90 vol.%), a CO_2 Purification Unit (CPU) is simulated for cement plants with Aspen Plus^{TM} . The present communication will be focused on the first step of the CPU, the "Sour-Compression Unit" (SCU), by the evaluation, through simulations, of its SOx and NOx removal performances which depend on the selection of the adequate chemical mechanism. An energetic and economic optimization of the SCU for the cement plant case are under progress.

Modeling and simulation of post-combustion CO_2 capture process using demixing solvents applied to cement flue gases

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Carbon capture is considered as a solution to mitigate industrial carbon dioxide emissions. Among the proposed technologies, post-combustion CO_2 capture with absorption-regeneration using solvents is by far the most advanced technology. However, the use of conventional monoethanolamine (MEA)-based absorption process involves high energy consumption. An innovative alternative to reduce the process energy consumption is a CO_2 absorption process using demixing solvents.
Demixing solvents exhibit a liquid-liquid phase separation, forming CO_2 rich and lean phases, for given temperature and/or CO_2 loading conditions. This phenomenon allows an important energy saving by regenerating only the heavy rich phase, after a separation in a decanter, and thus reduces the energy required for the regeneration step in the stripper. According to IFP Energies Nouvelles (DMX^{TM} solvent), the regeneration energy is reduced from 3.7 GJ/tCO_2 down to around 2.1 GJ/tCO_2 with the use of demixing solvents, which means a 40% decrease of the regeneration energy.
In our study, we will investigate the applicability of this technology to cement plants with the purpose of developing an innovative simulation model allowing to calculate the energy savings linked to the use of such solvents using Aspen software.

Simulations of various configurations of the post-combustion CO_2 capture process applied to a cement plant flue gas: parametric study with different solvents

by Dr Lionel DUBOIS, University of Mons (Belgium)

Different configurations of the absorption-regeneration CO_2 capture process using amine based solvents (MEA 30 wt.%, PZ 40 wt.% and MDEA 10 wt.% + PZ 30 wt.%) were simulated in Aspen Hysys^{TM} considering the Norcem Brevik Cement plant flue gas and the design parameters of the CASTOR European Project pilot. In order to be representative of the three categories of process modifications (absorption enhancement, heat integration and heat pump effect), four process modifications were investigated in the present study, precisely RSR (Rich Solvent Recycle), SSF (Solvent Split Flow), L/RVC (Lean/Rich Vapor Compression). Thanks to a parametric study carried out for each solvent, it was shown that with the heat pump modifications L/RVC the solvent regeneration energy can be reduced by 30% in comparison with MEA and conventional configuration. This work is still in progress with other configurations (e.g. the combination of RVC/LVC with an Intercooled Absorber (ICA)).

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Methodological selection of CO_2 conversion pathways:
First outlook of technico-environmental assessment
by Ir Remi CHAUVY, University of Mons (Belgium)

Carbon Capture Storage (CCS) and Utilization (CCU) are nowadays a well-studied and promising field in order to reduce CO_2 emissions, main driver of global warming. The CO_2 emissions of cement industries represent approximately 5 to 7% of anthropogenic global CO_2 emissions. Carbon capture and conversion is therefore a key issue to this cement sector.

As a multitude of processes and chemical reac–tions exists to convert CO_2 into valuable compounds, at different levels of maturity and performances, an original two-step method is proposed to reduce this panel using selection criteria and indicators developed for this purpose. Therefore, the technological maturity of the conversion route, based on the so-called Technology Readiness Levels (TRL) and timeframe to deployment of the technology, is assessed through a review of CO_2 usage activities around the world. In addition, a criterion evaluating the route potential to convert large volumes is relevant as a best available technology (BAT) cement plant emits around 2500 tons of CO_2 a day. Following this, the second step involves further criteria, mainly based on economic and environmental aspects as well as market considerations, to assess the routes with the help of a weighting matrix specially developed within this study. This second assessment helps to identify the CO_2 conversion routes which are the most suitable to be implemented in the cement sector within a mid-term time period.

Several routes which mostly fulfill these above criteria are thus selected for in-depth analysis, such as the CO_2-based production of methanol via catalytic hydrogenation, formic acid via electrochemical reduction or sodium carbonates through mineral carbonation. In parallel of the conversion of CO_2 to methanol already considered and simulated, an initial environmental assessment is carried out using the method of Life Cycle Analysis (LCA) in order to obtain a "global picture" of the process.

Focusing on suitable CO_2 conversion pathways through various deepened criteria for the cement sector will help final decision makers to fit the roadmap for the cement sector to mitigate their contribution on global warming.

CO_2 conversion into methanol
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The current research is dedicated to the optimization of the catalytic conversion process which converts purified CO_2 coming from industrial purified flue gases into methanol. This process relies on two catalytic reactors filled with $CuO/ZnO/Al_2O_3$-type catalysts. The water-methanol mixture produced in both reactors is then flashed and separated in a distillation column to provide a pure and continuous methanol stream with a purity higher than 99 mol%.

The CO_2 catalytic conversion process has been implemented on Aspen Plus®. A sensitivity analysis of operative parameters has been performed to quantify their respective influence on the process performances. A methodological approach has also been used to optimize this CO_2 conversion unit regarding economic indicators such as CAPEX and OPEX, and energetic considerations such as heat integration.

Apart from the simulated results, experiments are conducted to adapt the kinetic reaction laws to currently available commercial catalysts and finally compare their conversion performances and evaluate their assets.