CLEANKER – Clean clinker by Calcium Looping process for low-CO₂ cement production

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Abstract

The CLEANKER¹ project got EC support from October 2017 to September 2021 under the Horizon 2020 call LCE 29 – 2017². CLEANKER (www.cleanker.eu) aims at demonstrating at TRL³⁷³ the

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¹ CLEAN clinKER production by calcium looping process;
² Enabling decarbonisation of the fossil fuel-based power sector and energy intensive industry through CCS;
³ Technology Readiness Level 7: Demonstration system operating in operational environment at pre-commercial scale
Calcium Looping (CaL) concept in a configuration highly integrated with the cement production process, making use of entrained flow reactors.

The cement industry is a key-sector for the reduction of CO2 emissions. CO2 generation in cement production processes in fact, cannot be disregarded due to the calcination of limestone (CaCO3 dissociated to CaO and CO2), the most important raw material. Around 60% of the direct CO2 emissions from the clinker burning process are due to this reaction. In addition, there are the emissions from combusion of mostly fossil fuels, as well as the generation of electric power required by the process (e.g. grinding), as indirect CO2 emissions. Cement production is thus responsible for about 27% of global anthropogenic CO2 emissions from industrial sources worldwide4 and for 5% of anthropogenic global CO2 emissions5. According to IEA and ZEP studies, cement industry should contribute to the largest CO2 emission reduction through CCS in Europe, in order to meet the target of 2°C of global temperature increase (IEA 2DS scenario).

There are currently no feasible methods to produce clinker, and thus cement, without releasing CO2 from CaCO3, and, given the lifetime of a cement plant (30-50 years), the technologies to be developed have to be retrofittable. In addition to oxyfuel combustion and post-combustion solvent-based capture technologies, which have attracted most of the research efforts up to now, Calcium Looping is recognized as another very promising emerging technology for CO2 capture in cement plants. Calcium looping (or carbonate looping) is a regenerative process, which takes advantage of the capacity of calcium oxide-based sorbents to capture CO2 at high temperatures. The process is divided in two basic steps: (1) the capture of CO2 by “carbonation” of CaO to form CaCO3 in a reactor operating around 650°C; and (2) oxyfuel calcination in a reactor operating above 900-920°C, which makes the CaO available again and releases a gas stream of nearly pure CO2.

The highly integrated Calcium Looping process configuration allows achieving high-energy efficiency, with CO2 capture efficiency target over 90%. The overall energy consumption can be kept low by proper integration with raw meal preheating and heat recovery from the kiln flue gases. The adoption of entrained flow gas-solid reactors is particularly suitable for this Calcium Looping configuration, because in such reactors, the same very fine raw material can be used for clinker production (CaO) and for CO2 sorption without additional milling requirements. Moreover, entrained flow reactors are already commonly used in cement plants.

The core activity of the project is the design, construction and operation of a CaL demonstration system including the entrained-flow carbonator (the CO2 absorber) and the entrained-flow oxyfuel calciner (the sorbent regenerator). This demonstration system, connected to the Buzzi Unicem kiln of the Vernasca cement plant (Italy), will capture the CO2 from a portion of the flue gases of the kiln, using as CO2 sorbent the same raw meal that is used for clinker production. Other activities will include: (i) screening of different raw meals to assess their properties as CO2 sorbent, (ii) reactors and process modelling, (iii) scale-up study, (iv) economic analysis, (v) life cycle assessment, (vi) CO2 transport, storage and utilization study, (vii) demonstration of the complete value chain, including mineral carbonation of waste ash with the CO2 captured in the pilot system, (viii) exploitation study for the demonstration of the technology at TRL>7 and for its first commercial exploitation based on CO2 transport and storage opportunities.

It integrates the research of 13 organizations:

- Representatives from the academia: Politecnico di Milano (Italy), Tallinn University of Technology (Estonia), Lappeenranta University of Technology (Finland); University of Stuttgart (Germany) and Tsinghua University (China);
- Research centres: LEAP (Italy), CSIC (Spain) and VDZ (Germany);
- SME: Quantis (Switzerland);
- Technology provider: IKN (Germany);
- End users: Buzzi Unicem and Italcementi – Heidelberg Group (Italy);
- Environmental organization: Amici della Terra (Italy).

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4 IEA, 2011. Technology Roadmap: Carbon Capture and Storage in Industrial Applications
Thus including all the necessary expertise and access to the industrial facilities to reach the ambitious aim of the project.
The project is coordinated by LEAP.

Acknowledgements:
This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 764816. This work is supported by the China Government (National Natural Science Foundation of China) under contract No. 91434124 and No. 51376105.

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