



Development of cost effective and high performance composite for CO₂ capture in CaCu looping process

Saima Sultana Kazi¹, Asunción Aranda¹, Julien Meyer¹, Ramon Murillo², Gemma Grasa²

¹ Institutt for Energiteknikk (IFE), Department of Environmental Technologies, Instituttveien 18, 2007 Kjeller, Norway

² Instituto de Carboquímica (ICB-CSIC), C/ Miguel Luesma Castán 4, 50018, Zaragoza, Spain

Abstract

Calcium looping cycles (CaL) is an emerging technology for the reduction of CO₂ emissions from fossil fuels for energy production. In a calcium looping process, CaO-based sorbent circulates between the carbonator, where CaO reacts with CO₂ to form CaCO₃, and the calciner, where the reverse reaction takes place to regenerate CaO [1]. Chemical looping (CLC) involves circulation of a metal oxide (oxygen carrier) between a fuel reactor, where the metal oxide releases its oxygen to burn the fuel fed, and an air reactor, where the metal is oxidized by air to form the metal oxide again. Integration of calcium looping and chemical looping processes, designated as CaL-CLC or CaCu looping, is an attractive approach to solve the energy penalty for the regeneration of CaO-based sorbent. In CaCu looping simultaneous reduction of CuO and calcination of CaCO₃ in the same reactor provides very efficient heat transfer between reactions. No need of energy intensive air separation unit, easier to control the process and provides lower cost. Some well-known oxygen carriers are Fe, Cu, Ni and Mn. Among them, CuO is one of the most promising oxygen carriers because of its high oxygen-carrying capacity (0.20 g O₂/g CuO), high reactivity and due to its exothermic reduction with hydrocarbon based fuels [1, 2, 3].

The objective of this work was to develop new composite materials combining the two functions for CaCu looping, and to evaluate the effect of physical distance between the active phases on kinetics and/or heat transfer, compared to the use of separate materials (CaO-rich and CuO-rich) in independent pellets. For this purpose, IFE has designed and developed a novel approach of material synthesis, by combining into one single material with two functions (CO₂ sorption by calcium oxide and heat procurement for the calcination stage by copper oxide). A hydrothermal synthesis method was employed to prepare these composite materials which involve reaction between calcium, aluminum and copper precursors. The ratio of Cu/CaO in the prepared composite is 2, based on energy balance in the regenerator between the exothermic reduction of CuO with H₂ and the endothermic calcination of CaCO₃. Our developed final composite material contains copper oxide (CuO) and calcium oxide (CaO) supported on mayenite (Ca₁₂Al₁₄O₃₃). Composite materials were characterized by means of X-ray diffraction and scanning electron microscope. Long term chemical performances of the composites having different inert (Ca₁₂Al₁₄O₃₃) percentages for carbonation/calcination/reduction/oxidation cycles were tested in a thermogravimetric analyzer (TGA). In long term tests, the composite material containing 25% inert (Ca₁₂Al₁₄O₃₃) showed stable CO₂ capture capacity compared to 15% and 20% inert (Ca₁₂Al₁₄O₃₃) respectively. We have found that Cu/CuO has a significant influence on the cyclic reactivity of CaO and O₂ capacity. Scanning

electron microscopy was used to study the possible decline in CO₂ capture capacity as well as O₂ capacity. It is confirmed by SEM/EDX and EDS mapping that possible decline in capture capacity of the composite is probably caused by the migration of copper (Cu) to the surface of composite, forming a layer of CuO that hinders CO₂ permeation for the reaction with CaO. The promising results obtained from this work are expected to reduce production and transportation of materials, reduce reactor size and improved heat transfer and overall performance in CaCu looping process.

References

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