

COMPARATIVE STUDY OF CALCIUM-BASED ENHANCED SYNTHETIC SORBENT AND NATURAL SORBENTS FOR HIGH TEMPERATURE CO₂ CAPTURE

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Keywords CO₂ capture, sorbent

Since carbon-based fuel dependence is generally accepted in short to mid term, CO₂ capture (CC) technologies need to be further developed in order to be fully implemented in several existing and future processes, like energy generation systems and industries like, e.g., cement or steel production. Concerning high-temperature CO₂ capture (600-900°C), the use of calcium-based sorbents in looping carbonation/calcination cycles has been identified as a promising technology for future CO₂ separation processes, both *in-situ* and in post-combustion capture.

CC processes using solid sorbents operate in a cyclic mode where CO₂ is captured in a gas-solid reaction (by carbonation of the CaO particles into CaCO₃) and released by heating the compound formed in a calcination step to produce a pure CO₂-stream through the reverse reaction. Depending on the process scale and design, the capture can be run in multiple fixed bed reactors, operating alternatively in capture and regeneration modes, or in a continuous process using circulating fluidized bed reactors.

Thus, some of the key factors in the solid-based capture processes are related to the sorbent properties, which must include a large absorption capacity, fast reaction kinetics, good chemical and mechanical durability and a low cost. Considering natural sorbents, limestone and dolomite are the two calcium-based minerals most widely studied for this application, since they initially show suitable properties, are broadly available and have low cost, but, oppositely, they suffer absorption capacity decay along cycles. Therefore, research efforts are being pursued to develop synthetic sorbents which overcome this disadvantage and show long term chemical and mechanical stability in cyclic operation.

In the last years, Institute for Energy Technology (IFE) has carried out an extensive work on developing novel synthetic high-temperature solid sorbents and is establishing new paths of research on this topic in collaboration with ICB-CSIC. The field of application of the high performance calcium-based sorbent includes the possibility of using this material as a support for catalysts, such as nickel. The optimization of the catalyst loading on the 'sorbent + support' matrix can lead to long-term stable 'all-in-one' particles, where the reforming and the CC take place on the same material. Thus, Sorption Enhanced Steam Methane Reforming (SE-SMR) can be carried out with *in-situ* CC on this enhanced material.

The synthetic sorbent developed at IFE follows a low-temperature synthesis, advanced powder processing and high-temperature heat treatment in controlled atmosphere to obtain the optimum morphology of the particles. The developed sorbent shows a genuine composite structure that comprises stable nanoparticles of CaO (~100nm) homogeneously distributed on a Calcium-Aluminium mixed oxide matrix. The nano-scale size and the widespread-layered structure of the CaO particles on the surface of the support pores are believed to significantly improve the chemical stability of the sorbent. Long-term multi-cycling of the material in carbonation/regeneration conditions show remarkable long life-time (>500 cycles) in severe calcination conditions ($p_{\text{CO}_2}=0.50$ atm, $p_{\text{H}_2\text{O}}=0.50$ atm and $T=870^\circ\text{C}$) with improved absorption capacity, better reaction kinetics and higher mechanical stability compared to natural sorbents.

A thorough characterization of the synthetic sorbent, the optimization of synthesis variables and a kinetic study is hereby presented. This comparative study clarifies the differences between the synthetic sorbent and natural sorbents behavior – in terms of chemical and mechanical stability – and allows the optimized design of appropriate supports to develop the ‘all-in-one’ material for SE-SMR applications.