Comparison of a full range of oxygen carrier materials for Chemical Looping Coal Combustion

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Clean coal technologies, especially on the minimization of greenhouse gas emission, are nowadays more needed than ever. In this sense, CO2 capture and storage from coal combustion is a mid-term solution to stabilize CO2 atmospheric concentration. In this sense, Chemical Looping Combustion (CLC) technologies reduce the cost of the capture in coal combustion processes as inherent CO2 capture take place. The oxygen needed for the coal oxidation is provided by an oxygen carrier, a metal oxide, circulating between two interconnected fluidized bed reactors. In the fuel reactor the coal is oxidized to CO2 and H2O while the carrier is reduced. CO2 in the product stream can be easily captured, once the water has been condensed. The reduced oxygen carrier is then transported to the air reactor and re-oxidized in air.

Depending on the oxygen carrier properties, the process can be ruled by the gas-solid reaction between the gasification products and the metal oxide, like in the in-situ gasification process (iG-CLC), or by the high reaction rate between gas-phase oxygen released by the oxygen carrier and the char, like in the CLOU process. Among these two routes, other mixed mechanisms exist like in the Chemical Looping assisted by Oxygen Uncoupling (CLaOU) process. In this sense, materials based on cheap minerals like ilmenite, Fe-based or Mn-based ores, and residues, like redmud, were proposed as oxygen carriers for the iG-CLC process. However, synthetic materials based on cheap metals are also proposed due to its improved performance regarding reactivity, like bimetallic Mn-Fe particles. Finally, highly reactive Cu-based oxygen carriers have been demonstrated to be suitable for CLOU routes. All this different materials have been evaluated in a CLC unit in the Instituto of Carboquimica (ICB-CSIC).

In this work, the behaviour of these different materials, ranging from cheap but low reactive minerals to costly but more reactive synthetic oxygen carriers were evaluated in the combustion of coal in the 1.5 kWth continuously operated plant at ICB-CSIC. The effect of the different reactivity of the materials on the carbon capture efficiency and the oxygen demand of the process were analysed.

It was found that the whole CLC process performance can be highly improved by using an oxygen carrier with CLOU properties and the implications of the oxygen carrier selection on the process design have been also discussed.