Chemical Looping Combustion by Thermogravimetry

Introduction

Chemical Looping Combustion (CLC) or also called oxy-combustion is a process that was developed in 1994 by the laboratory of Professor Ishida (Japan) for the CO_2 capture. It is a new method of oxidizing fuels without the direct use of either air or oxygen.
The interest of such a combustion is to have a more efficient process for burning fuels (natural gas, coal) with a production of CO_2 for sequestration. In order to improve the fuel combustion, more oxygen is brought to the system through metal oxides. So the metal oxide is used as an oxygen carrier to facilitate the fuel combustion and is permanently regenerated and reoxidised.

Thermogravimetry is very well adapted to measure the oxygen transfer capacity (OTC) of the metal oxide sample.

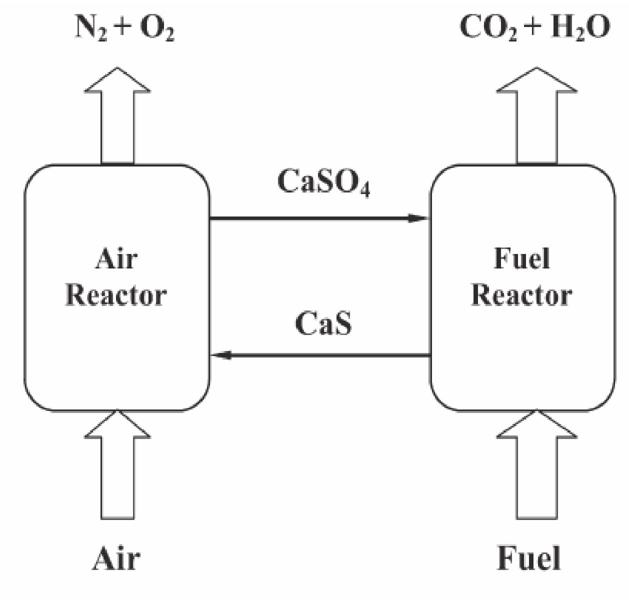

Figure 1 – Chemical looping combustion using a calcium based oxygen carrier

Principle

In the air reactor, air is supplied to oxidize CaS in $CaSO_4$, where oxygen is transferred from air to the oxygen carrier.
The reduction of $CaSO_4$ takes place in the fuel reactor.
The exit gas from fuel reactor is CO_2 and H_2O
After condensation of water, almost pure CO_2 is obtained and ready to be captured.

Experimental

The Setsys thermobalance is used for the investigation of $CaSO_4$ materials as an oxygen carrier (1).
The reduction tests are isothermally performed at different temperatures (from 850°C to 1050°C), using 24 mg $CaSO_4$ (sieved between 50 and 100 µm) placed in a alumina crucible (reduction test). The reduction gas was composed of 10% CO and 90% N_2.
The oxidation tests are isothermally performed at different temperatures (from 950°C to 1150°C), using 20 mg CaS (0.3 to 0.4 µm) placed in a platinum crucible. The reactant gas is synthetic air.
Gas flows of 80 ml/min are used for the respective tests.
The experimental chamber is firstly heated to the desired temperature under nitrogen and then kept at the desired temperature with the desired gas mixture.

SETSYS Evolution TGA (ambient to 1600°C)

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Results and conclusions

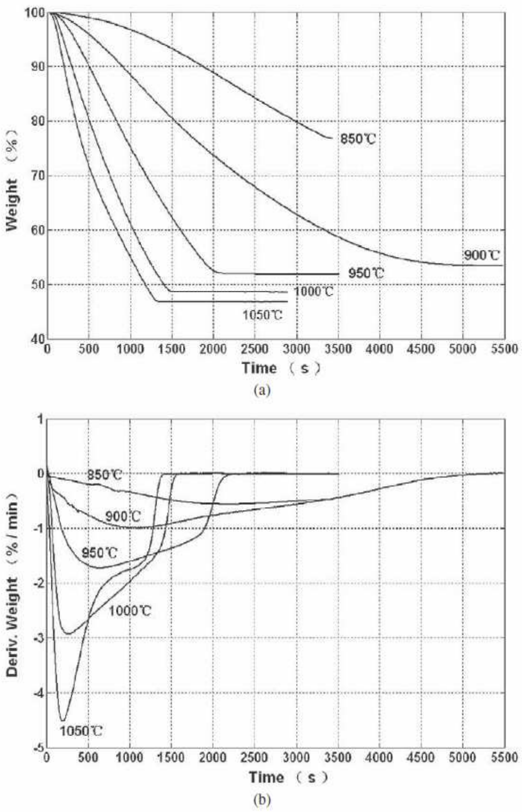

Figure 2 – TG and DTG traces for $CaSO_4$ reduction at p_{CO}=10kPa

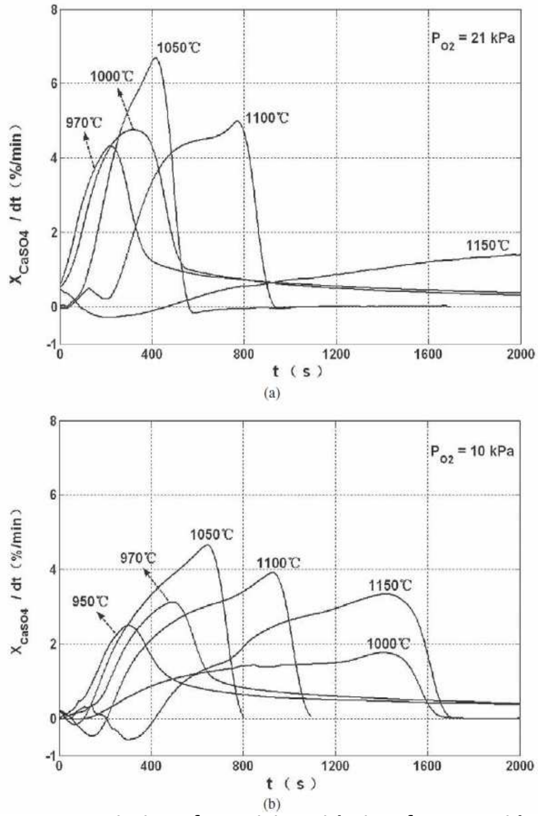

Figure 3 – Variation of reactivity with time for CaS oxidation at different oxygen partial pressures

On Figure 2a, it is seen that the reaction rate of $CaSO_4$ reduction increases very quickly with the temperature. The DTG curve (Figure 2b) shows that two consecutive reactions occur during the reduction process. This reduction time scale is suitable for the application of a fluidized bed as the fuel reactor in chemical looping combustion.

For the oxidation process, it is seen that the conversion of CaS to $CaSO_4$ shows a fast increase during the first phase of the test, followed by a deceleration period (Figure 3). The rate of conversion is higher for the lower selected temperatures and increases with the oxygen partial pressure.

The Setsys TGA has shown its flexibility of use with different types of gases (inert and reactive). From the tests, it is possible to deduce that the suitable temperature for the air reactor should be between 1050°C and 1150°C, and the optimal temperature for the fuel temperature should be between 900°C and 950°C in the process of chemical looping combustion.

The Setsys TGA was also used for the investigation of chemical looping combustion with NiO and Fe_2O_3 (2) with various gases (including humid gas). The consecutive reduction and oxidation cycles were also investigated on different Mn-Fe mixed oxides using the symmetrical TAG thermobalance (3).

Bibliography

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3- Arnold Lambert, Céline Delquié, I. Clémençon, Elodie Comte, Véronique Lefebvre, J. Rousseau, B. Durand, Synthesis and characterization of bimetallic Fe/Mn oxides for chemical looping combustion, Energy Procedia 1 (2009) 375–381