Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 114 (2017) 242 – 249

Energy Procedia

13th International Conference on Greenhouse Gas Control Technologies, GHGT-13, 14-18 November 2016, Lausanne, Switzerland

# Modelling a calciner with high inlet oxygen concentration for a calcium looping process

Jarno Parkkinen[a]*, Kari Myöhänen[a], Juan Carlos Abanades[b], Borja Arias[b], Timo Hyppänen[a]

[a] *Lappeenranta University of Technology, Skinnarilankatu 34, 53850 Lappeenranta, Finland*
[b] *CSIC-INCAR, Francisco Pintado Fe 26, 33011 Oviedo, Spain*

**Abstract**

A calcium looping (CaL) process is a carbon capture technology which utilizes calcium oxide to remove carbon dioxide from the flue gas of a power plant. Like most capture technologies, CaL process has a high energy demand, which reduces power plant efficiency. The energy penalty and the operating and capital costs of the unit can be reduced by increasing the concentration of $O_2$ in the oxidant flow to calciner. In this study, a calciner has been studied with a three dimensional, steady-state, CFB process model. First, the model was validated by test data of the calciner in la Pereda CaL pilot. Next, a 3D model was created for a 200 MWth commercial scale calciner, in which the inlet oxygen concentration was increased up to 75% to map the potentials of improving the heat balance of the system and to investigate how the calciner operates in these conditions. Based on the simulations, the CaL process is feasible even at very high inlet oxygen concentration.


Peer-review under responsibility of the organizing committee of GHGT-13.

*Keywords:* circulating fluidized bed; carbon capture; calcium looping; three-dimensional model

* Corresponding author. Tel.:+358-50-443-3234
*E-mail address:* jarno.parkkinen@lut.fi


Peer-review under responsibility of the organizing committee of GHGT-13.
doi:10.1016/j.egypro.2017.03.1166

## 1. Introduction

Greenhouse gas control and especially reducing of carbon dioxide emissions was one of the main topics in Paris Climate Change Conference in November 2015. In the agreement from this conference, the countries of United Nations agreed that the climate change is a threat to whole world and actions are needed to stop the global average temperature raise. Carbon capture and storage (CCS) is one option to reduce $CO_2$ emissions. The $CO_2$ can be captured before or after the combustion depending on technology. One promising post-combustion technology is the calcium looping (CaL) process where $CO_2$ is captured from the flue gas with irreversible carbonation-calcination reaction (1) which direction depends on temperature and partial pressure of $CO_2$ [1].

$$CaO_{(s)} + CO_{2(g)} \leftrightarrow CaCO_{3(s)} \qquad \Delta H_r^0 = -178\ \mathrm{kJ/mol} \qquad (1)$$

CaL process utilizes natural limestone which is cheap and well known material as precursor of the CaO carrier material for $CO_2$ capture. The process system is usually comprised of two interconnected circulating fluidized bed (CFB) reactors: carbonator and calciner, Fig. 1. In the carbonator, the $CO_2$ from the flue gas is captured by calcium oxide (CaO) in the exothermic carbonation reaction. The reaction takes place at temperature below 700 °C in $CO_2$ partial pressure after typical air-fired combustion with coal. The formed calcium carbonate ($CaCO_3$) is then led to the calciner, where this solid material is regenerated back to CaO and $CO_2$ which is led out of the reactor to the purification and compression. The calciner needs an additional heat source to raise the temperature to around 900 °C, which is needed for the reaction and to cover endothermic calcination reaction heat requirement. Most obvious way to produce this heat is oxy-fuel combustion, which produces flue gas containing mostly $CO_2$.

The oxy-fuel combustion requires air separation unit (ASU), which causes significant energy penalty to power plant. One way to improve efficiency is to increase the oxygen concentration in combustion. The advantages from higher $O_2$ concentration comes from lower total gas flow to furnace which decreases the heat demand and cross-section area of the furnace. A smaller heat demand means smaller fuel input, which reduces the required oxygen flow. A smaller furnace decreases the investment cost of the plant and this is significant especially in CaL process, where the calciner is an insulated reactor.

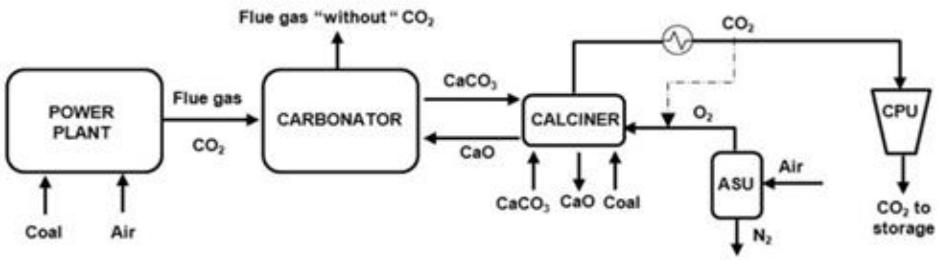


Fig. 1. Simplified process scheme of CaL process with high $O_2$ inlet to the calciner.

Oxy-fuel combustion is widely studied in PC and CFB boilers and higher $O_2$ concentration is a major development field [2]. In boilers, a high inlet $O_2$ concentration is challenging for heat recovery inside the furnace and the maximum level of $O_2$ is about 50 % [3]. In a calciner, the combustion heat is balanced by endothermic calcination reaction, which is occurring at same locations, where the combustion takes place. This provides a possibility to apply considerably higher $O_2$ concentrations.

The effect on plant efficiency with high oxy calciner concept has been presented in study by Romano [4] where the power plant steam cycle process is studied with the calcium looping process. In the study, oxygen concentration in oxidant was set to 50 %. In a small scale calcium looping testing, a 50 % oxygen concentration in oxidant flow to calciner has been reported at CANMET 75 kWth pilot-scale dual fluidized bed facility and IFK, University of Stuttgart, a 200 kWth dual fluidized bed facility for calcium looping tests [5,6].