Characterization of Calcium Carbonate Decomposition Thermodynamics in a Steam and Carbon Dioxide Suspension

Nathan Schroeder[1], Evan Bush[2], and Andrea Ambrosini[3]

[1] Affiliations: R&D S&E Mechanical Engineer, MSME, Senior Member of the Technical Staff at Sandia National Labs. Address: 1611 Innovation Pkwy NE, Albuquerque, NM 87123 United States of America, (505) 844-4945, and nrschro@sandia.gov

[2] PhD ME, Sandia National Labs, hebush@sandia.gov

[3] PhD Chemistry, Sandia National Labs, aambros@sandia.bov

1. Introduction

Nearly 6% of anthropogenic carbon emissions can be attributed to the calcination of calcium carbonate ($CaCO_3$) for the production of cement. A large fraction, 40%, of the carbon dioxide emitted during the process is a byproduct of the combustion of fossil fuels, such as pulverized coal or natural gas, used to heat the material to temperatures up to 1500 °C [1]. To decarbonize a substantial portion of the heat input, concentrated solar power (CSP), is under consideration as an alternate source of process heat. Synhelion has developed a high temperature solar receiver that is capable of collecting 1500 °C heat via a steam and carbon dioxide heat transfer fluid (HTF) [2]. The HTF is delivered to the precalciner where it directly heats the calcium carbonate. Understanding the decomposition thermodynamics and kinetics of the reaction is critical to the technology's development. In this paper an experiment is outlined in which a tube reactor is used to decompose calcium carbonate particles in a steam and carbon dioxide gas stream to inform the thermodynamics and kinetics for inlet gas temperatures between 800 and 1200 °C and steam mole fractions between 0.1 and 0.9.

2. Method

The tube reactor, shown in Fig. 1, consists of a high temperature HTF supply, calcium carbonate feed hopper, refractory lined steel tube, and cyclonic separator/material cooler. The HTF supply delivers the steam and carbon dioxide gas stream at temperatures up to 1200 °C to the refractory lined steel tube where the calcium carbonate particles are introduced via the feed hopper. The material is pneumatically conveyed from the inlet of the reactor to one of several outlets. The location of the outlet and the flow rate of HTF are used to regulate the residence time of the particles within the reactor. A cyclone located at the outlet of the reactor then cools and separates the reacted particles from the HTF using a secondary ambient temperature air stream. Two laser extinction probes, one at the outlet of the feed hopper and one at the outlet of tube reactor, provide a precise measurement of the particle residence time by measuring the time between when the material is released and when it is collected. Reacted particles gathered at the outlet of the cyclone are characterized via XRD and TGA to determine extent of reaction.

The high temperature steam and carbon dioxide gas stream is generated via the oxy combustion of propane, which produces a flame temperature of 2,800 °C. The combustion product gases will be mixed with and cooled by a carbon dioxide and water mixture which provides control of the outlet temperature and the mole fraction of steam.

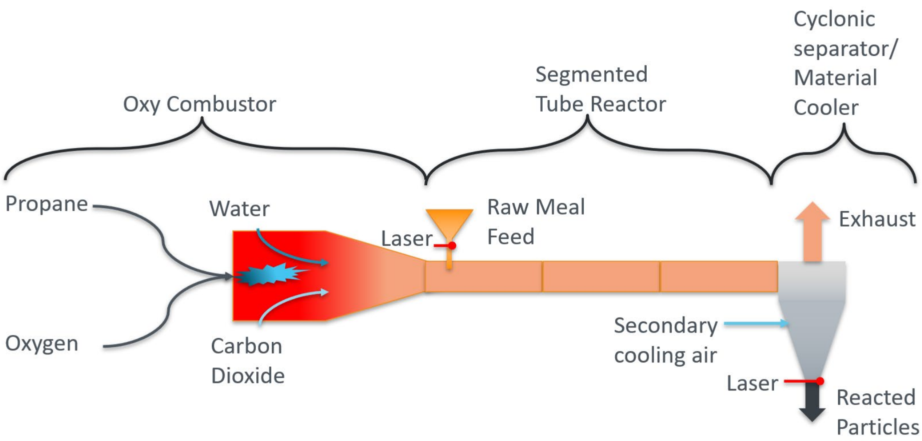

Fig. 1: Tube reactor experimental setup

3. Results

3.1. Raw Material Characterization

X-ray diffraction (XRD). Raw meal provided by Cemex was analyzed using powder XRD (Bruker D2 Phaser). (Fig. 2) Crytallographic phases were identified using PDF-4+ (International Centre for Diffraction Data, Newtown Square, PA, USA, 2016). PCPDF and whole pattern fitting (MDI Jade 9.5. Materials Data. Inc. Livermore, CA.) based on PDF reference cards was performed to estimate phase quantities. The three major phases identified were calcite ($CaCO_3$, ~87%), quartz (SiO_2, ~8%), and albite ($Na(AlSi_3O_8)$, ~4.6%), which is an aluminosilicate clay. Quartz and clay are common consituents of raw meal, which is locally mined. The results gathered in this experiment will inform the design of a solar heat precalciner system.

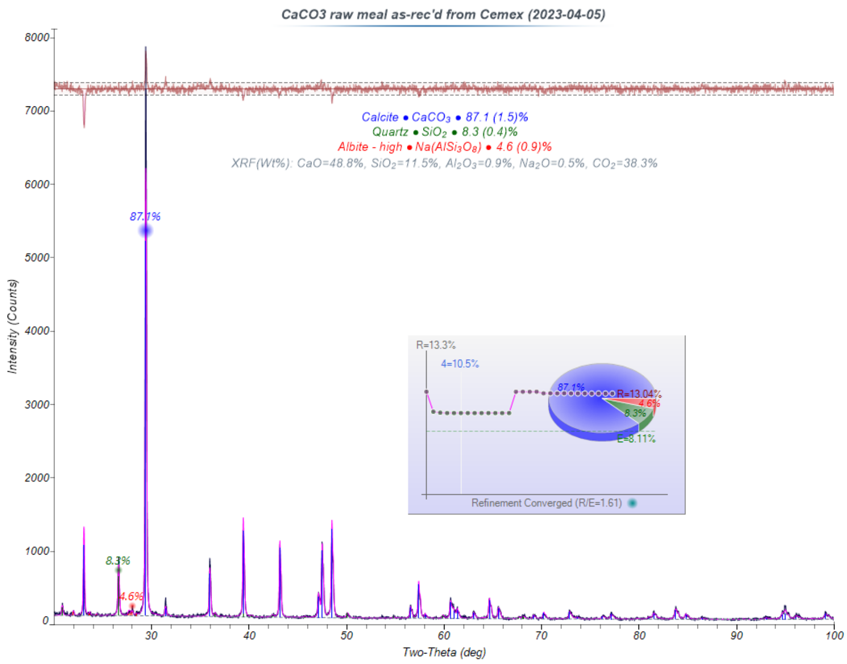

Fig. 2: XRD results for the Cement raw material

References

1. *Low-Carbon Transition in the Cement Industry*. IEA, 2018.
2. Ambrosetti, G. and P. Good, *A Novel Approach to High Temperature Solar Receivers with an Absorbing Gas as Heat Transfer Fluid and Reduced Radiative Losses.* Solar Energy, 2019. **183**: p. 521-531.