University of South-Eastern Norway

Faculty of Technology, Natural Sciences and Maritime Sciences, Campus Porsgrunn

FMH606 Master's Thesis

Title: CO_2 capture combined with calcination driven by oxyfuel combustion of green hydrogen

USN supervisor: Lars-André Tokheim

External partner: Norcem and HeidelbergCement Northern Europe (Christoffer Moen)

Task background:
USN is one of the partners in the research project *"Combined calcination and CO_2 capture in cement clinker production by use of CO_2-neutral electrical energy"*. The acronym ELSE[1] is used as a short name for the project. Phase 1 of the project was completed in April 2019, and Phase 2 was started in April 2020. The goal of the ELSE project is to utilize electricity (instead of carbon-containing fuels) to decarbonate the raw meal in the cement kiln process while at the same time capturing the CO_2 from decarbonation of the calcium carbonate in the calciner. A regular kiln system is shown in Figure 1.

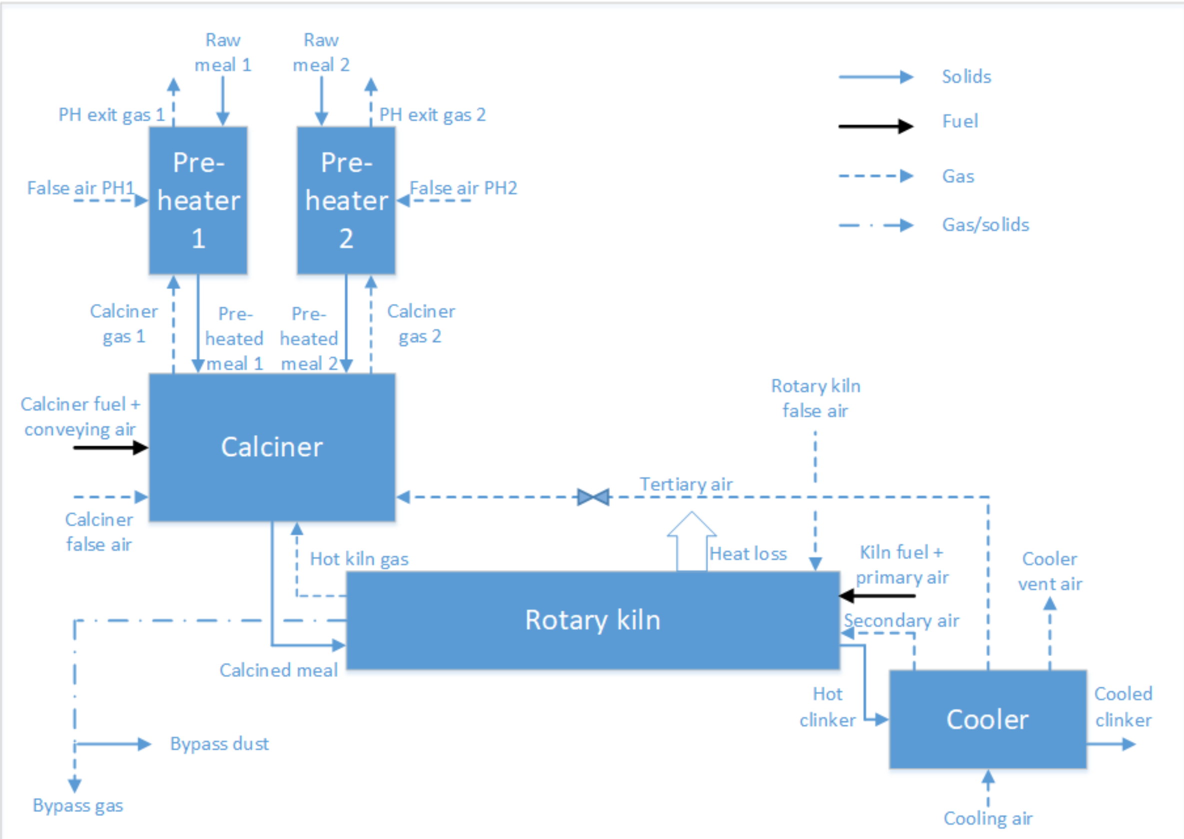

Figure 1: *A regular cement kiln process with two preheater strings.*

Different concepts to implement electrification of the calciner have been discussed. One alternative is to use electricity to produce hydrogen and oxygen from water in an electrolysis process, and thereafter burn the hydrogen in oxygen in the calciner. An advantage of this is

[1] ELSE is short for 'ELektrifisert SEmentproduksjon' (Norwegian) meaning 'electrified cement production'.

that the existing calciner may be used, maybe without doing big changes to the geometry etc.

If the hot kiln gas, the tertiary air and the carbon-containing fuels are no longer supplied to the calciner, then N_2 can be eliminated from the calciner exit gas, which will be a mixture of mainly CO_2 and H_2O. After condensation of the H_2O, the product will be more or less pure CO_2 (depending on the excess O_2 in the combustion reaction), which can be stored (or utilized in some way). Some recycling of CO_2 (or CO_2+H_2O) in the calciner may be necessary to control the temperature and the combustion properties. A block-diagram illustrating a potential concept is given in Figure 2.

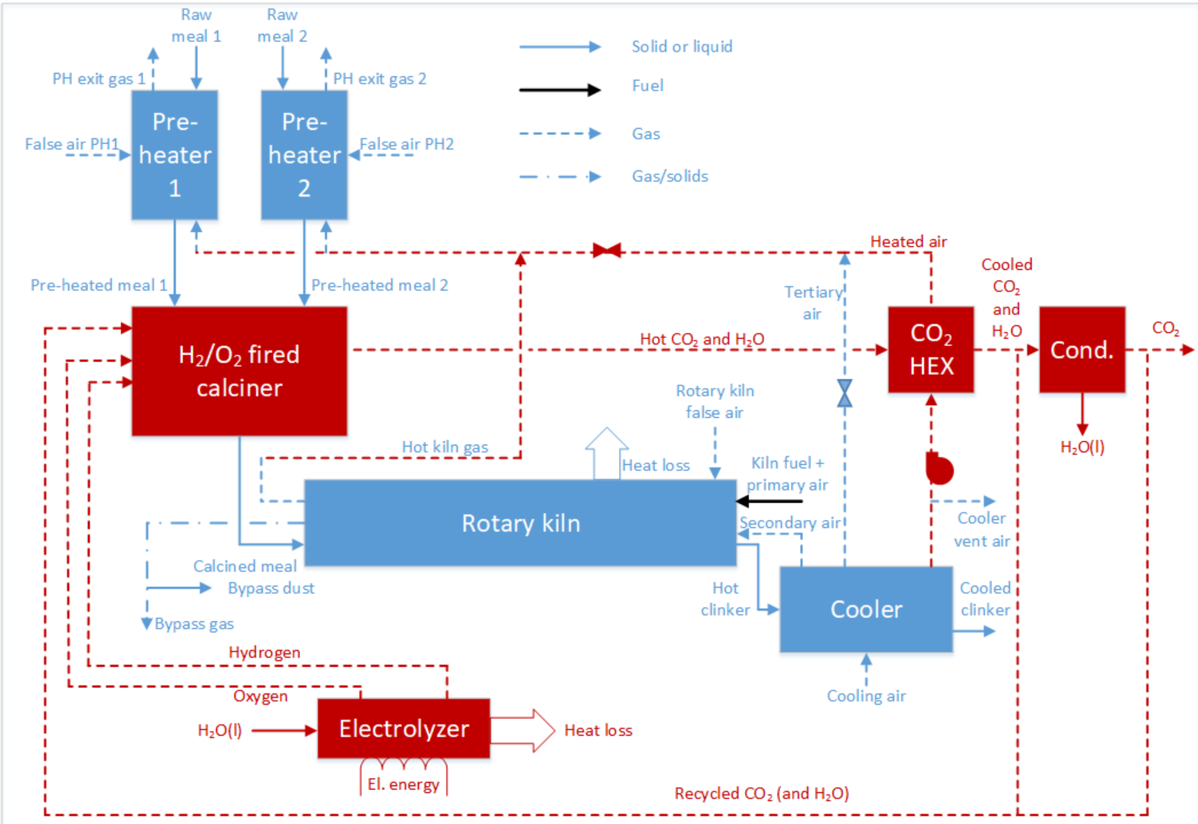

***Figure 2:** A modified cement kiln process applying hydrogen combustion for calcination.*

Such a concept may be less expensive than a regular post-combustion system applied to CO_2 capture from the cement plant. Moreover, as the fuel generated CO_2 will be eliminated, less CO_2 is produced in the calcination process.

<u>Task description</u>:
The task may include the following:

- Give a short overview of the regular calcination process used in modern kiln systems
- Give a short description of water electrolysis to generate H_2 and O_2
- Describe a process concept that combines electrolysis-generated H_2 and O_2 with calcination based on combustion of H_2 in O_2 (with CO_2 recycling)
- Investigate how combustion properties are affected by mixing H_2 and CO_2 (and possibly H_2O), using solid fuel combustion as the reference
- Assess safety aspects related to production, handling and combustion of hydrogen and oxygen in a cement kiln environment
- Make a mass and energy balance of the system and calculate mass flow rates, temperatures, duties, etc.

- Make a process simulation model of (part of) the system and simulate different cases, varying key parameters in the system
- Evaluate the main energy losses in the combined system
- Recommend a suitable reycling rate for CO_2 (or CO_2+H_2O)
- Make a process flow diagram with process values for selected cases
- Make estimates of investment costs (CAPEX) and operational costs (OPEX) of the suggested process, including calculation of costs per avoided CO_2 unit (€/t_{CO2}).
- Present key results in the form of graphical illustrations
- Discuss/explain the results and make conclusions about the technical and economic feasibility of the concept

Student category: EET or PT students

Is the task suitable for online students (not present at the campus)? Yes, both online and campus students may select the task.

Practical arrangements:
There will be meetings with Norcem to discuss the task and the progress, most likely via Teams.

Supervision:

As a general rule, the student is entitled to 15-20 hours of supervision. This includes necessary time for the supervisor to prepare for supervision meetings (reading material to be discussed, etc).

Signatures:

Supervisor (date and signature): 26 January, Lars Andre Tokheim

Student (write clearly in all capitalized letters): GLENN NEDRUM

Student (date and signature): 26 January, Glenn Nedrum