PhD Offer (M/F)

Development of a new process for the co-valorisation of CO2 from industrial flue gases and materials from the circular economy

Field: Chemical Engineering / Process Engineering / Mineral Process Engineering

Duration/Period: 36 months, starting before the end of September 2025

Location: Laboratoire de Génie Chimique (LGC https://lgc.cnrs.fr/en/ , Toulouse, France)

keywords: capture, storage and utilisation of CO_2; recovery of industrial waste; circular economy; mineral carbonation; performance study of processes

Required profile: Master's or engineering degree in Chemical / Mineral Processing Engineering with a strong interest in experimenting and modelling with G-L-S systems

1. Background

The research topic concerns the valorisation of calcium-rich sulphurous demolition waste in order to produce one or more mineral products that can be used in the construction sector, by means of accelerated carbonation in aqueous phase. The research, which is part of the PRECIZE[1] project, is coordinated by IMERYS, a world leader in mineral-based specialties for industry, and funded by the France 2030 DEMIBaC[2] (Development of technological building blocks and demonstrators) industrial decarbonisation programme managed by ADEME (the French Agency for Ecological Transition). The research project is unique in that it is based on 3 PhD theses carried out simultaneously with a common objective: the complete development of an operational CO_2 mineralisation process, which IMERYS will then develop on an industrial scale.

2. Thesis objectives

The PhD work involves the experimental development and modelling of two treatment routes for the production of calcium carbonates from gypsum waste (main mineral phase $CaSO_4.2H_2O$). The first route, referred to as direct, operates in an ammonium medium, while the second one involves an intermediate solid product, lime or $Ca(OH)_2$. The aim of the thesis is therefore to develop and model the complete treatment chain using these two routes, by combining experiments in multi-litre reactors, phenomenological modelling and process simulation. In addition to the key process steps of gypsum dissolution and carbonation - which will require an extensive experimental programme for their study -, upstream and downstream stages (solid-liquid separation, injection of gaseous CO_2 into the reaction system and management of impurities) will also be investigated. As this work is part of the France 2030 plan for the decarbonisation of the French industry, performance targets related to CO_2 utilisation, energy efficiency of the treatment chain, recycling of process water, etc., will be defined and used as guidelines for process development.

[1] https://www.zabala.fr/succes/projet-precize/

[2] https://www.id4mobility.org/appels-a-projets/aap-developpement-de-briques-technologiques-et-demonstrateurs-realisations-de-premieres-industrielles-associant-loffre-et-la-demande-demibac

3. Work programme

Experimentation : The experimental work expected constitutes the core of the thesis work and will focus on the implementation, in multi-litre reactors, of the treatment stages enabling calcium carbonate products to be produced from gypsum according to the two abovementioned treatment routes, the elementary processes of which are studied in a companion PhD thesis. In both cases, the process incorporates a carbonation stage, which involves injecting a gas stream containing CO_2 into an aqueous solution containing gypsum or milk of lime. The effect of the properties of the gas stream (CO_2 partial pressure of CO_2, presence of other gaseous species), whose industrial projection is that of the fumes from a new cement kiln, will be taken into account in the tests to be carried out. The experimental work will focus on evaluating the effect of the operating conditions on the carbonation rate and the properties of the products (PCC or cement-like materials and by-products), including temperature, CO_2 partial pressure, gas-liquid transfer rate, pH, addition of additives, slurry concentration and the initial properties of the solid (mineral composition, particle size distribution). In addition to monitoring the rate of CO_2 consumption, changes in the composition of the liquid phase and the properties of the solids produced (size distribution, elemental composition, mineralogy) will be evaluated using various physicochemical characterisation techniques (e.g. laser diffraction, ICP/AES, XRD, IR and Raman spectroscopy). The nature of the solids and co-products that come out of the process is essential for the project, as they will have to be valorisable by the industrial partner IMERYS.

Modelling: The expected work will range from the phenomenological modelling of the processing stages tested in the experiments to the modelling of the entire processing chain. In addition to modelling the dissolution and carbonation stages, which are the cornerstones of the process to be developed during the thesis, the modelling work will also pay particular attention to the management of aqueous flows and the possible pre-treatment of the fumes and particles used.

4. Work environment

The thesis will be carried out at the Chemical Engineering Laboratory (LGC http://www.lgc.cnrs.fr/en/), a joint research unit of the Institut National Polytechnique de Toulouse, Université Paul Sabatier and the Centre National de la Recherche Scientifique.
The doctoral student will be enrolled in the MEGEP doctoral school (https://adum.fr/as/ed/megep/index.html). She/he will be employed by the Institut National Polytechnique de Toulouse on a 36-month doctoral contract. The thesis work will be co-directed by Dr Carine JULCOUR-LEBIGUE (CNRS Research Director at the LGC) and Prof. Florent Bourgeois (University Professor INP-Ensiacet/LGC).
As part of the PRECIZE project, the PhD candidate will be expected to collaborate with other PhD candidates at the LGC, and to report on his/her work to the consortium coordinated by IMERYS and to the academic scientific community.

5. Candidate profile

The candidate must hold a Master's degree in Chemical/Process Engineering and have an initial research experience with pilot reactor units and scale for the development of an industrial process. The proposed subject thus requires a pronounced taste for experimental work and process development. The candidate should have a particularly strong background in chemical engineering process modelling and simulation of processes based on experimental results. Knowledge of techniques for characterising minerals and analysing aqueous solutions, thermodynamic modelling of multiphase systems and analysis of reaction kinetics in the presence of mass transfer resistances will be decisive factors in the selection of candidates for this post.

6. How to apply

Applications should be sent to the following contacts: carine.julcour@ensiacet.fr, florent.bourgeois@toulouse-inp.fr

The application file (**in the form of a single pdf file**) must contain the following information:

- Concise curriculum vitae, including current employment status and qualifications obtained
- Academic background and transcripts
- Subject of the research internship and letter of appreciation from the supervisor
- English language level
- Motivation letter showing that the applicant's profile is suited to the proposed subject.