ANICA

Advanced Indirectly Heated Carbonate Looping Process

Integrating the indirectly heated carbonate lopping process into the cement and lime industry for a sustainable CO_2-free production through CO_2 capture.

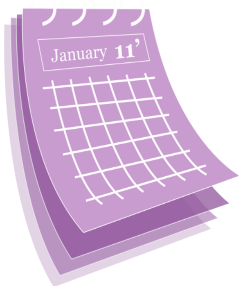
NEWSLETTER III - JUNE, 2021

What will you find here?

ANICA

CERTH
CENTRE FOR
RESEARCH & TECHNOLOGY
HELLAS

BUZZI Dyckerhoff

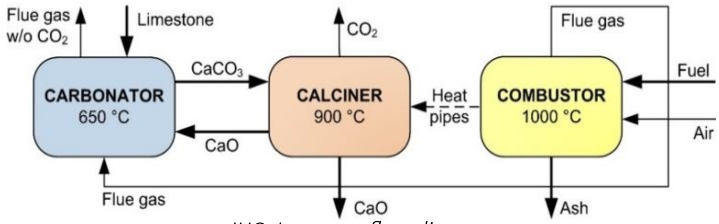


WHAT IS ANICA?

ANICA is an ACT project focused on developing novel integration concepts of the state-of-the-art indirectly heated carbonate lopping (IHCaL) process in cement and lime production. The project aims at lowering the energy penalty and CO_2 avoidance costs for CO_2 capture from lime and cement plants. Within 36 months, the project brings the IHCaL technology to a high level of technical maturity by carrying out long-term pilot tests in industry-relevant environments and deploying accurate 1D and 3D simulations.

WHY ANICA?

In order to decrease the global CO_2 emissions, sustainable and economical processes need to be applied in the energy and carbon-intense industry sectors. The production of lime and cement is one of the major sources of CO_2 emissions in the industry sector. During the production of lime and cement, natural Calcium Carbonate ($CaCO_3$) is calcined to Calcium Oxide (CaO). The necessary heat for calcination is generated by combustion of fossil fuels and waste. Process and combustion CO_2 from lime-based production accounts for around 8% of global fossil CO_2 emissions. These CO_2 emissions can be efficiently captured with the IHCaL process.



IHCaL process flow diagram

The indirectly heated carbonate lopping (IHCaL) process is a sorbent-based carbon capture process, in which the required heat is provided externally, thus avoiding the necessity of an air separation unit (ASU) and therefore, achieving higher efficiencies and lower CO_2 avoidance costs. The main components involved in the process are the combustor that provides thermal energy for the separation; the carbonator, where the CO_2 is captured by reacting into CaCO3; and the calciner, where the CaO is regenerated and the CO_2 is released.

WHAT CAN BE EXPECTED FROM ANICA?

The main objective of the ANICA Project is the efficient integration of the IHCaL process into lime and cement plants.

To achieve this, not only 3D and 1D simulations are being carried out, but also experimental research, including testing at a 300 kW_{th} pilot plant under realistic conditions. Moreover, novel concepts of the IHCaL reactor system are being developed, including the design of a new solid-solid heat exchanger concept.

Besides the industrial scale investigations, a 20 MW_{th} demonstration plant will be developed towards the end of the project. In the last stages of the project, the developed solutions will be analyzed in terms of economic performance, environmental impact and associated risks.

WHAT HAS BEEN DONE SO FAR?

So far, concepts for the integration of the IHCaL process into real lime plants in Hönnetal (Lhoist Group) and Thessaloniki (CaO Hellas) have been developed (see page 3). The corresponding one-dimensional simulations were successfully carried out. The first results were published at the GHGT-15 Conference (Greco-Coppi et.al.). Further results will be presented in the 11th Trondheim Carbon Capture & Storage Conference.

Parallel, the German Cement Works Association (VDZ) assessed concepts for the high level integration of the IHCaL process into a BAT (Best available technic) -cement plant. The results will be published in the following months.

Regarding the experimental work, some experimental results are already available and fascinating tests are being prepared right now at TUDA and at FAU. Long-term test-campaigns at TUDA will take place towards the end of the year in the 300kW_{th} IHCaL testing facility.

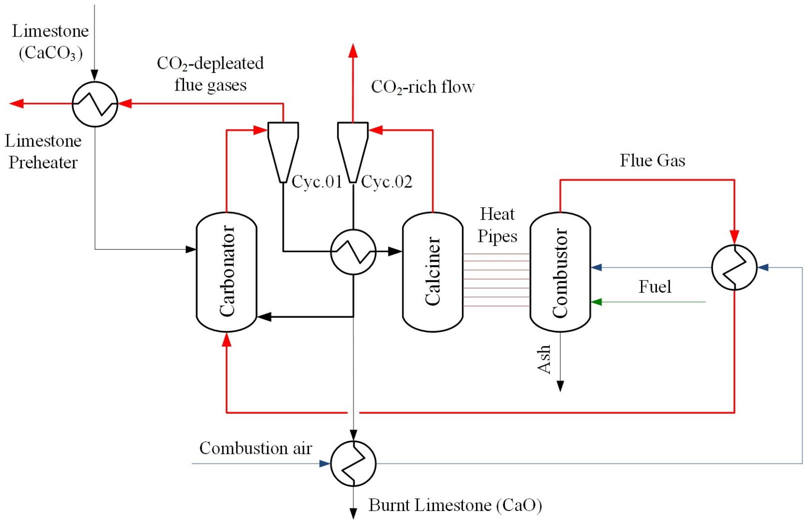
Furthermore, the first direct separation concepts for cement production are available, and the up-scaling works for an industrial-scale IHCaL facility are being performed, including technical and economical analysis as well as risk assessments with Monte Carlo simulations.

Finally, important results from the 1-D and 3-D simulations were produced. More information on the CFD simulations can be found on page 4.

SIMULATION WORK AT CERTH

PROCESS SIMULATION

In the framework of the ANICA Project, CERTH investigates two novel concepts, the tail-end and the fully integrated solution, for the integration of indirectly heated calcium looping (IHCaL) into the existing lime plant of CaO Hellas in Thessaloniki, Greece. The concepts are developed and simulated in Aspen Plus ™, heat and mass balance equations are established and a detailed sensitivity analysis is performed.



Flowsheet diagram of the fully integrated IHCaL solution

In the tail-end solution, the IHCaL facility is located downstream of the lime process unit. This concept entails a low amount of integration, which makes it suitable for retrofitting.

In the fully integrated solution, the lime kiln is holistically replaced by the IHCaL process and serves both as a calcination unit and as a carbon capture facility. Additionally, since the calcination is carried out with indirectly added heat, there is no contamination of the lime with fuel-related particles like ash or sulfur. Thus, a purer final product than in the conventional process is to be expected.

From the sensitivity analyses, it is concluded that a low energy penalty in the IHCaL processes can be achieved with the maximization of the preheating temperature of the combustion air and with the best possible heat exchange in the solid-solid heat exchanger. Another important aspect of the model is the utilization of the sorbent purge as lime product. The purge lime extracted from IHCaL shows a high purity (98 wt% CaO). Consequently, it can be sold as product of the lime production, which makes both IHCaL concepts especially suitable and profitable for application to lime industries.

Finally, the following highlights can be mention from the evaluation of the integration concepts:

- The carbon capture efficiency of both IHCaL processes is high, reaching 90% and 92% respectively.
- As a result, the direct CO_2 emissions in both IHCaL processes are reduced significantly.
- An important indicator is the product ratio, which shows the production capacity of the new process in comparison to the original production. It was calculated that, in the tail-end solution, the amount of final product increases by 63%.
- The direct fuel consumption is 2.62 times higher in the tail-end solution and 1.97 times in the integrated process, when compared to the reference plant.
- Additional electric power can be generated in both IHCaL concepts. This power can be sold to the grid, decreasing thus the net operating cost of the plant.

Key performance indicators for the examined scenarios

Key Performance Indicators	Reference Plant	Tail–End IHCaL	Integrated IHCaL
Carbon Capture Efficiency [%]	-	90	92
Direct CO_2 emissions [kg/t_{CaO}]	1026	128	88
Product Ratio [-]	1.00	1.63	0.98
Power generation [MJ/t_{CaO}]	-	0.88	0.72
Direct fuel consumption [MJ/t_{CaO}]	470	1264	928

CFD SIMULATIONS OF THE CALCINER

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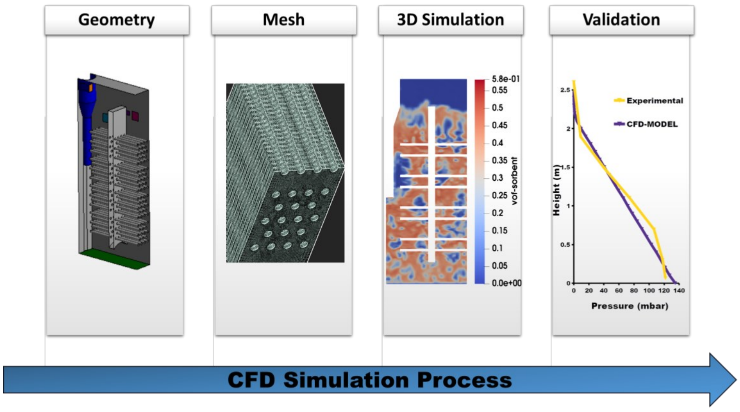
One of CERTH's major contributions into ANICA Project is to provide a validated transient CFD model of the bubbling calciner of the 300 kW power plant. This model will be later used to investigate the effect of several operating conditions (e.g. Geldart A vs. Geldart B particles, operating regimes) and/or heat pipes arrangements (design optimization) on the performance of the heat pipe heat exchanger.

CERTH has a wide experience with Eulerian-based CFD modelling in the CFB field and energy processes, by taking part in several EU-funded projects. In 2016, it has been accredited the ANSYS Academic Hall of Fame price. In addition, its personnel has long expertise in CO_2 capture-related modelling.

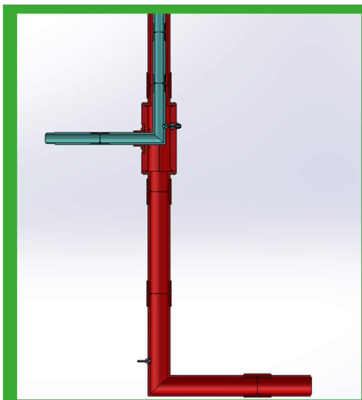


The granular flow in the calciner is modelled following an Euler-Euler (TFM) approach, which treats the gas and sorbent as interpenetrating continua. CERTH applies an in-house version of a sophisticated, high validity drag model, i.e. the sub-grid EMMS (Energy Minimization Multi-Scale) model, built for the specific operating conditions of the calciner reactor. This model, in contrast to conventional ones (e.g. Gidaspow), is able to accurately take into account the effect of the flow heterogeneity. Another important aspect of the CFD model is the heat transfer from the heat pipes into the bubbling bed. The main heat transfer mechanisms in this case are particles as well as gas convection, and radiation. Here, due to the high operating temperature (900 ^{0}C), radiation is anticipated to contribute significantly to the overall heat transfer.

In parallel, CERTH is currently developing an Euler-Lagrange model, i.e. the Dense Discrete Phase Model (DDPM), which utilizes closure terms from the Kinetic Theory of Granular Flows (KTGF). The main advantage of the DDPM methodology is that it is capable of incorporating a PSD into the model, which is a key parameter to improve the heat transfer and reaction modelling accuracy. However, DDPM has not been extensively validated especially for dense flows, compared to the much more mature Eulerian TFM. As a result, its successful implementation in the complex geometry of the calciner is quite challenging, often requiring special numerical treatment. The simulations are conducted within the commercial platform ANSYS Fluent, using numerous in-house built-in subroutines regarding the KTGF closure terms, reaction kinetics, and drag force models.

SOLID TO SOLID HEAT EXCHANGER (STSHE)

One innovative contribution of CERTH in the context of the ANICA project is to provide the design, proof of concept and simulation of an innovative StSHE. The StSHE is based on a concentric L-VALVE concept. The heat exchange takes place along the vertical section of two concentric L-VALVES where the particles from the calciner (hot stream) “flow” concurrently to the particles of the carbonator (cold stream) without any mixing taking place. CERTH will develop, design, manufacture and test a “cold model” of such an assembly to test the system’s flow controllability. This prototype will be constructed on acrylic (plexiglass) tubular sections and will be of a modular design in order to provide flexibility on the control parameters of the design.



Double L-VALVE bottom section

THE VIEW FROM THE INDUSTRY

DYCKERHOFF

Dyckerhoff is an internationally operating producer of cement and concrete within the group of companies belonging to Buzzi Unicem (Italy). With approximately 2000 employees at 138 locations (9 cement plants, 125 ready mix plants and 4 gravel and stone pits) in the German / Western European business unit, Dyckerhoff produces and distributes hydraulic binders like grey and white Portland cements, special cements and binders, lime-mixed products, mortars, and ready-mixed concrete, spanning the entire value chain from the raw materials required and production to construction-related consulting and other services.
Dyckerhoff operates a dedicated central laboratory (WDI) with appropriate technical facilities for concrete and mortar investigations, materials and durability testing, chemical and physical analysis.

THE INTERVIEW

Which role does the ANICA project play in the vision of the company?

In line with the objectives that have been established over the years by international climate protocols, Dyckerhoff and its Italian-based mother company Buzzi-Unicem are committed to reducing their CO_2 emissions. After the Paris agreement of December 2015, the commitment was extended to all the countries in which the group operates. This includes investments in research and development for the development of technologies for reducing carbon dioxide emissions into the atmosphere. Dyckerhoff and Buzzi-Unicem are involved in several projects with industry associations and academic institutions in order to achieve the target of lowering the total amount of CO_2 emissions. In order to develop the best possible technology for this, Dyckerhoff is involved in the ANICA project.

OUR INTERVIEWEE: DR. MARCUS PAUL

Marcus Paul, Study of Chemistry, MSc and PhD in Materials Chemistry, employed as project manager by Dyckerhoff in Wiesbaden (Germany), working in several R&D projects ranging from the development of new building materials to carbon capture, utilization and storage (CCUS)

Why is it important that referents from the industry, such as Dyckerhoff, are involved in the project?

Not just Dyckerhoff, but the entire cement industry has the goal of reducing CO_2 emissions. A project like ANICA can only be successfully advanced if specialists from all areas dealing with CO_2 reduction work together in an interdisciplinary manner. Therefore, in addition to the scientific experts, representatives from the industry must also participate in such projects to bring in their experience and the industrial needs.

Do you expect the results of the ANICA project to have a direct impact on the company? In which way?

The ANICA project will provide important results for the further development of systems for capturing CO_2 in cement production. There are several methods of capturing carbon dioxide from the cement manufacturing process. Which method is the most optimal depends on many given conditions. In case that the indirectly heated carbonate looping process proves to be the most optimal for the prevailing conditions, it could certainly be used on an industrial scale in at least one of our plants in the future.

What appealed to you personally in the ANICA project, sparking the interest to get involved in it?

During my studies in materials chemistry, I was already working on an interdisciplinary basis with experts from the fields of chemistry, physics, materials research and mechanical engineering. That is the reason why I work in the cement industry, because this industry gives me the opportunity to work in this broad area dealing with all aspects of cement production and the properties of the products. Carbon capture technologies are relatively new and will certainly affect the entire chain from the production to the quality of cement. Therefore, it goes without saying that I am interested in such a complex topic as CO_2 reduction and try to bring my knowledge and experience to the ANICA project.

What is your role in the project and what expertise do you bring to the consortium?

As mentioned before, I am a chemist working in the cement industry for a quarter of a century. During my career I have dealt with all aspects of cement production as well as the properties of the products which our company puts on the market. A change in the production process, which the carbon capture technology will inevitably bring with it, may also affect the product properties. It is my job to recognize such effects and, if necessary, react to them.

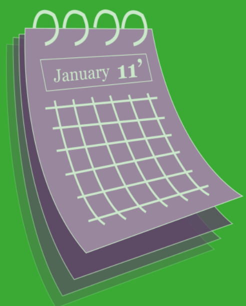
Why do you think ANICA is an important project for society?

Global warming and the associated significant consequences for society can only be averted or at least mitigated by drastically reducing CO_2 emissions. A project like ANICA can help us to develop technologies to reduce the increase in CO_2 concentration in the atmosphere and thus to stop—or even reverse—the climate change.

Do you have any final words for our readers?

I hope that ANICA will be a successful project and will help us to implement our climate goals in the future.

Save the Date



"Workshop on the Development of Efficient CO_2 Capture Technologies for Cement and Lime Industries"

A workshop organized by ANICA ACT Project Consortium

October 6, 2021

09:30a.m. - 12:45p.m. (CEST)

The Consortium

Technische Universität Darmstadt

CaO Hellas Natural Chemicals

FAU Friedrich-Alexander Universität Erlangen-Nürnberg

CERTH Centre for Research & Technology Hellas

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