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 VI - MARCH 2023

What will you find here?

PROJECT OVERVIEW

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. The project is bringing 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.

WHAT HAS BEEN ACHIEVED SO FAR?

Four concepts for the integration of the IHCaL process into existing lime plants in Hönnetal (Lhoist Group) and Thessaloniki (CaO Hellas) have been developed. The concepts were analysed with process simulations and economic analysis (see, e.g., Greco-Coppi et.al., 2021).

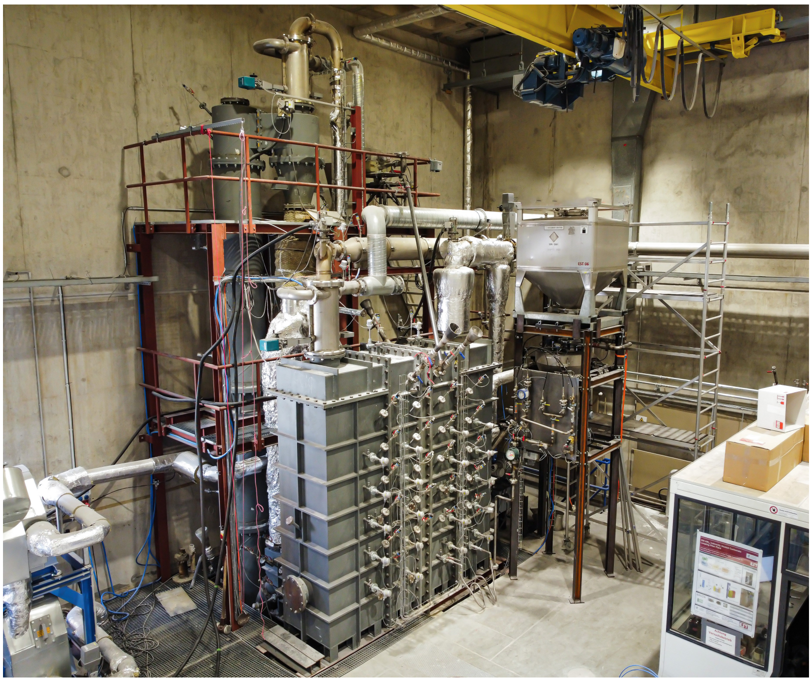
Regarding the experimental work, the 300 kW_{th} IHCaL testing facility at TUDA was upgraded with a solid sampling system, a solid-fuelling station, and a flue gas recirculation path. Long-term tests took place within two campaigns during 2022. A summary of the results is presented in this newsletter. Publications were made with information on the adaptions (Hofmann et al., 2022b) and the preliminary experimental results (Hofmann et al., 2022b).

IHCaL pilot plant at TUDA

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. The results of the process assessment are available and will be presented during the ANICA & AC^{2}OCem Workshop (see page 5). Important results from the transient CFD model of the 300 kW_{th} bubbling bed calciner, modelled following an Euler-Lagrange (DDPM) approach, were produced. More information on the CFD simulations can be found on page 4.

PILOT TESTS

In the second quarter of 2022, one important milestone of the ANICA project was achieved: pilot tests under different conditions for the integration into cement and lime plants were performed and showed promising results for the further application and up scaling of the technology. At the outset, the 300 kW_{th} test rig was modified with additional components, typical for industrial operation, in order to decarbonize the generated flue gas from coal, refuse-derived fuel (RDF), or propane firing in the carbonator. The new components area flue gas path with a cooler, bag filter, two fans, and a dosing system for RDF or coal, including a frequency controlled screw, a weighted dosing container, and a rotary valve.



IHCaL 300 kW_{th} pilot plant facility at TU Darmstadt

All in all, the plant was operated for over 400 h. A sorbent made of typical German limestone with a PSD of 100 – 700 µm was used. In addition to propane, a dried grained lignite (typical for fluidisation systems) with a lower heating value of *LHV* = 21.5 MJ/kg, and pelletized waste derived fuels (RDF) with a low chlorine content and *LHV* = 19.6 MJ/kg were used. During the pilot testing, a maximum solid firing of 200 kW_{th} was obtained and the balance was delivered by co-firing propane. The operation of the immersed heat pipe configuration of the calciner and combustor with solid firing gave important findings for the large-scale applications of the technology.

Fuels used in the pilot tests: pelletized RDF (left) and LEG coal (right)

First results were presented at the 24th International Conference on Fluidized Bed Conversion (Hofmann et al., 2022a). The operation data and the solid samples are still being assed. In particular, the influence of the solid firing (coal and waste-derived-fuel) on the reactor components, such as the heat pipes, the flue gas ducts, and the flue gas filter and cooler.

Various kilos of used purged sorbent from various sampling points of the test rig were collected and stored during the pilot tests. These samples are important to assess the performance of the Indirectly Heated Carbonate Looping Process. Additionally, the samples will be used to determine if the sorbent purged from the system can be used as intermediate or end product in the production of cement and lime. Analysis of the purge's quality are currently ongoing.

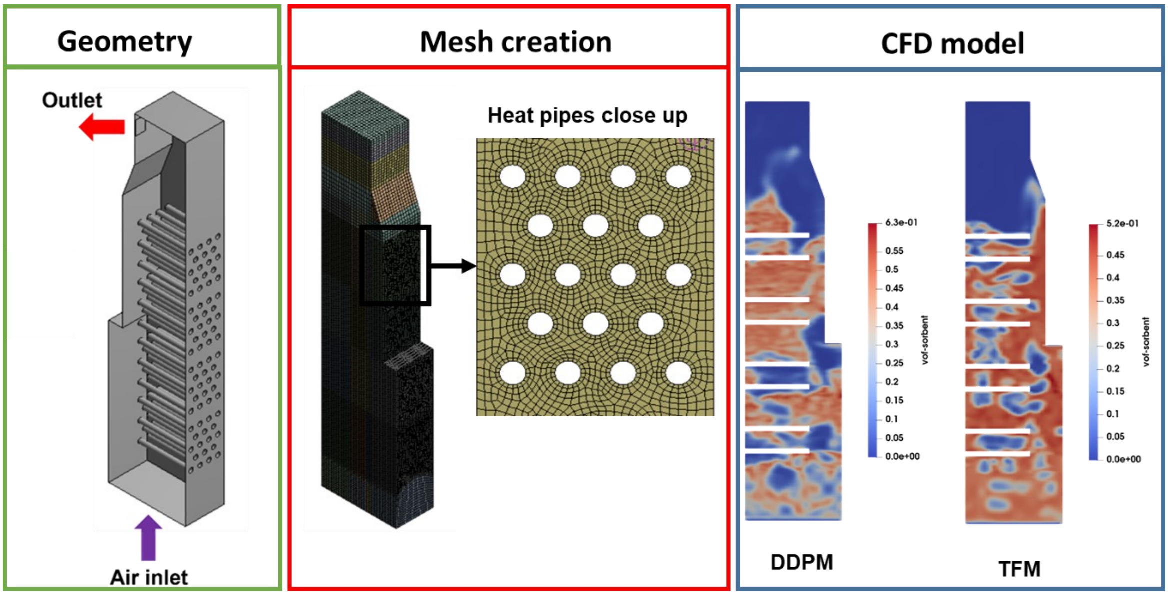
More publications of the experimental results are planned for the year 2023. In particular, new findings will be presented during the upcoming ANICA & AC^2OCem Workshop (see page 5) and the 9th IEAGHG High Temperature Solid Looping Cycles Network Meeting in March 2023.

CFD SIMULATIONS OF THE CALCINER

One of CERTH's major contributions into ANICA Project is to provide a validated transient 3D Computational Fluid Dynamics (CFD) model of the bubbling bed calciner of the 300 kW_{th} pilot plant. This model can be used to investigate the effect of several operating conditions (e.g. particle size, operating regimes, fluidization velocity) and heat pipes arrangements (design optimization) on the performance of the heat pipe heat exchanger.

CERTH has developed an innovative Euler-Lagrange model; i.e. the Dense Discrete Phase Model (DDPM), which utilizes closure terms from the Kinetic Theory of Granular Flows (KTGF) and uses the sub-grid Energy Minimization Multi-Scale Scheme (EMMS) as a drag force model between the gas-solid phases. The main advantage of the DDPM methodology is that it is capable of incorporating a wide range of particle size distributions (PSD) into the model, which is essential for the heat transfer and reaction modeling accuracy. Additionally, it combines the high accuracy of the Lagrangian Discrete Element method (DEM) and the high speed of calculations offered by the Eulerian-Eulerian Two-Fluid-Model (TFM). However, the DDPM has not been extensively validated especially for dense flows, compared to the much more mature 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 of ANSYS Fluent, using numerous in-house subroutines regarding the KTGF closure terms, reaction kinetics, and drag force models.



Methods and results of the CFD models of the IHCaL calciner.

Due to its complexity, the DDPM model has been tested on half of the 300 kW_{th} calciner geometry with a solids inventory equal to 174 kg. DDPM is an attractive alternative to TFM offering the advantages of a Lagrangian method at a reasonable computational cost, rendering the method a viable option for larger scale applications. DDPM and TFM numerical predictions are in a good agreement in terms of reaction kinetics and heat transfer (radiation accounts for 27% and 25% of the total heat flux according to the TFM and DDPM models, respectively). However, DDPM predicts larger bubbles leading in an over-prediction of the bed length by 12% in comparison with TFM, while it predicts the same overall pressure drop of around ~110 mbar. Therefore, DDPM, being at an early stage of development, requires further work to become as mature as the state-of-the-art TFM method.

ANICA AC²OCem Workshop

The ANICA and AC²OCem consortia cordially invite you to the **"Workshop on Carbon Capture for the Cement and Lime Industry"**, organized by VDZ on the 7th and 8th of March 2023. It is a hybrid (i.e., online participation is possible) workshop for all the industrial stakeholders and academic institutions involved in the cement and lime industry. Within this workshop, results from both projects as well as lighthouse projects in the cement industry will be presented and discussed. More information, including the link for the registration, can be found in the website of the ANICA

Visit to Thessaloniki Lime Plant CaO Hellas

The ANICA consortium visited the Thessaloniki Lime Plant CaO Hellas in the fourth quarter of 2022. The visit took place after the biannual General Assembly meeting in Thessaloniki, Greece.

Lime Plant CaO Hellas Natural Chemicals is the largest group of companies in the lime manufacturing sector in the greater Balkan Area. The group includes four plants manufacturing lime for environmental and chemical applications, as well as building lime products. The extensive range of products also offer numerous opportunities for both industrial and chemical uses. Furthermore, CaO Hellas participates in the ANICA project providing valuable input from the industry for the implementation of the IHCaL process to enable efficient carbon capture in the lime production.

The Thessaloniki Lime Plant CaO Hellas has a capacity of 50,000 tonne of lime per year and can produce 30,000 tonne of hydrated lime yearly. The calcination takes place in an efficient petcoke-fueled double shaft kiln.

Within the ANICA project, two integrated concepts were analyzed to capture CO_2 from this lime plant. The results of this work were published in the 11th Trondheim Conference on CO_2 Capture, Transport and Storage Trondheim (TCCS-11, Peloriadi et al., 2021).

The ANICA consortium in front of the CaO Hellas facility, Thessaloniki

Lime Plant CaO Hellas in Thessaloniki, Greece

Limestone, the main raw material at Thessaloniki Lime Plant CaO Hellas

THE INTERVIEW

What is CaO Hellas? Can you tell us about its mission?

CaO Hellas is a group of companies producing lime products for a wide range of applications. The last few years, the company shifted its direction towards environmental industrial applications producing specialised sorbents for the mitigation of industrial pollutants such as SOx, Hg, Cl, and dioxins. Further to its involvement in the environmental industrial sector, the main aim is to produce carbon neutral products. Hence, it is keen on investing money, effort, and time in research and innovation projects about carbon neutrality and industrial pollutants mitigation.

How does the ANICA Project align with the company's vision?

Focusing on carbon neutrality and industrial environmental application, and enrolling in projects such ANICA, helps us prepare and facilitate our adaptation when such state-of-the-art technologies come into implementation. There are aspects such as government legislation and permits that have to be addressed. Furthermore, the much-needed collaboration between research and academic bodies within the industry is deepened.

How is CaO Hellas contributing to the project? What role does it play in the consortium?

CaO Hellas provides technical data about the operation of its main plant such as operation parameters, emission levels and composition, composition and properties of its products. It also serves as a case study for assessing the technical and economic viability of the Carbonate Looping process.

OUR INTERVIEWEE: KONSTANTINOS INTZES

Konstantinos Intzes is a graduate of the Chemical Engineer Dept. of the Scholl of Engineering of the Aristotle University of Thessaloniki. He holds an MSc in Mechanical Engineering from the Eindhoven University of Technology with focus on numerical simulation methods. He has been working in CaO Hellas Group for 4 years in its Engineering Department as a deputy Technical Director.
He has an active participation in various funded research projects such as Horizon 2020, Act and others, being the technical representative of CaO Hellas Group in consortia and supporting its collaboration with partners.

Key roles: **Know-how development, exchange of technical knowledge, monitoring green house gas emissions, monitoring compliance with environmental regulations, and quality assurance.**

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

CaO Hellas is actively involved in the development of various emerging Carbon Capture and Storage, and Carbon Capture and Utilization technologies. The ANICA project stands out as the most by-product free. It also incorporates the progressive concept of isolating the process CO_2.

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

I collaborate in the development of a process model by collecting all the necessary data from the operation of the real-life lime plant CaO Hellas. I also perform laboratory tests on the materials involved in the Carbonate Looping process. In the next step, I will provide my technical know-how in the study of a viable implementation of the concept in a real industrial level.

(Interview continues onto page 7)

In your opinion, which repercussions will the ANICA Project have in the lime industry?

ANICA offers technology for carbon capture that will be exceptionally friendly to lime and cement industry. However, further research has to be made for the technology to be introduced to the several kiln types that are widely used with different fuels, calcination technology, and processes.

Considering your knowledge of the sector, which changes are coming to the lime industry regarding sustainability and production?

Lime production is a very energy-intensive industry with the largest amount of CO_2 emissions originating from the process itself rather than fuel burning. Therefore, carbon capture and utilization are crucial for the sustainability of the sector in the near future. Furthermore, utilization of biomass and biofuels will be of increasing importance in the effort towards carbon neutrality.

What impact do you expect the ANICA project to have in the lime industry?

ANICA and the technology proposed are based on a solid concept that promotes lime products and decarbonisation. Carbonate Looping offers an excellent platform for a diversity of future Carbon Capture and Utilization applications when the relevant technology matures. The biggest challenge, as of today, is to provide the lime and cement manufacturing sector with a viable retrofittable technical solution.

Final words

The technology developed in the ANICA project will soon reach TRL 6. This is exciting news. Some parts of its concept can already come to life. However, I believe the technology is best suited for future investments in combination with the emergence of kilns of the next generation.

PUBLICATIONS (SELECTION)

M. Greco-Coppi et al., *Negative CO2 Emissions in the Lime Production Using an Indirectly Heated Carbonate Looping Process*, 2nd International Conference on Negative CO_2 Emissions (2022).

C. Hofmann et al., *Operation of a 300 kW_{th} Indirectly Heated Carbonate Looping Pilot Plant for CO_2 Capture from Lime Industry*, 24th International Conference on Fluidized Bed Conversion (2022a).

C. Hofmann et al., *Adaption of a 300 kW_{th} Pilot Plant for Testing the Indirectly Heated Carbonate Looping Process for CO2 Capture from Lime and Cement Industry*, 13th European Conference on Industrial Furnaces and Boilers (2022b).

G. Kanellis et al., *Development and numerical investigation of a DDPM-KTGF model for modeling flow hydrodynamics and heat transfer phenomena in a bubbling calciner reactor*, 24th Int. Conference on Fluidized Bed Conversion (2022).

G. Kanellis et al., *CFD modelling of an indirectly heated calciner reactor, utilized for CO_2 capture, in an Eulerian framework*, 24th International Conference on Fluidized Bed Conversion (2022).

A. Rolfe et al. *Indirectly Heated Calcium Carbonate Looping - Reducing CO_2 Emissions from Lime Plants. A Techno-economic and Environmental Assessment*. In: 14th International Conference on Applied Energy (ICAE, 2022).

M. Greco-Coppi et al., *Efficient CO_2 Capture from Lime Production by an Indirectly Heated Carbonate Looping Process.* International Journal of Greenhouse Gas Control 112 (2021) 103430. https://doi.org/10.1016/j.ijggc.2021.103430

Peloriadi et al., *Process Integration of Indirectly Heated Carbonate Looping in Lime Plant for Enhanced CO_2 Capture.* In: Short Papers from the 11th International Trondheim CCS Conference (2021).

The Consortium

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www.act-anica.eu

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