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Upcoming ECRA online seminars:

- State of the Art Calciner Technology
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Pre-treatment of alternative fuels in calciners for more flexibility

New designs for pre-combustion chambers for thermal pre-treatment

Today, pre-calcining technology is included in the design of virtually all new kiln installations in the cement industry worldwide and in major upgrades. Precalciners provide particular flexibility, as alternative fuels can be fed at several firing places at different temperature levels. In addition to economic criteria, physical (e.g., particle size) and chemical (e.g., chlorine, sulphur, alkali and phosphate content) criteria play a decisive role in the selection of alternative fuels. Thermal pre-treatment can increase flexibility even further.

Alternative fuels are usually fed directly into the calciner. In principle, all firing positions at which fossil fuels are fed are also suitable for the input of alternative fuels. Depending on the properties of the alternative fuel to be used, some considerations have to be made. To provide optimum conditions for combustion the proper mixing of combustion air and fuel in the calciner is always of paramount importance.

Fuel characteristics

The most common alternative fuel in European cement plants is refuse-derived fuel (RDF) from industrial or municipal wastes. In its pre-processed form it is often referred to as solid recovered fuel (SRF) and can be fed directly to the calciner since it is fine enough to ensure proper combustion. The criteria must be defined for each kiln individually depending on its specific plant design. Fig. 1, for example, shows particle size distributions of SRF for 4 different kilns, as determined by sieving of the SRF. Between 5 and 15% of the fuel (mass fraction) is larger than 20 mm, so these fuels are generally coarser than those for the main firing.

It may be reasonable in individual cases to subject alternative fuels to thermal pretreatment in a separate device first. This is especially useful for coarse fuels, for fuels with low ignition behaviour or in cases where fuel metering becomes complicated.

Thermal pretreatment

Basically, two types of pretreatment plants must be distinguished: in gasifiers the fuel is pyrolysed under extremely low-oxygen conditions, and the lean gas produced is subsequently fed to the calciner as fuel. In pre-combustion chambers, by contrast, a considerably higher proportion of fuel is converted at over-stoichiometric or slightly under-stoichiometric conditions. The devices for thermal pretreatment currently existing in Europe are gasifiers, such as the circulating fluidised bed from Envirotherm, and precombustion chambers from A TEC, FLS (HotDisc), IKN (fire bed combustor), KHD (pyrorotor), and thyssenkrupp Industrial Solutions (PREPOL_SC; step combustor). The circulating fluidised bed is suited to the intake of fairly fine-grained fuels only, while most pre-combustion chambers are rather designed for coarse fuels, but fine-grained fuels can also be treated with these designs.

The choice of the most suitable system is influenced mostly by investment and operating costs, but also by fuel processing costs, the availability of the waste fuels, the removal of contaminants and substances forming cycles in the system, and safety concepts which might be required. As gasifiers and combustion chambers permit a high degree of flexibility in terms of the type, composition and nature of the fuels utilised, the number of such plants in the cement industry can be expected to grow in the long term.

Designs of pre-combustion chambers

In the HOTDISC pre-combustion chamber from FLSmidth A/S, the coarse fuels are transported by a rotating disc. The disc is speed-controlled so the retention time of the fuels on the rotating disc can be varied, depending on the fuel. To cool the outer walls of the refractory-lined pre-combustion chamber, a part of the fuel of the penultimate cyclone stage is fed together with the fuel. In this way the temperature in the HOTDISC can be controlled. The air required for combustion is drawn from the tertiary air duct. The HOTDISC is flanged to the existing calciner, into which the residues of the burned fuel then fall.

thyssenkrupp Industrial Solutions AG has developed the so-called Prepol Step Combustor (SC). The basic idea is the implementation of a step-like grate surface by which a residence time of several minutes can be achieved for the alternative fuel. Hot tertiary air passes over the fuel, which dries and ignites the material and provides combustion air for over-stoichiometric combustion. An adjustable meal divider feeds uncalkined hot meal into the combustion chamber to control the combustion temperature. The fuel is fed into the combustion chamber via feeding screws and is transported further by a flexibly adjustable air blast transport system. Light and already size-reduced particles enter the ter-
Carbon neutrality in the cement industry needs a complete CO₂ economy

Creating value chains for CO₂ capture, transport, storage and use

All roadmaps towards carbon neutrality include carbon capture as a breakthrough technology to fully decarbonize cement and concrete. ECRA has addressed carbon capture early in its work, on the basis of which this technology can now be implemented step by step in the cement industry in the near future. Post-combustion technology is already available today. Compared to this, oxyfuel technology has higher energy efficiency but requires a retrofit of the kiln. The implementation of this technology in pilot or demonstration projects has begun. At the same time, however, solutions for CO₂ need to be developed in which utilisation and storage will both play an important role. Many initiatives and projects have been launched. However, all of them require an infrastructure for CO₂ comprising CO₂ hubs and transport schemes which still need to be developed. This is certainly a matter of great urgency, and ECRA has therefore now broadened its focus on carbon capture to include CO₂ infrastructure.

A typical cement plant of 1 million t of clinker/year produces roughly 2,000 t CO₂/day. It is clear that this sheer volume entails challenges in many different ways. How can this amount be utilised? Is there sufficient green energy to transform the CO₂ into chemical raw materials? Is there enough storage capacity already available? And, above all, how will the CO₂ get from the cement plant to the utilisation or storage site?

CO₂ transport
Experience with CO₂ transport in pipelines for enhanced oil recovery projects exist in the US and Canada. In Alberta, Canada, a 240 km CO₂ pipeline went into operation in 2020. It has the capacity to transport nearly 15 Mt CO₂/year for enhanced oil recovery and permanent CO₂ storage. In Europe, some countries are reserving corridors for pipeline infrastructures in their long-term regional planning, and an existing short CO₂ pipeline in the Netherlands is linked to large-scale projects which are now being proposed by North Sea ports.

In the transition period, CO₂ transport will depend on trucks, trains and, if applicable, ships for river and sea transport. However, ultimately a pipeline system will be needed as the backbone of CO₂ infrastructure to handle the amounts of CO₂ from cement production alone (Fig.1). For this reason the European Union is addressing the need for appropriate infrastructures in its strategy for trans-European networks for energy (TEN-E), which comprises not only electrical infrastructure but also the infrastructure for hydrogen and CO₂. Several projects are providing initial infrastructure ideas and the European Commission is starting a special geography lab in its Joint Research Centre to collect and provide comprehensive information.

The time required to develop new CO₂ infrastructure might well become the most time consuming element and the bottleneck for the implementation of applying carbon capture in process industries. Its availability could become a strategic question for the applicability of CO₂ capture for inland plant locations. In the light of the significant investments for pipelines a key question arises: How can infrastructures and value chains be designed and established to realise effective and eco-

Figure 1: Comparison between different transport media for CO₂
nomic CO₂ mitigation in good time? This question involves significant political aspects, which need to be resolved and discussed together with society.

**CO₂ storage and utilisation**
For the geological storage of CO₂ parallel developments in Europe are gaining visibility with new projects in the North Sea. Some of them plan to start storage operation before 2025. On the whole, significant offshore CO₂ storage capacities are envisaged (Fig.2) which have the potential to store CO₂ from process industries like cement and lime for several decades.

When it comes to the utilisation of CO₂, regional potential comes into focus. Currently, there seem to be only limited capacities available. However, these small volumes of CO₂ can readily be transported on trains or trucks. The respective projects are of high importance because they can help to get the whole process started. For a scale-up it will then be important to create partnerships with potential CO₂ users. Here, there is certainly sufficient potential which can be developed. The crucial aspect, however, will be access to green energy. It must be available reliably and at sufficient low costs, whether as electrical energy or already transformed into hydrogen. Excess energy from wind farms or PV plants has already today proven to be a good starting point for upcoming pilot and demonstration projects.

**Initial cost indicators**
The cost for carbon capture is primarily related to its energy demand at the cement plant. This depends on the technology used and the availability of excess heat available from the existing plant. But all other costs for onshore and offshore CO₂ transport, storage, CO₂ handling and conditioning must be covered too.

From today’s perspective, the additional CCUS cost elements can only be estimated. Fig. 3 shows the estimates for the various carbon capture technologies, i.e. post-combustion, oxyfuel and calcium looping. Also included are cost figures for transport and storage. Still missing are figures for the utilisation of the CO₂. These figures depend on many conditions, most of which are however not clear at this time. The important factor of course will be the price for electrical (green) energy. It can be expected that this will further decrease over time and finally make utilisation a business case for all participants in the value chain.

The cost example given here refers to a future oxyfuel CCS application. With additional costs of 65 – 160 €/t CO₂, additional clinker costs will be in the range of 55 to +140 €/t clinker.

The figures indicate the enormous increase in CO₂ costs in the value chain of cement and concrete. Today, these figures are not reflected in the CO₂ price, which is ultimately needed to mirror the efforts taken by the cement producers. This will also imply a global carbon market, since not only all cement producers have the same target of carbon neutrality, but also other industrial sectors, including transportation and building.