EcoKiln for the production of highly reactive lime

Sustainable lime burning technology for steel plants

Hannes Piringer

Maerz Ofenbau AG is developing a new generation of lime kilns to achieve global climate goals. The kilns' operating mode can be flexibly adapted to the environmental requirements – they can be operated both conventionally and in oxyfuel mode. In oxyfuel mode, CO_2 concentrations in the kiln exhaust gas of 90 to 95% can be achieved, so that an inexpensive CCUS system can be implemented downstream.

The transformation of steel production to virtually zero greenhouse gas emissions is a very important contribution to limiting global warming and will be completed by 2050. According to a study of the International Energy Agency IEA [1], one of the most important pillars for this transformation is the use of new steel production technologies. Both hydrogen-based technologies, such as direct reduction, as well as CCUS-based technologies will be the most important technology paths for climate-neutral steel production in the future.

For the formation and the conditioning of slags, a decrease in limestone demand and an increase in quicklime demand is to be expected, since sinter is no longer used in the direct reduction plants and lime is advantageously used in the downstream melters or electric arc furnaces. The new Maerz EcoKiln for the production of highly reactive lime is based on oxyfuel technology and, at the same time, it generates an exhaust gas with a very high CO_2 concentration, which can be liquefied for further use or for sequestration, without much effort.

Regardless of the steelmaking technology path, the demand for oxygen in steel plants will always be high. For oxygen production, the steel plant may either operate an air separation plant or, in the future, an electrolysis plant for H_2 direct reduction – or a combination of both technologies. In any case, the production costs for oxygen in a steel plant are much lower than in other industries. Taking this into account, it immediately becomes clear that using a Maerz EcoKiln directly in the steel plant is the most cost-effective solution for climate-neutral lime production.

Transition from conventional to emission-free lime kiln operation

In order to limit global warming to well below 2°C, greenhouse gas emissions must be gradually reduced to zero by 2050. In a first step, fossil fuels could be replaced by renewable forms

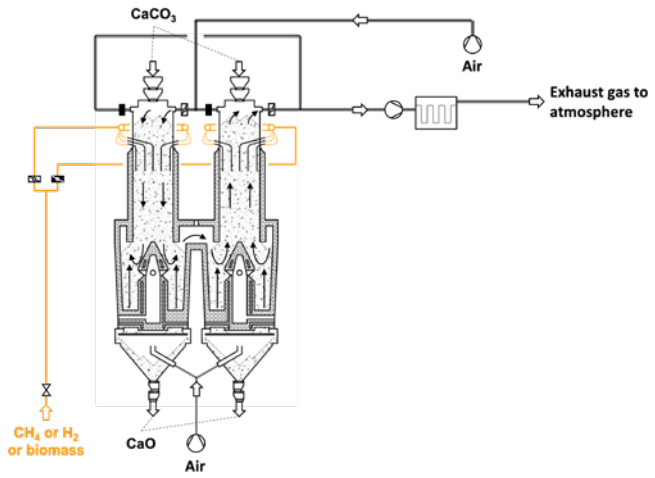


Fig. 1: Schematic drawing of the Maerz EcoKiln with air as the oxidant

of energy. Currently, the CO_2 pricing instruments such as the European ETS are a political means to achieve this goal. However, this is not enough, as the CO_2 from the decomposition of limestone is still emitted into the atmosphere. It is therefore very well possible that all greenhouse gas emissions (not only emissions generated by the combustion process) will be prohibited in the future. For these reasons, it is necessary for the steel and lime industries to take appropriate precautions. From today's perspective, there are no known ways to replace the required amount of quicklime with other substances. Therefore, there is only the possibility of converting the CO_2 generated in the lime burning process to other substances or sequestering it (CCUS).

The best time to install a CCUS system depends on various factors and can vary in different locations and companies. A flue gas treatment system, for enriching the CO_2 content by means of amine scrubbing, is feasible, but both the investment and the operating costs are very high.

So far, no technology has been developed to retrofit existing lime kilns with an oxyfuel combustion system to reach a very high CO_2 concentration in the exhaust gas stream. However, a lime kiln,designed to be ready for oxyfuel combustion, can currently be built without significant additional costs and can be operated conventionally without process risks. Depending on the development of the ETS price for CO_2, the necessary additional equipment for oxyfuel combustion and flue gas recirculation may be added later. The operating mode can then be selected in such a way that exhaust gas with a very high CO_2 concentration will be produced.

As the profitability of the lime kiln operation depends on many factors, it is important to be able to be flexible in choosing when and to what extent to switch to oxyfuel operation. The novel Maerz EcoKiln systems presented below, for which several patents are pending, allow both conventional combustion with air as well as operation with oxygen (oxyfuel operation) and thus offer full flexibility to optimise production costs.

The Maerz EcoKiln based on PFR technology

Figure 1 shows a schematic drawing of the Maerz EcoKiln based on Maerz' "Parallel Flow Regenerative" kiln technology (PFR) in conventional operating mode with air as the oxidant for the fuel. This lime kiln can already be built today and converted to oxyfuel firing at a later stage

The mode of operation corresponds to that of the Maerz PFR kiln [2], which is well known in the industry and is therefore not described again here. The structure of the Maerz EcoKiln PFR only differs in the slightly higher shafts below the connecting channel, and the design of the displacement bodies in the cooling zones, which allows the cooling air to be extracted thereby preventing it mixing with the kiln process gases. In conventional operation mode, CO_2 concentrations of

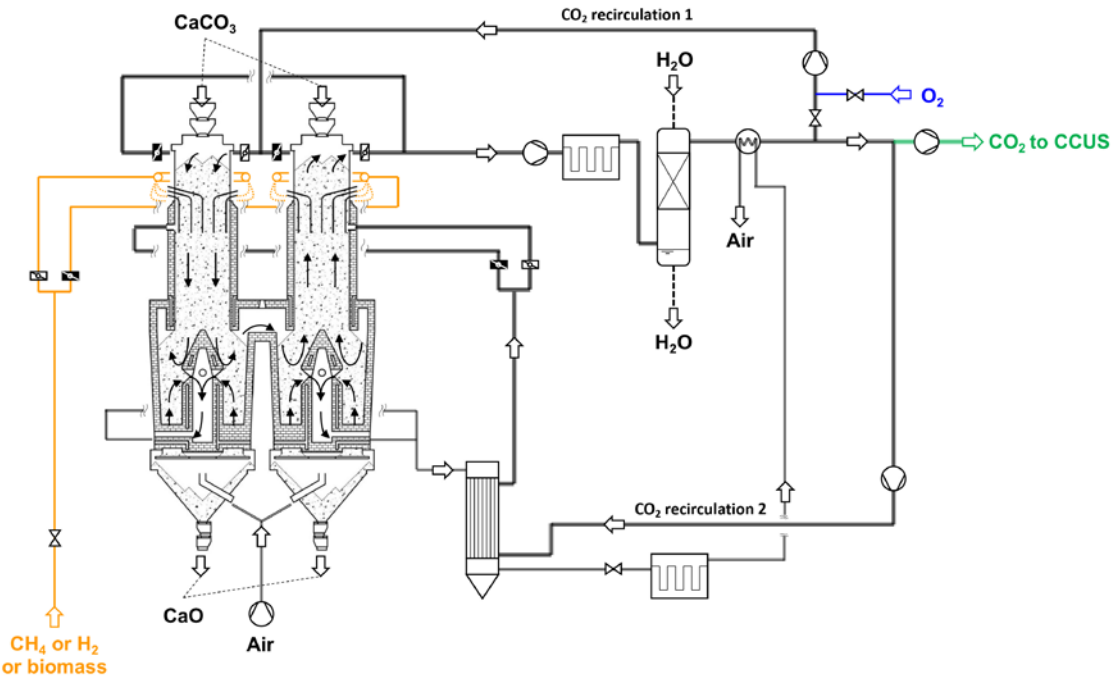


Fig. 2: Maerz EcoKiln PFR with oxyfuel combustion, cooling air extraction and double flue gas recirculation

around 20 vol-% are achieved in the kiln exhaust gas, which is usually emitted into the atmosphere.

Figure 2 shows the Maerz EcoKiln PFR with oxyfuel combustion, cooling air extraction and double flue gas recirculation. In this mode of operation, CO_2 concentrations in the kiln exhaust gas of more than 90 vol-% can be achieved. A CCUS system for processing the kiln exhaust gas can be retrofitted,with no need for an expensive CO_2 enrichment system such as amine scrubbing or other CO_2 enrichment technologies.

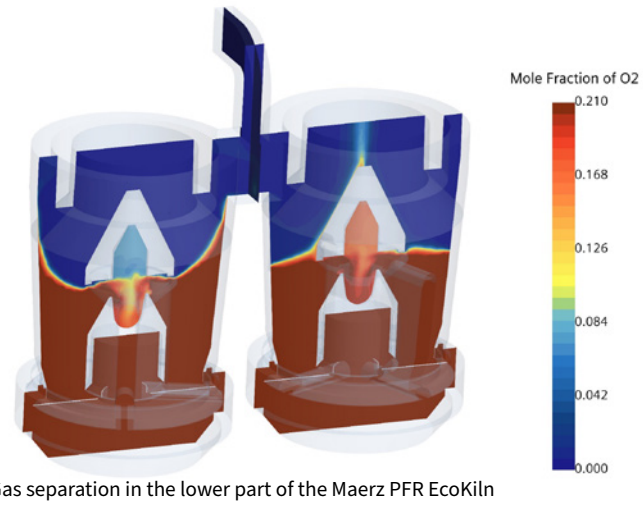
The major advantage of the Maerz EcoKiln PFR is its flexibility in terms of the operating mode: as production costs will depend heavily on the ETS and CCUS costs in the future, the operating mode can be freely selected, to achieve the highest economic efficiency.

The high CO_2 concentration in the exhaust gas is achieved by using a mixture of oxygen and recirculated flue gas instead of air, and by discharging the cooling air into the atmosphere instead of mixing it with the combustion gases in the non-burning shaft. As an oxidising agent for the fuel, the oxygen-flue gas mixture has the advantage over air that no nitrogen is introduced into the lime kiln. To moderate the combustion temperature, the oxygen is mixed with kiln exhaust gas (CO_2 recirculation 1 in Figure 2) and fed to the lime kiln as an oxidising agent for the fuel. This oxidising agent, which has a temperature of around 100 °C, is compressed up to 450 mbar with a high pressure fan. As in conventional operation, this gas is preheated in parallel flow in the preheating zone of the combustion shaft to a temperature of around 700 °C and reacts with the fuel, which is fed through the burner lances. This operating mode of the preheating and burning zones is practically identical to the conventional operating mode. Both the temperatures and the pressures are almost the same, making this process ideally suited for the production of high-quality quicklime with high reactivity.

The kiln exhaust gas and the cooling air are separated below the connecting channel and the cooling air is extracted from the kiln through the two displacement bodies. In the preheating zones, an exhaust gas mass flow equivalent to the discharged cooling air mass flow (CO_2 recirculation 2 in Figure 2) is fed, so that the exhaust gas mass flow of the lime kiln is the same as in conventional operation. The heat dissipated by the cooling air is partially transferred to the kiln exhaust gas and returned to the preheating zones by means of a heat exchanger (recuperator or regenerator). The achievable gas temperature after the heat exchanger is between 500° and 750 °C, depending on the type of heat exchanger.

When designing the Maerz EcoKiln PFR emphasis was placed on largely using well-known and technically proven kiln components: only the gas separation and the cooling air extraction had to be developed. An important base for the kiln development was the use of the most advanced software for fluid dynamic calculations, combined with the year-long expertise of Maerz' process engineers.

Figure 3 shows the gas separation in the lower part of the Maerz EcoKiln PFR. With an appropriate kiln geometry, a CO_2 content in the kiln exhaust gas of more than 90%, based on dry gas, can be achieved. At the same time, the CO_2 content in the discharged cooling air does not rise above 3%. This



Gas separation in the lower part of the Maerz PFR EcoKiln


Maerz HPS EcoKiln

means that approximately 99% of the total CO_2 produced in this lime kiln can be provided for CCUS.

The Maerz EcoKiln PFR can be built for a production of 300 to 800 t/d and, just like the well-known Maerz PFR kiln, can be fired with all common fuels. When using hydrogen, the Maerz EcoKiln PFR has the advantage that the combustion temperature in the kiln can easily be adjusted with the help of the exhaust gas recirculation, despite the higher adiabatic combustion temperature compared with natural gas as well as the significantly higher combustion speed. If hydrogen is

used in a Maerz EcoKiln PFR, there are no emissions: as no nitrogen enters into the kiln, neither with the fuel nor the oxidising agent, no NOx will be produced. There are also no carbon monoxide or hydrocarbon emissions because hydrogen as fuel does not contain any carbon.

Summary and outlook

The climate goals and climate policy are currently challenging the industry and creating some uncertainty. Modern lime kilns emit around one tonne of CO_2 per tonne of lime; around three quarters of which come from the decomposition of limestone. By 2050, no more CO_2 may be emitted to the atmosphere, regardless of whether it comes from fuel combustion or limestone decomposition. It is highly likely that CCUS technologies will also have to be used in the steel and the lime industries in the future. In order to give the industries the necessary flexibility for this, Maerz Ofenbau AG has developed the Maerz EcoKiln series. These lime kilns allow conventional operation, but can be switched to oxyfuel operation at any time if necessary. With the new Maerz EcoKiln series, CO_2 concentrations of 90 to 95% are achieved in the exhaust gas. This means that, if necessary, a CCUS system can be connected downstream, without an expensive CO_2 enrichment system, thereby completely avoiding CO_2 emissions into the atmosphere. The new Maerz EcoKiln series (patents pending) enables the production of highly reactive quicklime, can be operated flexibly and allows a seamless transition to emission-free lime kiln operation.

Literatur

[1] International Energy Agency, Achieving Net Zero Heavy Industry Sectors in G7 Members, May 2022

[2] H. Piringer, Lime Shaft Kilns, INFUB – 11th European Conference on Industrial Furnaces and Boilers,
INFUB-11, ELSEVIER, Energy Procedia, www.sciencedirect.com

Author

Hannes Piringer
Maerz Ofenbau AG
Zurich/Switzerland
Phone: +41-44-287 27 26
Mobile: +41 79 654 33 51
hannes.piringer@maerz.com