Oxygen enrichment: a critical enabler towards net-zero

While helping to reduce overall GHG emissions and being economically attractive, alternative fuels can present a combustion challenge to producers. The strategic use of oxygen-enhanced combustion technology can significantly improve the combustion of these fuels, increasing the flame temperature and allowing for greater levels of alternative fuel substitution. And the more alternative fuels can be employed, the more CO_2 emissions savings cement producers can claim, including refuse-derived fuels (RDF).

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The challenges of climate change now need little introduction. The most recent Intergovernmental Panel on Climate Change (IPCC) report in 2018 delivered its assessment that we have an extremely short window to act on climate and limit global warming to 1.5˚C. The IPCC made plain that limiting warming to 2˚C will not be enough to prevent the most serious impacts.

Like many other industries, the cement sector is facing pressure to find technological solutions to greenhouse gas (GHG) emissions resulting from its activities. The cement industry accounts for eight per cent of global emissions and represents around 16 per cent of all emissions emanating from industrial operations globally.

A changing landscape

The majority of GHGs produced during the manufacturing of cement occur during the calcination of limestone. As a result, GHG emissions from cement production are broadly divided between the calcination process – emitting roughly 70 per cent – and the combustion process, emitting around a further 30 per cent. Only a small amount of GHGs come as indirect emissions from electricity consumption and transportation.

The EU cement industry is under a very strict target to reduce carbon emissions by 30 per cent by 2030 and to reach net-zero by 2050. Longer-term solutions will be needed to reach the goals. Effective and easily-installed solutions are required in the interim to deliver the 2030 goals and to help the cement industry's gradual transition to carbon capture.

Oxygen-enhanced combustion in cement kilns is a proven solution to provide the GHG emissions reductions needed over the next 10-15 years before long-term solutions are deployed

On a per capita basis, the consumption of cement is second only to water and there are currently no substitutions. Therefore, it is critical that neither product quality nor productivity is impinged. For these reasons, oxygen-enhanced combustion in cement kilns is a proven solution to provide the GHG emissions reductions needed over the next 10-15 years before long-term solutions are sufficiently deployed.

Increasing fuel costs and sustainability legislation have driven cement producers to use ever-larger amounts of alternative fuel (AF) sources. Natural gas gave way to pulverised coal, with the proportion of coal then being reduced with the introduction of much cheaper refuse derived fuels (RDF) as a secondary kiln combustion feed. Typically consisting of 35-50 per cent biomass – which is CO_2 neutral – RDF as a secondary fuel can make an important contribution to limiting a cement plant's carbon footprint. In addition, the cement producer can claim an element of CO_2 neutrality from that portion of its kiln combustion fuel, which given the increasing price of CO_2 allowances, also provides an economic advantage.

RDF as a secondary fuel can make an important contribution to limiting a cement plant's carbon footprint

Optimising the use of AFs

While helping to reduce overall GHG emissions and being economically attractive, AFs, in comparison to fossil fuels, can present a combustion challenge to producers. Typically, RDF has higher moisture levels, lower calorific values and different particle sizes, making it more difficult to burn. Yet, maintaining sufficient front-end temperatures is paramount to


Oxygen can be supplied by tanker truck to a customer's site or can be generated on location

consistent kiln operation. If an optimal temperature cannot be maintained due to the low heating values of the AFs used, productivity and clinker quality will suffer. As a result, the share of AFs used is limited to a maximum level for each individual kiln.

The strategic use of oxygen-enhanced combustion technology can significantly improve the combustion of these fuels, increasing the flame temperature and allowing for greater levels of AF substitution. And the more carbon-neutral AF can be employed in the combustion process, the more CO_2 emissions savings can be realised.

The case for oxygen enrichment is reinforced when the role of nitrogen in air is considered. With air consisting of 78 per cent nitrogen – a relatively inert gas that both inhibits fuel from reacting with oxygen and absorbs heat from the combustion – this results in a flame temperature below that attainable with greater levels of oxygen.

The principle behind oxygen enrichment is well established. By substituting pure oxygen for a portion of the primary combustion air – usually 2-7 per cent – or injecting it to react directly with the fuel, flue gas flow rates are reduced while heat transfer, flame temperature and thermal efficiency are increased. In a cement kiln, in addition to the opportunity for increased AF utilisation, this also means a more consistent burn and improved kiln control and stability, enabling operators to increase feed rates for improved productivity throughput by 5-30 per cent.

Economic advantages

Costs to install oxygen-enhanced combustion technology are typically very low compared to other capital equipment or system upgrades, and are not a significant factor when considering the supply of oxygen. In most cases payback is in the region of one year and the installation can be undertaken as a retrofit to an existing operation without stopping the kiln for longer than a few hours.

Across the several cement plants in Europe where Air Products has implemented its oxygen enrichment combustion solutions, customers have saved on average 11,000tpa of GHG emissions and as much as 35,000tpa in some installations.

When considered in light of the increasingly-stringent carbon emissions allowances, the economic advantages are clear: in May 2021 cost of emissions allowances exceeded €50/t of CO_2 emitted, meaning that every 10,000t represent more than €500,000 per annum in savings. In addition, free allocated allowances will inevitably decrease as the climate emergency becomes more urgent.

At the same time, numerous experts are forecasting the price of CO_2 allowances to rise to €120-160/t by 2050, which will further increase the attractiveness of oxygen-enhanced combustion technology.

Reliable, safe and proven

Since 1997, Air Products' proprietary enrichment systems have been installed and demonstrated in over 30 kilns around the world. The technology is applicable to all types of kilns and its low installation costs make it an attractive alternative to expensive equipment modifications.

Cemex – a case in point

Air Products has been working with Cemex since 2010 supplying oxygen-enhanced technology to several of its plants. Cemex' strategy to contribute to a low-carbon economy and help limit climate change is to reduce the carbon footprint of its processes and the products it markets. One of the ways it is working to reduce its emissions is by increasing the use of AFs. Oxygen injection allows us to increase the consumption of these fuels in an efficient way. Cemex has chosen Air Products Vacuum Swing Adsorption (VSA) oxygen generators for on-site gas production.

"Air Products' improved oxygen solutions have allowed us to not only increase the use of alternative fuels, but to ensure the level of productivity, the quality of our products and most importantly, from a sustainability perspective, to support compliance/fulfilment of our roadmap," says Tomás Sánchez-Corral, Cemex Processes Director for Europe and Cement Operations for Spain. ■

Air Products' VSA oxygen generators for on-site gas production at Cemex