Emissions reduction remains a major objective for many cement producers. How can burner design minimise the production of harmful emissions?

FCT Combustion: CO_2 and NOx are the main emissions of concern in the cement industry, but these emissions can be significantly reduced by utilising a specialist burner.

The calcination of limestone is the main cause of the CO_2 emissions in cement production, followed by combustion products, while NOx emissions are caused both as an inherent byproduct of the combustion process and due to heat flux characteristics.

Regarding the CO_2 emissions there is not much a burner can do, except increase its efficiency, which would reduce the CO_2 emissions due to the combustion, or replacing the fuels for some with less or none carbon, such as hydrogen for instance. To reduce CO_2 emissions from the limestone calcination, a complete shift in technology is required, including the replacement of clinker with calcined clays.

The kiln burner design can influence NOx emissions significantly as NOx is correlated to several factors which fall under burner control, such as: flame ignition distance from the front of the burner, total primary air volumes, both axial air and swirl air distribution and location, rate of secondary air entrainment, and flame momentum, among others.

A burner which can control heat flux also has the ability to control NOx. FCT's Turbu-Flex™ burner has been designed to meet this challenge and includes a nozzle that can be adjusted to suit the fuel mix by offering two modes to operators: one mode is characterised by a more moderate flame specifically for reducing NOx emissions, while the other maximises alternative fuel firing and thereby reduces CO_2 emissions.

FCT's Turbu-Flex burner allows for switching between two operating modes by pressing a button in the control room: the boost mode, designed for efficient combustion of high volumes of alternative fuels, and the standard mode, for NOx reduction.

When speaking specifically about gaseous fuels, FCT's Gyro-Therm burner was designed with these factors in mind, and uses precessing jet technology to

World Cement Burner Design Q&A

World Cement **invited experts in the field of burner design to answer questions relating to alternative fuels, process stability, maintenance, and more. Contributions to this year's edition of the Q&A come from: FCT Combustion.**

significantly reduce NOx. Clients have reported a reduction of more than 30% in their NOx emissions, compared to when using traditional turbulent jet burners.

Some of the other harmful emissions can also be reduced by using proper combustion controls to manage the main burner. For instance, a short and intense flame will help to reduce SOx emissions trapping the sulfur inside the clinker matrix instead of being thrown into the atmosphere with the exhaust gases. Other minor components can benefit from similar effects.

Alternative and refuse-derived fuels (RDFs) continue to see significant usage in cement production, particularly in the wake of rising fossil fuel prices. What can be done to ensure the efficient combustion of these fuels?

FCT Combustion: A distinction has to be made between firing alternative fuels in the calciner and the rotary kiln.

To ensure efficient combustion in the calciner, it is important to study the aerodynamics to ensure RDF is introduced in the correct location to experience full residence time, oxygen availability, temperature zones, and mixing, as these are the major aspects impacting efficient combustion. In many cases, FCT has used computational fluid dynamics (CFD) to modify the tertiary air inlet ducting, goose neck, exit ducting, and firing locations to improve aerodynamics, turbulence, and temperature distribution, improving combustion performance and raw meal calcination.

In the rotary kiln burner, RDF can be successfully fired at high substitution rates above 80%. Depending on the characteristics of the RDF to be used, it can be introduced via a channel in the burner, or it can be introduced adjacent to the burner in a satellite burner. The knowledge accumulated over the years with difficult-to-burn fuels shows that flame momentum, secondary air entrainment, injection location and distribution of fuels and air within the flame, together with the characteristics of the alternative fuel itself, are the major influences on efficient combustion at high substitution rates.

In cases where high substitution rates are difficult to achieve, a study, which may include a CFD element, can help clarify the reasons why, identifying solutions that will allow higher substitution rates.

Hydrogen is also being increasingly considered as part of a more environmentally friendly fuel mix. What impact does hydrogen have on burner performance?

FCT Combustion: Hydrogen is an emerging fuel that could replace traditional fossil fuels when it is able to be produced from renewable energy in sufficient quantities and at a reasonable cost.

At present, small amounts of hydrogen can be introduced in the kiln burner, where it can have positive effects on the early ignition of alternative fuels. Any hydrogen usage will reduce CO_2 emissions from the combustion process as well as allow the use of more alternative fuels.

FCT's current range of multi-fuel burners can be adapted for hydrogen in rotary kilns, and the company have previous experience successfully installing burners with hydrogen substitution rates of up to 65% in other high temperature processing industries.

FCT is a key partner of the heavy industry low-carbon technology (HILT) CRC research programme, which includes a focus on hydrogen, working alongside academic and industry partners to find solutions for the challenges that currently exist in mainstream hydrogen adoption, including the potential for lower heat transfer to the clinker as well as the potential for NOx emissions to increase due to the high adiabatic flame temperature.

FCT is currently developing a rotary kiln burner design capable of firing up to 100% hydrogen. The company's R&D team has already designed a low-NOx iron ore pelletising version of the burner for travelling grate kilns, which is in the prototype phase and will be tested in the facilities of a European industry partner in 2023.

An article which explores hydrogen as a method for reducing CO_2 emissions in clinker production in greater detail, including its productions, benefits, and downfalls was written by FCT, and is available in the November 2022 edition of *World Cement*.[1]

How can burner design play a role in maximising process stability?

FCT Combustion: Burner design plays a very important role in process stability. The burner produces the flame and radiation which is used in the clinkering process. The flame length and radiation profile are critical to controlling the burning zone temperature and location. A stable burning zone location and temperature leads to stable kiln operation.

To counteract the natural variations of the process, a burner with flexible operation is required. In that way, the burner can cope and even minimise some instabilities caused by factors other than the burner itself such as fuel characteristics, raw material variability, and operational instabilities, among others.

FCT's Turbu-Flex burner has a wide operational range, specifically designed to be able to adjust to the needs of the client. The burner can be operated in standard mode or alternative fuel boost mode, depending on the operator's choice of fuel, and features one 'on-off valve' to easily switch between the two with no interruptions to operation or production.

As fuel mixes change, particularly if using variable RDF, it is important the burner maintains a stable flame length and position. In some specific cases or for troubleshooting, FCT uses CFD to ensure the burner is matched to the kiln aerodynamics and the range of expected fuel mixes to ensure a stable burning zone.

What steps can be taken to reduce maintenance costs and maximise burner lifetime?

FCT Combustion: Monitoring parameters in the burner, such as the primary air or gas pressures and flows (if gas is used as a fuel), are essential to ensuring the burner is in good mechanical condition. Any deviation outside normal operating conditions should be investigated immediately to minimise damage to a burner. Additionally, the temperature at some critical burner parts can be measured online to anticipate any failures.

Intentional burner design also reduces maintenance costs and increases lifetimes. FCT takes into account the expansion of burner channels relative to each other in its design to avoid damage from differential expansion. Tip designs do not constrain axial expansion.

FCT also uses special coatings on critical face plate items to prolong burner life, as well as using wear-resistant materials, high grade heat-resistant steels, and smart design to minimise wear and facilitate maintenance.

What trends do you believe will shape the evolution of burner design over the coming years?

FCT Combustion: As hydrogen becomes more prevalent, it will deliver environmental benefits in terms of CO_2 reductions. However, it is important to note that the use of hydrogen will create its own challenges due to its combustion properties, as it burns with low radiation and high NOx. Additional considerations will include bespoke valve train design to deal with hydrogen leakage, component selection due to hydrogen embrittlement issues, burner management system (BMS) design and safety due to the very wide flammability limits, and flame detection due to the low radiation. FCT is experienced in working with hydrogen and can assist operators in safely adopting the new fuel into their process.

Alternative fuels (AF) including refuse derived fuels (RDF) will also continue to shape burner design. In particular, the use of biomasses will likely be popular for their low-to-no nett CO_2 emissions. For high levels of AF and RDF fuel substitution in the rotary kiln, FCT offers the Turbu-Flex burner, which is proven and trusted by clients across the globe. For the calciner, a well-designed injection point will contribute to higher substitutions.

FCT has a team of in-house CFD Specialists who can assist clients in optimising the design for their specific needs. CFD gives insights that cannot normally be seen, and can assist in solving 'new' and challenging problems that are yet to appear. ■

References

1. MAIA, J., FCT Combustion, 'Placing Our Hopes In Hydrogen', *World Cement*, November 2022, p. 56