Boosting AF rates with flame thermography

Over the past 30 years the cement industry has witnessed an increasing use of alternative fuels (AF), but the amount that can be fired in the main burner is limited by different process factors. To optimise AF firing in the main burner, VDZ has conducted several research projects with the aid of flame thermography. The know-how gained has been used to support producers seeking higher AF substitution rates, including a European plant that reached 100 per cent in the main burner without compromising clinker quality.

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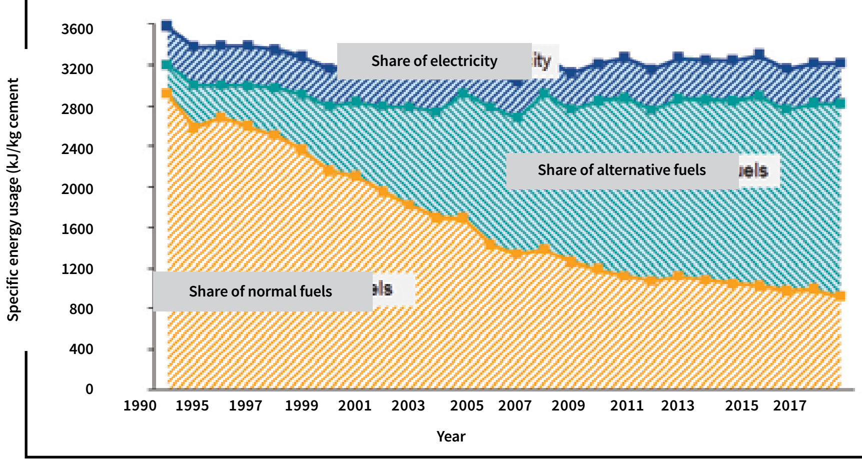
In recent decades, the cement industry has come to recognise the importance of alternative fuel (AF) firing. In the case of Germany, a leader in this technolgy, the evidence of considerable economic and environmental benefits has boosted the country's thermal substitution rate (TSR) to an average of around 68 per cent in 2018, with some plants reaching over 90 per cent. Energywise the share of AF in cement-specific energy consumption has grown from a mere 282kJ/kg of cement in the 1990s to a remarkable 1901kJ/kg of cement in 2018 (see Figure 1). On a global scale the average AF substitution rate was around 17 per cent in 2016[2] and is expected to rise steadily.

Despite European cement producers having much experience with AF, increasing the TSR remains a daily challenge for kiln operators and process engineers. TSRs of up to 100 per cent in the calciner are already a reality in many plants. However, firing high rates of AF in the main burner remains a more complex task. Even firing high-quality AF and operating a modern multichannel burner alone might not be sufficient to reach the desired targets. Meanwhile, some cement plants have invested in the installation of satellite burners and reported very promising results with increasing the AF rate.

Figure 1: energy share of AF in Germany, 1990-2017[1]



Impact of flame characteristics on pyroprocess & clinker quality

The amount of AF that can be fired in the main burner is limited by different process factors. These include:

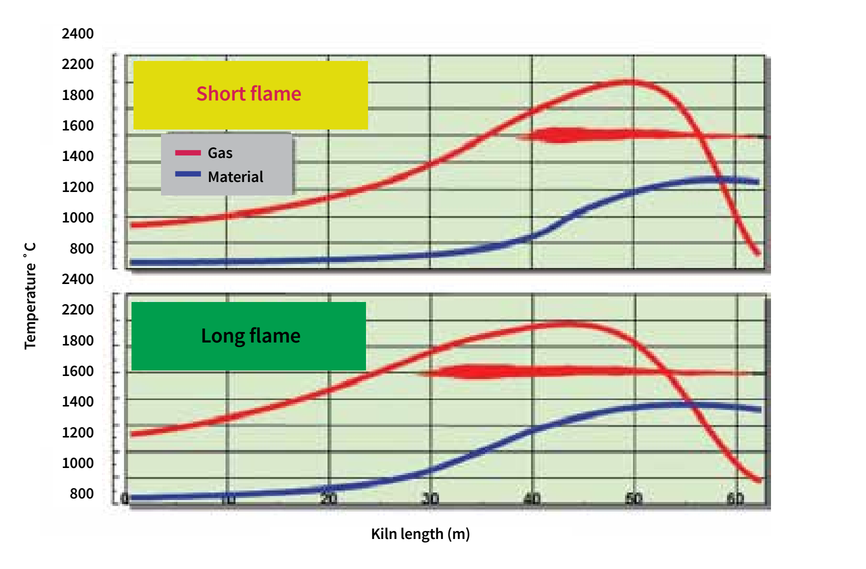
- secondary air temperature: strongly influenced by cooler operation settings
- fuel mix and respective characteristics: eg, particle size, heat value, volatile and ash content, moisture, etc
- burner type and settings: ability to shape the flame with burner air.

All these factors influence the flame characteristics, and ultimately the temperature profile in the kiln (see Figure 2) and the clinker quality. The fuel portfolio and the type of burner can usually only be changed or improved at the expense of considerable investment or higher operational costs. Therefore, the optimisation of the burner and the cooler operation settings is the most cost-effective approach to enhance the AF rate in the main burner.

Modern multichannel burners are designed with a variety of nozzles and channels and enable flame shaping through the adjustment of different burner air streams (eg, axial and swirl air, central air, etc). Despite their flexibility to fire multiple fuels with different combustion characteristics simultaneously, the adjustment of the burner settings to compensate for the undesired effects of AF is neither a totally risk-free nor a trivial task, and requires experience and know-how.

Burner axial air plays a relevant role in the combustion process as it is responsible for pulling the hot secondary air into the flame (external recirculation). Thus, a higher amount of burner axial air tends to make the flame shorter due to the acceleration of the combustion process. On the other hand, the positive impact of burner axial air on flame behaviour is also dependent on the burner swirl air.[4] The swirl air sets the burner air into rotation and the individual burner air streams are twisted (internal recirculation). The flame twisting improves the secondary air entrainment and keeps the flame close to the burner tip. A fuel ignition point close

Figure 2: effect of the flame's length on gas and kiln feed temperature profiles,[3] edited by VDZ



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to this tip brings some benefits in terms of flame stability, fuel combustion and avoidance of temperature peaks.

However, a proper balance between secondary and primary air, and also between axial air and swirl air volume flows, should be sought. The incorrect adjustment of the burner settings may result in the incomplete combustion of AF particles. Partly unburnt particles can fall into the kiln charge causing locally-reduced burning conditions. This increases the risk of recently-formed alite decomposing into belite and free lime, affecting the early strength of the cement. The enhancement of AF in the main burner tends to make the flame longer, sometimes with two temperature peaks, and cooler at peak temperature. Consequently, a lengthening of the precooling zone and of the sintering zone, as well as a reduction of the sintering zone temperature and of the clinker exit temperature, are commonly observed. A longer sintering zone tends to form larger alite crystals and diminish clinker porosity. The clinker degrees of sulphatisation and grindability are negatively affected.[4] On the other hand, a cooler sintering zone at peak temperature increases free lime formation, which impairs cement strength development and soundness. With a lengthening of the precooling zone the clinker cools down more slowly and some recently-formed alite crystals convert to belite. In addition, the alite reactivity of C_3A-rich clinkers may also be affected.[5]

In summary, the generation of a hot and short flame close to the burner tip should be sought to diminish the potential negative effects of using high rates of AF in the main burner as described above. However, the evolution of a coating formation in the burning zone should be closely monitored, as the significant heat release resulting from a short and intense flame may erode the coating and shorten refractory life.

Burner optimisation with the aid of flame thermography

The development of flame monitoring systems has helped scientists and engineers improve their knowledge of the effects of fuel characteristics on the combustion process. Over the past few years, VDZ has conducted several research projects with the aid of flame thermography in rotary cement kilns. The aim of the research was to define the sensitivities and relationships between several factors that influence the combustion process in the main burner in a form applicable to cement kilns in general. The scientific know-how gained by VDZ during these projects has been used to support cement plants seeking higher AF substitution rates.

Obtaining a first impression of how the pyroprocess is performing as a whole, and knowing the equipment characteristics, operation settings and the type of fuels beforehand, is crucial for quick and effective burner optimisation. During on-site visits a thermo-camera is installed in the most suitable kiln hood opening and parameterised accordingly (see Figure 3). The correct selection of the location and parameterisation of the thermo-camera plays a key role in the quality of the gathered data and, therefore, on the optimisation procedure and final outcome. The thermo-camera is a valuable aid for the assessment of the impacts of different fuel mixes and burner settings on flame characteristics. Although measurements with the thermo-camera are not always achievable under the most favourable conditions, the evolution of the flame shape, flame temperature and fuel ignition point over time can usually be observed.

Under stable kiln operations, and before starting to increase the AF rate in the main burner, the flame characteristics are recorded and later used as a baseline measurement. Raising the AF substitution rate is carried out using a step-wise approach. Before conducting any new adjustment of the burner, both the results

Figure 3: set up of VDZ's thermo-camera in the kiln hood and flame thermogram

of the measurements performed with the thermo-camera and some relevant process data available in the control room need to be properly interpreted and assessed. Only both of these together will provide the necessary basis for an effective identification of the optimisation steps that need to be followed. As the secondary air temperature plays a key role in the combustion process, sometimes the clinker cooler performance also needs to be readjusted.

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Case study: reaching 100 per cent AF substitution rate in the main burner

VDZ was commissioned by a European cement plant to increase the AF rate in the main burner as much as possible without jeopardising clinker quality. The plant had already tried to increase the AF rate numerous times but without long-lasting success. After a while, the kiln always became unstable and the burnability of the clinker was negatively affected. This issue had been reported even when the plant was firing plastic fluff with a high calorific value and low moisture content.

The first measurements performed with the thermo-camera (ie, the baseline measurement) revealed that the flame was slim and colder than expected (see Figure 4). The first step by VDZ was to make the flame hotter and shorter before raising the AF rate, which was obtained through the correct adjustment of the burner axial air and swirl air streams. By keeping the amount of combustion air constant, VDZ decreased the axial air and raised the swirl air on a step-by-step basis. The beneficial effects on the flame were not only confirmed through flame observation but also indirectly by the increase of the secondary air temperature (due to a shorter precooling zone) and of NO_x at the kiln inlet (hotter flame). No negative impact on clinker quality was observed at this stage. The basic conditions to start feeding more AF in the main burner had been met.

As expected, the rise in the AF rate in the main burner was challenging. Nevertheless, the negative effects on the pyroprocess linked to high AF rates could be counteracted by the proper adjustment of the burner settings with the aid of flame thermography. During the optimisation process the cooler operation settings also had to be readjusted to generate hotter secondary air. Moreover, the results of the clinker analysis performed by the plant and also the kiln shell temperature presented by the shell scan were continuously monitored on site by VDZ experts.

After one week of optimisation all the initial expectations had been substantially exceeded. The plant was able to fire 100 per cent AF in the main burner without a negative effect on clinker quality. A stable, short and intense flame could be generated and maintained even with 100 per cent AF (see Figure 5).

Conclusion

The use of AF is proof that reducing a cement plant's carbon footprint and operational costs can go hand-in-hand. Despite the win-win situation for the industry and the environment, achieving high AF substitution rates is not straightforward due to the complexity of the clinker burning process, the quality of available fuels and strict regulatory constraints. VDZ has proven that the use of flame thermography is a reliable and effective approach to optimising the firing of AF in the main burner. However, only field experience with flame thermography combined with profound process know-how can provide quick, low-risk, successful and long-lasting optimisation. Based on VDZ's experience, boosting the AF rate in the main burner with the aid of flame thermography to 100 per cent remains rare but is still possible under optimum conditions. However, the results achieved are plant-specific and a case-by-case assessment is essential. ■

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Figure 4: baseline – flame thermogram before optimisation

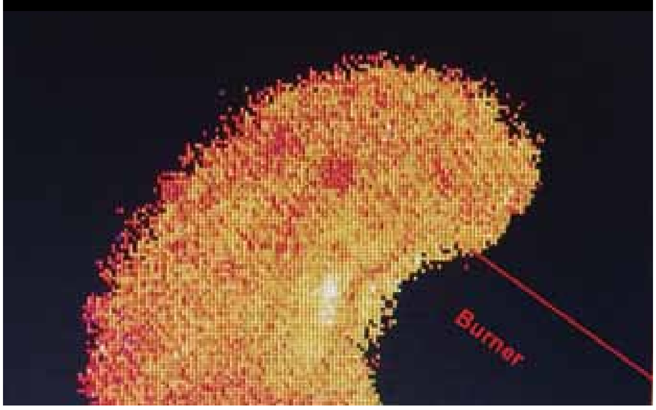

Figure 5: flame thermogram after optimisation – 100 per cent AF