Higher AF rates through new satellite burner design

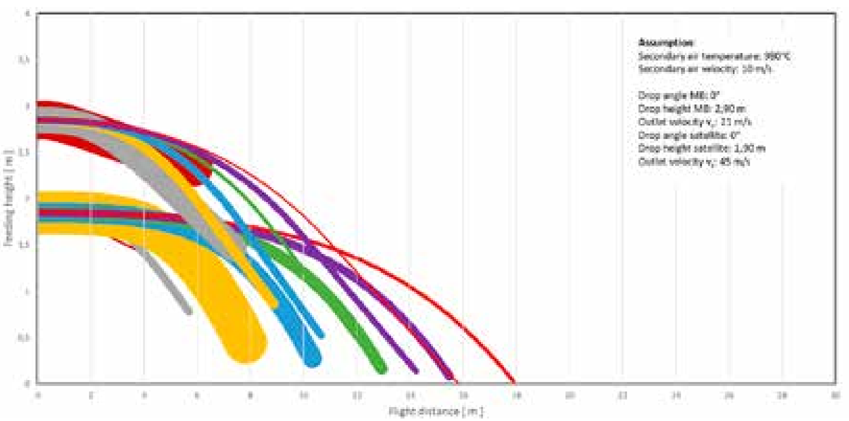
To achieve higher thermal substitution rates (TSRs) cement producers rely on advances in kiln burner technology and suitable strategies to overcome any issues in the burning process. The use of innovative satellite burners in the kiln firing process can support higher TSR rates.

■ *by **ROCKTEQ GmbH**, Germany*

Cement plant operators have successfully implemented various levels of fossil fuel substitution with alternative fuels (AFs), achieving substitution rates exceeding 90 per cent in some cases during prolonged operations. Although calciners can achieve substitution levels up to 100 per cent, significant further increases in substituting fossil fuels within the cement manufacturing process can only be attained through advancements in kiln burner technology.

This article investigates the use of solid recovered fuel (SRF) derived from municipal solid waste (MSW) as an AF, displacing traditional fuels such as coal, oil and gas in cement plants. The calciner accounts for approximately 60 per cent of the total heat demand in the pyroprocess, while the remaining portion is consumed at the kiln burner. Despite advancements in multi-channel burners and new satellite burners supporting high thermal substitution rates (TSRs), the cement industry encounters operational challenges, including incomplete combustion, increased specific heat consumption, reduced flame temperature and an enlarged kiln coating build-up. Therefore, strategies to overcome or minimise these issues by incorporating satellite burners into the kiln firing process are also discussed.

Figure 1: comparison of SRF from a kiln burner and a satellite burner trajectories derived from Analytical Air Classification results and an assumed burner setting. The residence time (Rt) ends when the heavy matter reaches the clinker bed. The thickness of the trajectories in the analysed fuel mixture also represents the proportion of each fraction[2]



Source: H Baier[2]

SRF combustion

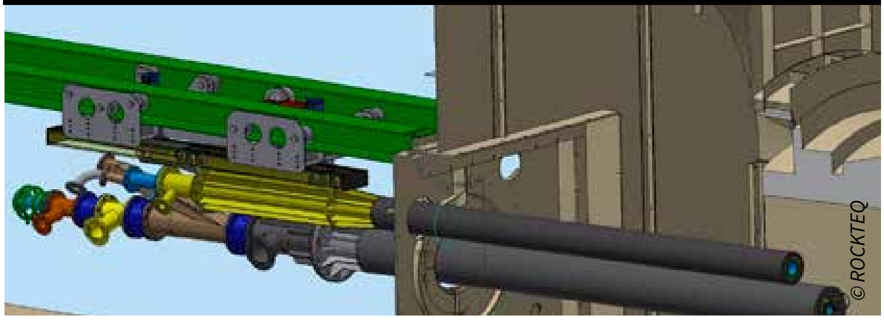
Until now the specified temperature profile crucial for achieving high-quality clinker in the kiln has limited the use of AFs. Beyond the properties and quantities of the fuels employed, combustion characteristics are influenced by the plant and burner design, the supply of cold primary air, hot secondary air from the clinker cooler and the design of the fuel feeding system to the burner.

A pivotal element in combustion analysis is the thermal radiation of the flame, strongly affected by the concentration and particle size distribution (PSD) of the fuel. Mass flows, injection velocities, geometry and fuel properties typically dictate the flame shape. The injection of fuel, primary air and secondary air determines flow turbulence and internal and external recirculation to the flame, providing control over the location of the flame temperature peaks. It is important to note that recirculation is influenced not only by velocity components but also by the design of the burner tip.

The combustion of AF in the primary firing of a rotary kiln is intricate and can only be evaluated concerning the temperature distribution in the gas phase and combustion within the kiln. Consideration must be given to the impact of changes on the formation of clinker phases and the interaction of fuel particles with clinker (such as reducing burning conditions and the incorporation of inert fuel components into the clinker). Extreme injection velocities in the fuel supply can accelerate flight speed, thereby reducing residence times in the hot flame zone. Coarse, three-dimensional fuel particles can descend into the clinker bed, causing reductive burning conditions.

Currently-used kiln burners in the cement industry are engineered for multi-fuel operation. All kiln burner suppliers are configuring their burner tips with multiple air jet nozzles. The advantage of the air jet design, evident in faster fuel quality, is particularly relevant for SRF burners, which operate with increased axial burner momentum.[1] Alterations in primary air settings consistently impact the fuels used. For instance, a higher swirl enhances

Figure 2: a ROCKTEQ satellite burner has a specific position, fully adjustable to allow a fast fuel ignition for a well-controlled sintering zone length. Individual settings, pivoting in directions (inclined) and adjustable length independent from the main burner are an advantage to control the AF- combustion process



the mixing of hot, oxygen-rich secondary air and fuel, resulting in a broader and hotter flame. Conversely, SRF particles are expelled from the flame and make contact with the kiln wall or clinker bed earlier. Central air injection into the flame core supports rapid fuel ignition, influencing the ignition distance of the fuels. These possibilities help mitigate the frequently-observed stretched flame profile in the kiln due to SRF usage. Compensation for heat shift due to increased secondary fuel usage is achieved through axial air and flame swirl. Adhering to these principles empowers operators of kilns to selectively tailor the firing to the solid fuels used.

However, there are some drawbacks to burning an increasing amount of SRF in the rotary kiln burner:

- high water content of SRF cools the flame (eg, coal is dry)
- burner diameter increases unfavourably due to the additional fuel channels
- oxygen availability in the flame centre is limited
- there is a risk of a double cooking effect due to an extended flame
- kiln inlet temperature is too high.

Typically, as the share of SRF increases, it results in more extended temperature profiles with higher concentrations of CO at the kiln inlet. The cause of this lies in significantly larger particle masses, lower heating rates, longer residence times, and greater thermochemical, physical and geometric heterogeneity among individual AF particles compared to fossil fuels.

Consequently, SRF combustion exhibits a wider range of heat release along more varied trajectories. Additionally, residues of the fuel particles can enter the clinker bed, creating locally-reducing zones that negatively impact product quality.

SRF injection

Most burner suppliers offer tools or equipment to control the centrally-arranged SRF injection tube, reducing the risk of fuel drop-out onto the clinker bed. However, a mere acceleration in SRF delivery can cause it to shoot through the flame, resulting in a double-flame formation and creating unfavourable conditions for the clinker. This scenario is characterised by high free lime, reduced C_4AF content and a brownish colour in the produced clinker. Research has validated that kiln-burner designs with higher oxygen (O_2) availability inside the flame centre promote the ignition reaction, especially for SRF.

Physical air classification provides a realistic understanding of the flight behaviour of SRF in an actual burner. This method relies on the physics of air classification and fuel particle separation. Therefore, determining the characteristics of each fraction, including sink rate, density, drag coefficient, quantity and distribution, is crucial. Based on this data, the flight distance and position probability of each fraction of SRF particles are calculated, significantly enhancing the comprehension of the complex combustion conditions during operation. This implies that different AF qualities necessitate flexible, adjustable SRF fuel injection into the kiln. Operators require the flexibility to correct combustion if necessary; they need a tool!

Enhancing operator flexibility with satellite burners

When increasing the thermal substitution rate for SRF in the kiln, installing a satellite burner is advantageous. This additional, smaller and adjustable SRF satellite burner, positioned beside or above the kiln burner inside the kiln hood, is designed to inject SRF directly into the hot secondary air. This configuration provides higher O_2 availability, faster ignition and an extended burn-out time. It helps prevent premature fuel drop-out into the clinker bed. Designing a smaller kiln burner diameter becomes possible, favouring coal combustion and resulting in a shorter, more uniform flame shape. Satellite burners can be directed to increase the retention time of particles in the hot secondary air, ensuring complete combustion without deposition on the clinker bed. Moreover, satellite burners are easier to adjust and many major cement suppliers are starting to adopt them as a standard practice.[3] It is a tool for operators to react to process deviations and qualities.

The advantages of satellite burners in AF combustion control include:

- higher oxygen availability for SRF combustion
- pre-drying of AF by secondary air before ignition
- adjustable AF trajectory independent of the main burner
- longer fuel retention time for burn-out
- reduced cooling of the main burner's flame
- flexibility for operators.

A separate fuel supply through a satellite burner ensures that the trajectories of SRF particles are less affected by primary air settings at the main burner. The position and orientation of the satellite burner are crucial for combustion and temperature distribution in the gas phase. Optimal placement involves positioning the satellite burner not too high above the main burner and aligning it along the kiln axis. Introducing SRF through a satellite burner in the kiln hood results in earlier AF fuel ignition.

Using a satellite burner for the combustion of SRF can decouple the settings for regular and AFs at the main burner. Operational measurements have demonstrated that combustion intensifies, the flame shortens and the free lime content in the clinker decreases. Additionally, there are indications of a shortened preheating zone and an increase in secondary air temperature, as reported by VDZ, the German cement association.[4]

Secondary air and kiln hood design

The flow of secondary air from the clinker cooler has a significant impact on the kiln, influencing temperature

Figure 3: increased availability of oxygen by secondary air flow pattern is increasing the ignition reaction, shortening the ignition distance (pre-dried AF), accelerating the carbon burning reaction (shorter flame), minimising the tendency of particle fall-out of flame, provides higher clinker quality, maintains sintering zone length at lower kiln inlet temperature and results in less sulphur circuits

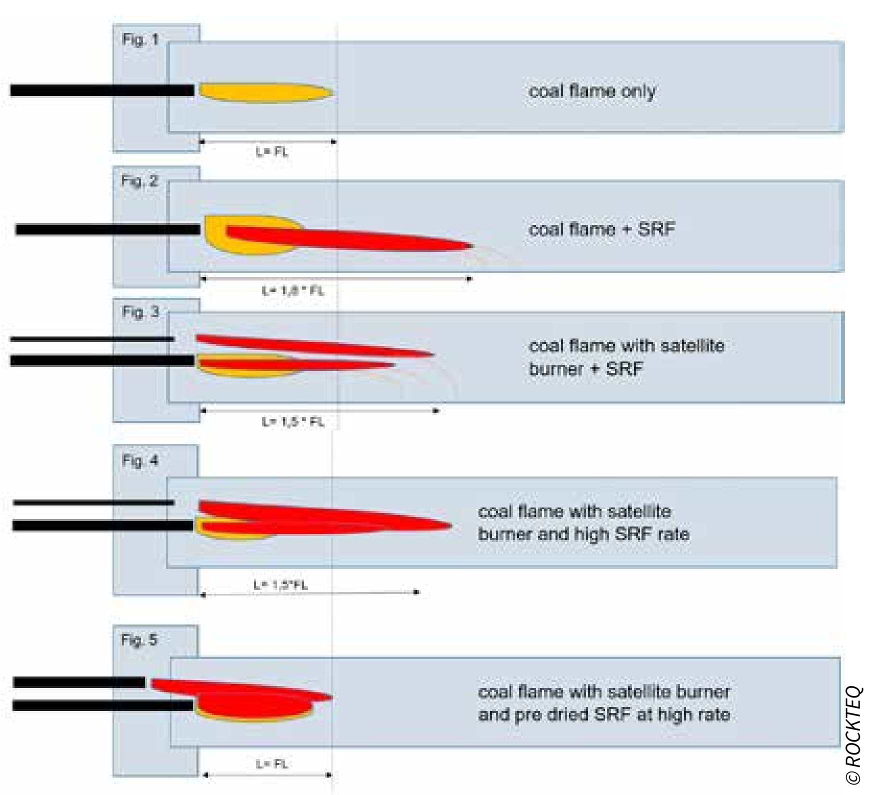


Figure 4: specifically designed satellite burner by ROCKTEQ

and oxygen distribution, as well as particle trajectories. The formation of the secondary air flow is highly dependent on the kiln design. Higher temperatures of the secondary air contribute to improved SRF combustion. With an elevated temperature level in the kiln system, the heating and thermal conversion of particles increase.

Results from computational fluid dynamics (CFD) modelling studies, which included the combustion of solid fuel particles and radiation heat transfer, revealed that temperature values in the clinker bed region can exhibit differences of up to 200˚C depending on the kiln hood design. Kiln hoods without tertiary air duct and centralised tertiary air duct showed slightly deflected profiles, impacting temperature and particle trajectories. The case without a tertiary air duct exhibited lower velocity in the kiln hood and kiln, with a highly uniform and symmetrically-distributed profile. These two cases underscore the importance of designing and adjusting satellite burners based on the geometry of the kiln hood.

Fuel properties

While fossil fuels like coal dust can be assumed to be uniform in terms of size, density and shape, the situation differs when using SRFs. The particles of waste-derived SRF consist of varying densities and shapes, resulting in different chemical and physical properties when leaving the tip of the kiln burner. The risk of affecting the pyroprocess and clinker quality increases with the level of 50 per cent SRF substitution rate.

When increasing the use of SRF in the main firing, the following rules should be applied:

- SRF moisture content ~10 per cent
- 3D particles <5 per cent
- input control of SRF by automated sampling
- burner adjustment according to the

Figure 5: kiln hood without tertiary air duct

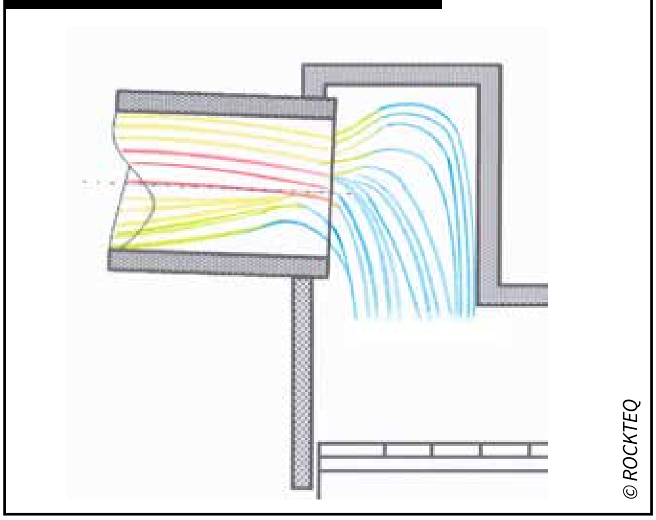


Figure 6: kiln hood with tertiary air duct

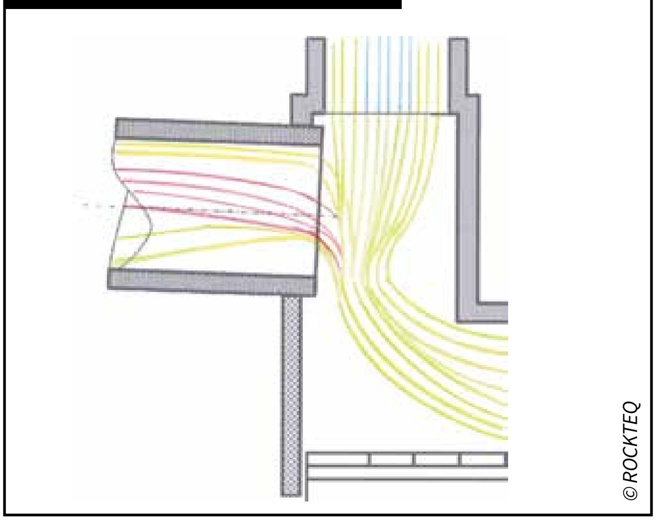


Table 1: SRF properties

	Problem	Solution	Result
LHV (CHV)	too low	sorting, drying	faster ignition
fuel dimension	too big	classifying	faster burn-out
fuel moisture	too high	drying	faster ignition, less kiln gas volume
oxygen availability	too low	satellite burner	higher TSR, better flame, better clinker quality

trajectory and burning behaviour of the SRF.

If SRF has a high moisture content or oversized particles, ROCKTEQ offers the "AF-Booster system®" to reduce fuel moisture by waste heat drying and classifiers, ensuring suitable and sustainable fuel quality for the kiln. In the case of several changing suppliers, the fuel reception should be equipped with a combination of a classifier and dryer, allowing for the acceptance of multiple fuel "qualities." This approach ensures that the SRF better fits the pyroprocess, resulting in significantly lower water evaporation, improved performance and a temperature profile in the kiln that can lead to a smooth kiln run with a further increased TSR.[5]

SRF is comminuted down to 15-30mm and mandatorily classified to achieve the shortest retention time in the flame. Due to its compound composition, its calorific value is normally in the range of 22±2MJ/kg or even higher. It should be considered that the presence of compact 3D particles, an inhomogeneous composition, and insufficiently extracted ash components such as metals, glass, ceramics, and stones will affect clinker quality by altering its ash chemistry.

The moisture content can often exceed 20 per cent due to the management of input materials. The fluctuating moisture content of SRF has a significant impact on stable kiln operation as it also affects the calorific value. Additionally, the moisture cools the flame of the kiln burner, leading to poor burning conditions and weakly-burned clinker with a high free lime content, beside a higher gas volume and a higher specific heat consumption of the kiln system.

If compact 3D fuel particles are not entirely burned out before entering the kiln bed, they will impact the pyroprocess by causing build-ups, ring formation, or releasing circulating elements, free lime and colour changes during clinker formation due to reductive burn-out.[6]

To ensure adequate fuel quality, especially at the kiln burner, it is necessary to guarantee that the SRF has low moisture content, a large particle surface free of 3D particles, a suitable and consistent ash composition, minimal impurities and a low content of cycle-forming elements.

Summary

The success of achieving a high substitution rate lies in the combination of well-prepared AFs, which should be dried and classified. It is crucial to remember that, in the past, ensuring the quality of coal grinding and drying was a non-negotiable task. A well-designed AF dosing system, along with a flexible combustion system featuring a satellite burner, empowers the operator to effectively control the pyroprocess.

The inclusion of a satellite burner enables precise control and preparation of the AF, leading to a reduction in ignition time, an enhancement of the pyrolysis process, and an overall reduction in flame length. This, in turn, helps avoid the formation of longer double flames. Maintaining clinker quality is facilitated by minimising fuel drop-out. A decrease in kiln gas volume and specific heat consumption contributes to the reduction of operating costs, such as electric power demand and maintenance expenses, while still maintaining clinker production rates at levels comparable to those achieved with fossil fuels. ■

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Figure 7: SRF<30mm suitable for main kiln firing

Figure 8: RDF >30mm for calciner firing