INCREASING AF USAGE AT THE KILN

Dr. Klaus Eichas and Christian Helmreich, ROCKTEQ, and Dr. Hubert Baier, WhiteLabel-TandemProjects e.U., explain the importance of drying alternative fuels and their impact on cement production.

Cement plants are striving to reduce fossil fuel usage for cost savings and to lower CO_2 emissions by adopting alternative fuels (AF) like solid recovered fuel (SRF) for the kiln burner and residue derived fuel (RDF) for the calciner burner. The goal is to achieve a 100% thermal substitution rate (TSR) without compromising clinker quality, the pyro process, or environmental impact.

However, various limiting factors must be addressed. Since many alternative fuels have high moisture content, drying them before use is essential. Additionally, particle size and shape significantly influence combustion. While coarser 3D particles can be used in the calciner, the kiln burner or satellite burner requires fine and flaky 2D materials. The use of a satellite burner further enhances combustion and flame stability in the rotary kiln.

This article emphasises the importance of drying and classifying alternative fuels and their impact on clinker and cement production.

Importance of drying alternative fuels

The drying of alternative fuels plays a significant role in the clinker burning process in the cement industry. Alternative fuels are increasingly being used as a sustainable substitute for fossil fuels to reduce CO_2 emissions.

Since many alternative fuels have a high moisture content, it is important to reduce the water input by drying them before co-processing.

High moisture content cools the flame at the kiln burner and reduces thermal NOx emissions, but it also reduces kiln performance and dramatically increases ID fan power consumption by raising exhaust gas volume.

While fossil fuels like coal dust can be assumed to be uniform in terms of size, density, and shape, the situation becomes different when using AFs. The particles of waste-derived SRF consist of different densities and shapes, resulting in different chemical as well as physical properties when leaving the tip of the kiln burner. The risk of affecting the pyro-process and clinker quality increases with the level of AF substitution rate.

Insufficiently pre-processed alternative fuels are characterised by a high variation in moisture content (Figure 1). During winter, the moisture content can often exceed 20% 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. Furthermore, the presence of compact 3D particles, an inhomogeneous composition, and insufficiently extracted ash components such as metals, glass, ceramics, and stones will affect the clinker quality by altering its ash chemistry. The high content of volatile circulating elements such as chlorine, sulfur, and alkalis also negatively impacts process control.

To ensure adequate fuel quality, especially at the kiln burner, it is necessary to guarantee that the SRF has a 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.

Several technologies are available for drying alternative fuels, including drum drying, belt drying, and flash drying.

- In drum drying, the alternative fuels fly through a rotating drum while hot air circulates, carrying only the light, dried particles. The heavy, moist particles remain until they can be captured by the hot gas and discharged in a cyclone.
- In belt drying, the alternative fuels are dried while lying on a slowly running belt. The air is heated indirectly via radiators from above or below. In belt dryers, hot air can also be efficiently directed through the conveyor belt to dry the material. At the end of the belt, all particles are discharged, regardless of whether they are completely dry or not.
- Flash dryers use the turbulence of hot exhaust gas mixed with AFs to dry them in suspension. Heavy particles are separated in the process, but without any control. Drying the alternative fuel in a flash dryer (Figure 2) significantly reduces its moisture content.

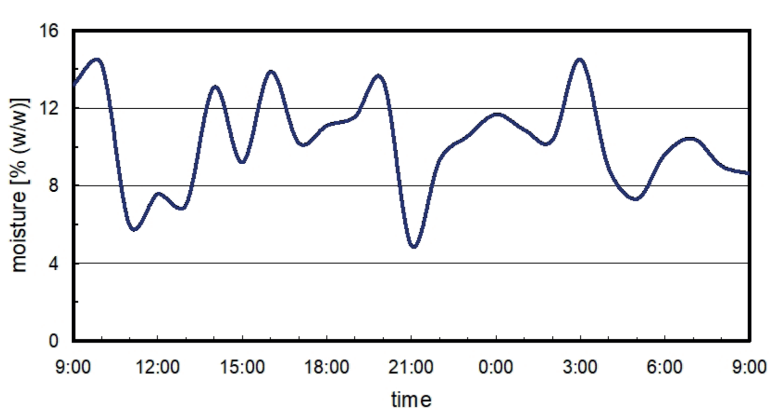

Figure 1. Moisture fluctuation in typical SRF before kiln burner (Source: VDZ).

Depending on the moisture content of the input material, some plants have reported a residual moisture of 5 – 9% after the flash dryer. For higher moisture content, cement plants also use belt dryers. Usually, hot exhaust air from the clinker cooler serves as the heating and drying medium. By taking the dryer exhaust air to the first compartment of the clinker cooler, drying occurs in a closed circuit, avoiding any adverse effects on the environment.

By adjusting the air flow (lifting speed) in a flash dryer, reliable removal of impurities is possible. Moreover, flash dryers offer lower investment costs compared to other systems.

Importance of classifying alternative fuels

A closer examination of combustion reveals that all fuels undergo the same simplified sequence of drying, pyrolysis, ignition, and burnout until one of the reaction partners (fuel or oxygen) is completely consumed. The quantity and type of particles, along with the time for drying and ignition, and the residence time, determine the position and shape of the flame, thus influencing the temperature profile in the rotary kiln.

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

Therefore, it is necessary to focus not merely on particle size, distribution, or superficial specifications and monitoring, as they do not provide a comprehensive understanding of how fuel particles behave in the kiln air stream. Instead, it is crucial to comprehend the actual flight behaviour and trajectories of SRF particles after leaving the burner tip of the rotary kiln. This knowledge allows for meaningful matching of fuels and burners. Analytical air classification is an immensely valuable method of analysis and can aid in the following ways:

- Monitoring the quality of the conditioning process.
- Adjusting the fuel specification to meet the requirements of the pyro process.
- Optimising burner settings based on SRF flight behaviour and residence time.
- Providing data on the advantages of installing a robust classifier upstream of the truck discharge point.
- Avoiding elongated or even double flames, reducing kiln intake, preventing reductive burnout, and minimising increased cycling.
- Achieving a more stable kiln operation and increasing the TSR.

In addition to a CFD simulation, physical air classification provides a more realistic understanding of the flight behaviour of the SRF used in an actual burner. This method relies on the physics of air classification and fuel particle separation. Therefore, it is crucial to determine the characteristics of each fraction, including sink rate, density, drag coefficient, quantity, and distribution. Based on this data, the flight distance and position probability of each fraction of SRF particles are calculated, which greatly enhances the comprehension of the complex combustion conditions during operation.

Last but not least, the analytical air classification method can be used to fine-tune the kiln burner, ensuring a more effective combustion of the SRF particles.

Figure 4 displays the test results of air classifying at different velocities of descents to obtain various SRF fractions or qualities, separated into light and heavy fractions. The measurement begins at the lowest fan speed (top left image) and concludes at the highest speed (bottom right corner picture). As the SRF transitions from light to heavy, it is categorised into classes with the same flight, corresponding to identical injection properties, but

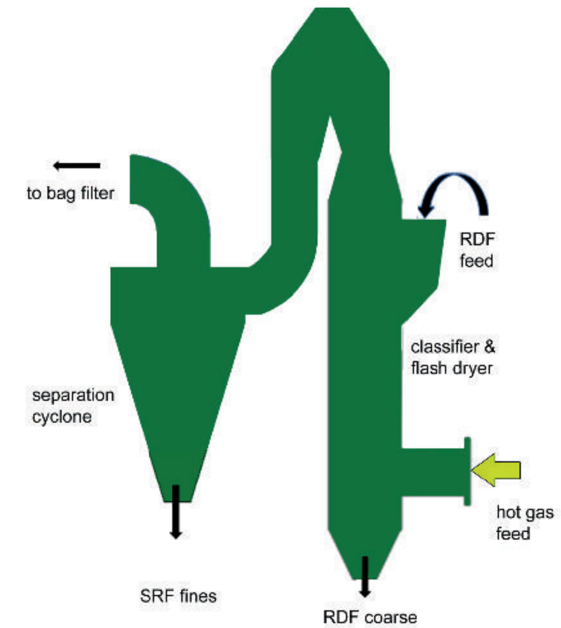

Figure 2. RDF flash dryer principle (Source: ROCKTEQ).

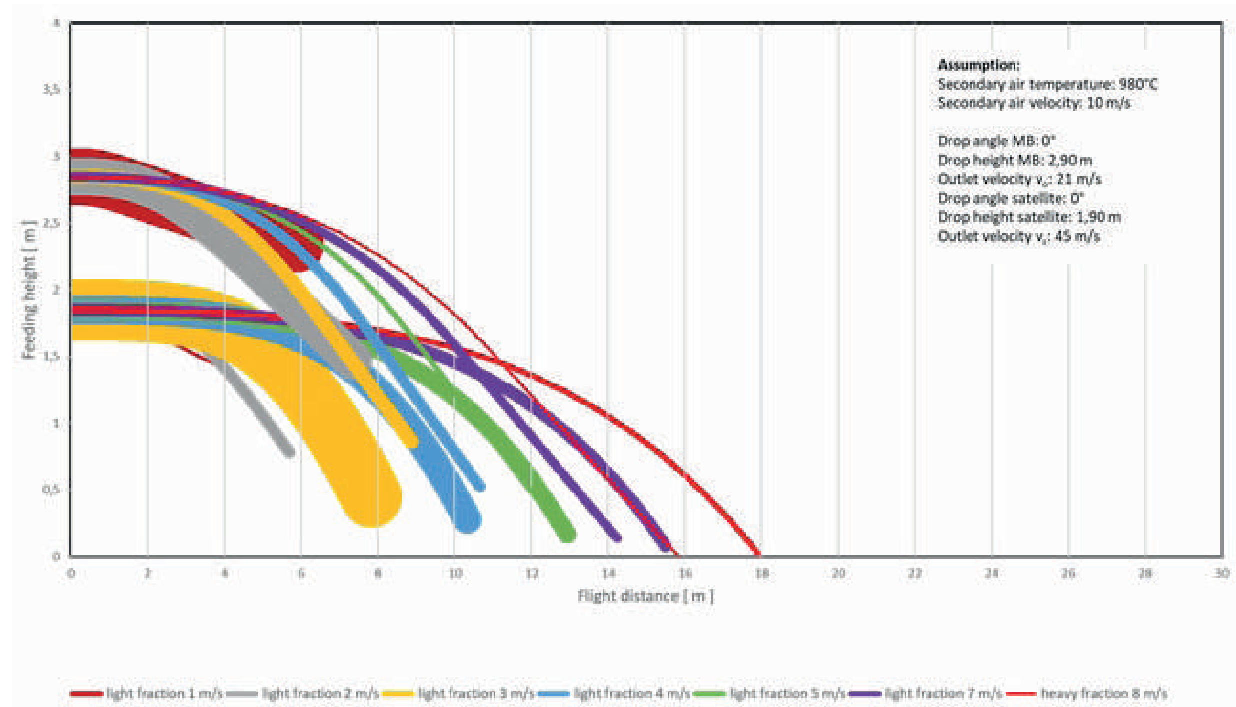

Figure 3. Comparison of SRF from a kiln burner and a satellite burner trajectories derived from Analytical Air Classification results and an assumed burner setting. The residence time (Rt) ends when the heavy matter reaches the clinker bed. The thickness of the trajectories in the analysed fuel mixture also represents the proportion of each fraction (WLTP 2019).

exhibiting different trajectories after leaving the burner's tip.

The calculation of these trajectories is based on the dynamic equilibrium of forces acting on the particles, which includes gravity (g), mass force from initial velocity (v0) when leaving the burner, mass correlated to volume, density, and shape, as well as the breaking force from air resistance (cW). Using this calculation, the flight behaviour of SRF particles can be simulated (Figure 3). The thickness represents the relative proportion of the total mixture in the SRF.

Based on years of experience, it is well-established that SRFs with a size of less than 30 mm, properly classified, and completely free of three-dimensional particles, exhibit short floating trajectories during conversion in the flame without ending up in the clinker bed and causing reductive burning conditions. Classification can be effectively carried out during fuel production or after delivery or storage at the plant.

It is worth noting that the finest possible comminution is not necessary. Instead, the focus should be on exclusively two-dimensional particles with a large surface and short residence time, independent of the classical particle size. From a combustion standpoint, all SRF for the kiln burner should, therefore, be dried and classified beforehand to ensure the best possible combustion behaviour with the least negative impact on the kiln system.

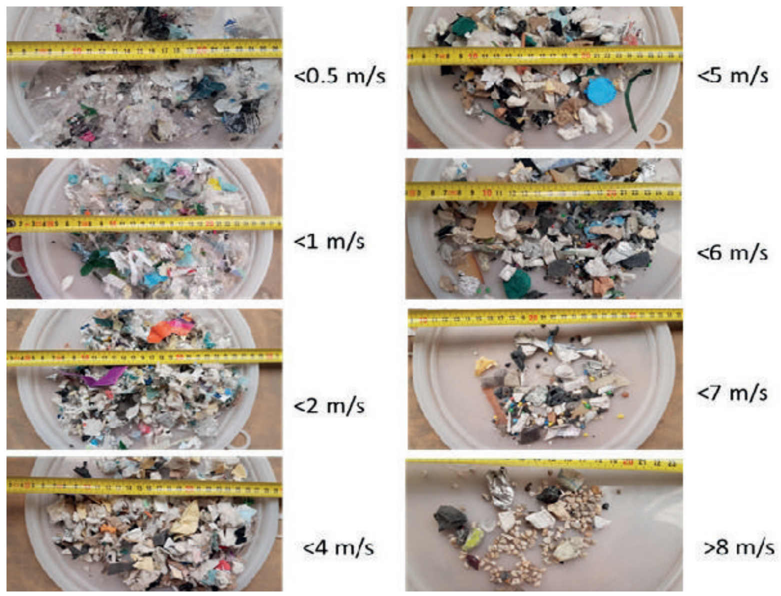

Figure 4. A mixture of SRF has been split into its classes at different velocities of descents. Although it could be seen that the grain size is not important and their chemical composition varies greatly, but each class shows the same sinking behaviour (WLTP 2019).

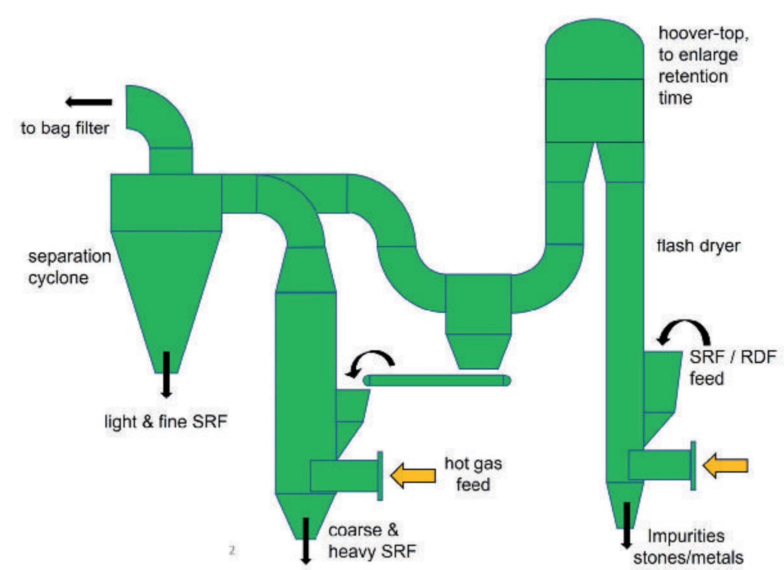

Figure 5. AF-Booster System (source ROCKTEQ).

Combination of drying classifying and burners for SRF

Alternative fuels, especially SRF processed from waste that cannot be recycled or separately collected, may contain a high content of biogenic materials such as wood, rubber, carpets and textiles, paper, cardboard, etc., coming from commercial and industrial sources. Additionally, solid household waste often carries a high percentage of moisture. Drying during processing or before using these alternative fuels leads to:

- More efficient combustion → higher TSR
- A more stable burning process → higher CHV of fuel
- Reduced kiln gas volume
- Lower pressure drop of ID-fan → saving electric energy
- Decrease in specific heat consumption → fuel reduction
- Performance and capacity of the kiln are not affected
- Better clinker quality

Furthermore, drying can enhance cement quality. A stable pyro-process results in better homogeneity, consistent colour, and improved strength development of the final product. As a result of better kiln performance, drying reduces reliance on primary fuels such as coal or oil, leading to cost savings and reduced environmental impact.

The AF-Booster System® process (Figure 5) combines drying, classifying and combustion of alternative fuels into one system, designed to stabilise kiln operation, increase the use of SRF, and extract the best SRF quality, resulting in two fractions. In particular, it proves highly beneficial in stabilising kiln operation, especially at high thermal substitution rates.

When increasing the TSR at the entire kiln system, it is essential to use the most suitable injection point of SRF/RDF. The required time of pyrolysis of alternative fuels and flight conditions must be respected. In case the calciner is already running with 100% alternative fuels, it is the aim of the AF-Booster System to increase the alternative fuel rate at the kiln hood towards 100%.

The technology comprises a dryer (usually a flash dryer), a specific air classifier and the burners. After drying with clinker cooler exhaust gas or bypass gas, the light and suitable SRF fraction is effectively prepared in the air classifier for the main and/or satellite burner, reducing the influence of unburned 3D particles. The dried and classified SRF quantity is divided into two SRF material flows according to burnability (Figure 3). One alternative fuel material fraction is burned at the main burner. The second AF material fraction is burned at a satellite burner. The advantage of this combination of two burners with two different classified and dried SRF, is that the substitution rate can increase at the kiln without a negative impact on the clinker quality.

The main burner can be smaller in diameter and equipped with classic fuel(s) such as coal/petcoke or oil/gas for start-up and stabilisation. An existing equipped main burner with a SRF channel can be used as well. The adjustable satellite burner has a SRF channel with a surrounding process air channel for cooling and dispersion of SRF. That configuration is allowing a flexible flame adjustment for AF-fuels which is important to increase the AF-rate on the kiln hood to almost full substitution of classic fuels like coal. (Figure 6).

The technology aims to reduce fuel costs and enhance TSR. The system offers flexibility and adjustability with its two-step drying process. This approach not only provides better burning conditions but also significantly reduces fuel costs due to improved SRF properties. Moreover, it contributes to a reduction in CO_2 emissions by utilising higher rates of biomass with low moisture content in SRF. Additionally, the reduced moisture content in SRF has a positive impact on kiln production capacity. The ROI of that system is between one and two years with the smallest footprint against other systems inside the plant.

Furthermore, some countries have implemented regulatory incentives to promote the use of biomass in alternative fuels within the cement industry, such as tax benefits or CO_2 reduction certificates.

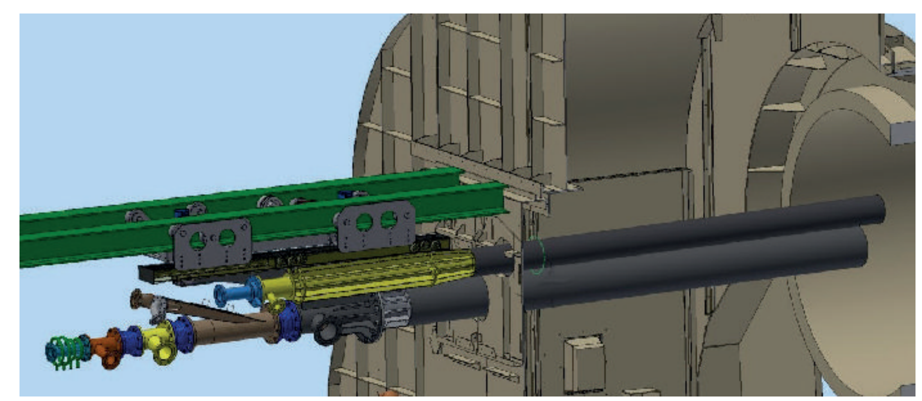

Figure 6. Kiln burner with satellite burner arrangement individually designed on kiln geometry by ROCKTEQ.

Conclusion

Drying and classifying alternative fuels for the rotary kiln burner is a crucial step in the pyro process of cement production to ensure efficient combustion and sustainable utilisation. Several successful installations for drying alternative fuels, particularly SRF, have been accomplished. ROCKTEQ has developed an innovative technology, the AF-Booster system, which reduces moisture content and eliminates 3D particles, increasing the TSR up to 95%.

Analytical air classification proves invaluable in supporting the selection of suitable fuel suppliers and parameterising burners. The proper selection of drying and classification technology, along with the optimisation of the drying and classification process, play a decisive role in maximising thermal conversion, maintaining a smooth kiln run, and ultimately improving cement quality while minimising process impacts.

The use of a satellite burner resolves issues with the existing kiln burner and opens up additional opportunities to utilise SRF that cannot be fed through the kiln burner due to design constraints.

Continuous research and development in this field are essential to develop state-of-the-art technologies and enhance the sustainability of the cement industry as a whole. Through the effective drying and classification of alternative fuels, the cement industry can significantly reduce its environmental footprint and contribute to a more sustainable future. ■

References

1. ZAMRUDY, W., SANTOSA, S., BUDIONO, A., NARYONO, E, 'A review of Drying Technologies for Refuse Derived Fuel (RDF) and Possible Implementation for Cement Industry', International Journal of ChemTech Research, Vol.12, No.1 (2019), pp. 307 – 315.

2. Baier, H, 'Solid recovered fuels for the use in co-incineration plants', Process Know-how *ZKG*, Vol. 59, No. 3 (2006), pp. 78 – 85.

3. Baier, H, 'Analytical air classification for quality assurance', 4th Virtual CemFuel Seminar, (2022).