Versatile AF burning

The KHD Pyrorotor® is a rotary combustion reactor that processes waste materials with inferior burning properties as alternative fuels in the cement production process. With seven industry installations to date, the versatile reactor for high thermal substitution rates (TSRs) enables the complete burn-out of any fuel and the usage of almost all types of unprepared waste materials.

■ *by **Matthias Mersmann** and **Sven Schmitgen**, KHD Humboldt Wedag, Germany*

Burning waste-derived fuel (WDF) has been carried out for seven decades in central Europe and has now developed into a specific field of competency in the cement industry on the back of massively increased knowledge and experience. Using a wide range of different wastes to produce a variety of WDFs has grown in popularity, triggered by several enabling and driving factors within the ecosystems of regional markets.

The most basic enabling factor for co-processing in cement plants is the sufficient availability of waste material. If sourced from municipal solid waste (MSW) streams, the region or municipality needs to implement a collection system that enables the centralised pick-up for pre-processing as a basic prerequisite. This requires the socio-economic system to have developed to a certain stage.

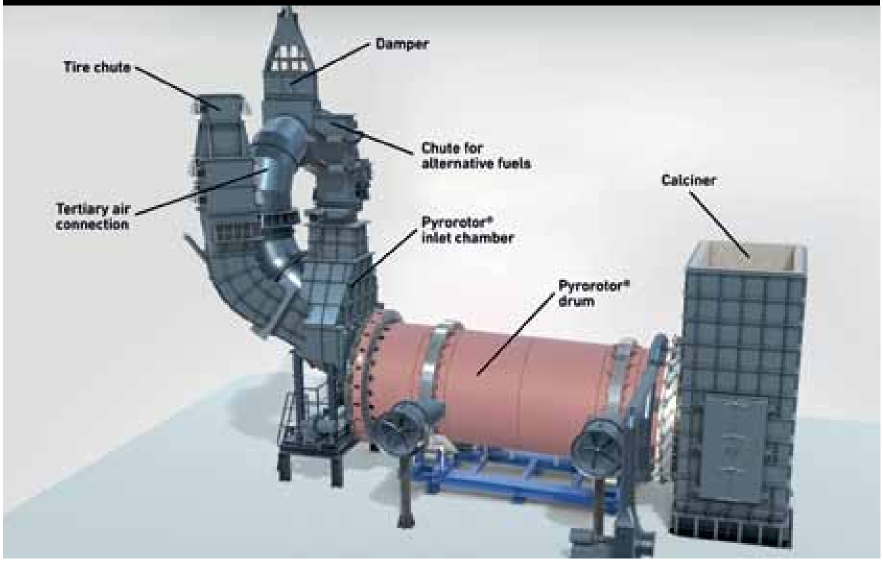
The next driving factor is facilitating the use of MSW in larger amounts when the dumping of MSW becomes expensive due to increasingly stringent environmental regulations in developed countries. It is recognised all over the world that raising the substitution of fossil fuels with alternative fuels (AF) in cement kilns goes along with the development of a society's awareness for the re-utilisation of waste and technologies for its pre- and co-processing.

Properties of the AF

AFs vary greatly in their chemical and physical properties as well as their denominations: solid recovered fuel (SRF), refuse-derived fuel (RDF), MSW and fluff are only a few of the name tags established in recent years. Meanwhile, some attempts at standardisation have been undertaken, none of which are understood to have been generally adopted on a wider scale.

From a technical point of view, the actual chemical and physical properties are much more relevant than the afore-mentioned denominations. Looking at the ability of certain WDFs to replace noble fuels, we have to accept one very basic understanding: none of the WDF material that is finally burnt in the kiln was ever initially put into its lifecycle with the intention of being used as fuel. This means that its chemical, physical and particulate properties are far from matching the ideal requirement specifications for fuel.

Figure 1: overview of KHD Humboldt Wedag's PYROROTOR®



What is generally accepted without any discussion in the case of noble fossil fuels – namely the necessity to pre-process any fuel to achieve a desired ideal combustion state – is debated intensely among cement production specialists when it comes to WDFs. While coal is ground to a very fine powder, WDFs are sought to be burned in lumpy particles. While coals are being classified into internationally-accepted categories in terms of their main combustion properties , such as ash content, moisture, content of volatile matter and heat content, there is no way to generally classify these properties with the heterogeneous mixtures of material that make up WDF. Material (eg wood, plastics, textiles, rubber, paper, glass, mineral), size (eg small, medium or large) and shape (eg flat, round, cylindrical, cubical) and the chemical properties as mentioned above, all mix across their categories and form their special combustion behaviour, leading to very different ignition and burn-out time requirements. The only thing that seems to be safe to say is that AFs are always more challenging to burn because solid fuel comes in a bigger particle size than noble fuels and liquid WDF always has either a lower heat content or higher contaminant content.

Investigations into the ignition and combustion behaviour of certain typical constituents of WDF mixes[1] show that, depending on size, shape and material, individual pieces of AF can take up to several minutes to burn out.

Interaction of pre-processing and co-processing

What has become increasingly understood is that it is important to look at the complete processing route: from the source of the waste material all the way to its final use as fuel in kilns. The totality of this chain is best described by the terms 'pre-processing' and 'co-processing.' Pre-processing covers all preparatory steps up to the injection of the material into the kiln. Co-processing covers the energy- and mass-integration of the material within the clinker production process.

The interaction between pre- and co-processing is vital for the successful use of WDF in the cement industry as each has its own costs and applicability features. For instance, a widely-used path in pre-processing is sorting and size reduction to produce so-called high-quality RDF. This may consist of mainly lightweight, dry and small-sized particles with a high calorific value. The RDF can be injected into either the main burner or the calciner without much technological adaptation to the co-processing technology (ie the kiln burner or calciner). This path requires much effort in the pre-processing stage and a small amount of effort in the co-processing stage.

The other extreme would be to spend little effort in the pre-processing stage by just sorting out the inert matter and then using the resulting low-quality WDF in a special reactor which needs high technological effort for the co-processing.

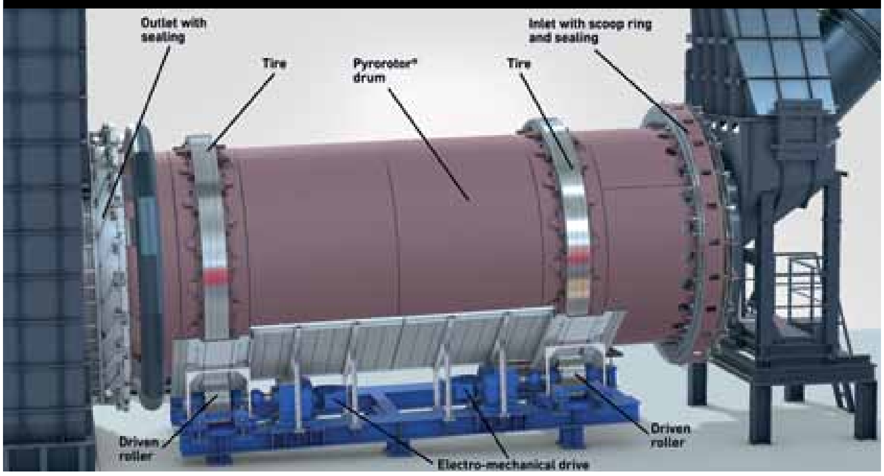
The optimal pre-processing depth – or, in other words, the optimal handover point from pre-processing to co-processing – certainly depends on a number of case-specific influences such as available co-processing technology at the plant and available RDF supply and pricing, to name just the most important factors. Also, many cement producers have experienced that WDF markets change over time owing to availability, price levels and quality.

There is a perceivable trend for more versatile and robust special equipment in kiln plants that allows a multitude of different WDFs of changing qualities to be co-processed. All major OEM equipment-suppliers offer such reactors that are intended to enable WDF burning at low pre-processing levels. These technologies must incorporate long fuel retention times, a high degree of robustness against operational problems and good combustion regimes for sufficient burn-out and clean combustion.

Figure 2: simplified classification and requirements of typical alternative fuels and raw materials (AFR) for use in the kiln burner and different PYROCLON® calciner applications

	Pyrojet® Kiln Burner	Pyroclon® R Calciner	Pyroclon® R with Pyroincinerator	Pyroclon® R with Comb. Chamber	Pyroclon® R with Pyrorotor®
	Pre-processing demand				Usable particle size
Waste oil / Animal meal / Sewage sludge	✓	✓	✓	✓	✓
Biomass	max. 2×1×1 mm (3D)	max. 5×5×2 mm (3D)	max. 20×20×5 mm (3D)	max. 40×40×10 mm (3D)	max. 100×100×15 mm (3D)
Plastics	max. 2×1×1 mm (3D)	max. 5×5×2 mm (3D)	max. 20×20×5mm (3D)	max. 40×40×10 mm (3D)	max. 300×100×100 mm (3D)
RDF / Fluff	max. 10×10 mm (2D)	max. 30×30 mm (2D)	max. 70×70 mm (2D)	max. 100×100 mm (2D)	max. 300×300 mm (2D)
Tire Chips	×	max. 40×40×25 mm (3D)	max. 50×50×25 mm (3D)	max. 70×70×25 mm (3D)	max. 300×300×25 mm (3D)
Whole Tires	×	×	×	×	✓

Figure 3: PYROROTOR roller bearings and drives



KHD's PYROROTOR® – versatile AFR reactor for high TSR

The PYROROTOR® is a rotary combustion reactor that processes waste materials with inferior burning properties as AFs in the cement process.

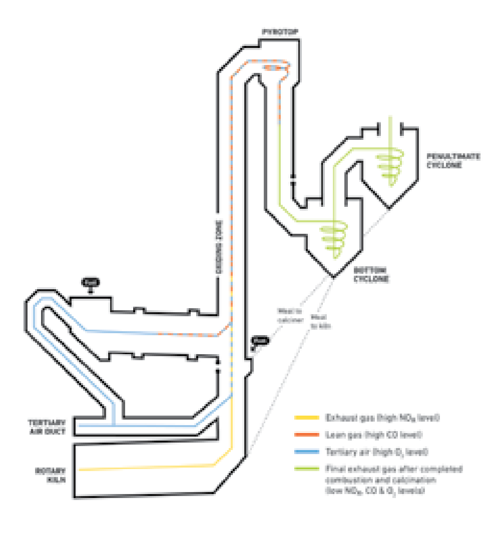
Within the range of KHD's modular solutions for co-processing of AFs in the clinker production process, the PYROROTOR covers demands for the highest thermal substitution rates (TSR) of even the least pre-processed AF, as can be seen in Figure 2. The technology offers a great deal of flexibility in terms of the size and materials of the AFs that can be processed. Whole tyres, tyre chips, coarse and lumpy materials, hard-to-ignite materials or even contaminated and hazardous materials can be combusted in the PYROROTOR. The need for complex and expensive pre-processing of the waste materials can be minimised or avoided completely.

The PYROROTOR can be installed in new plants and also easily retrofitted in existing kiln lines because it neither requires space in the existing tower structure, nor does it add an additional load to it.

The mechanical concept behind the PYROROTOR is based on the most robust combustor type known and trusted for difficult material properties in the cement industry: the rotary kiln (see Figure 3). The rotating drum generates an intense mixing of the AFs with hot tertiary air, as well as a long retention time for complete burn-out of waste materials. At the same time, the constant movement avoids build-ups and clogging.

All mechanical parts have been tried and proven in hundreds of kiln installations. The rotary tube is safely supported and balanced in a defined way on two roller stations. The required torque for the rotation of the drum is induced by two friction-driven rollers. The installed drives offer a large reserve in terms of the torque that can be provided, to be prepared for a wide range of loads and rotation requirements. The rotational speed of the drum can be adjusted, usually in the range of 0.3-3.0rpm to adapt the AF retention

Figure 4: PYROROTOR gas flow scheme



time to the needs of the specific material. AFs are fed into the PYROROTOR via suitable sluice systems like rotary airlocks or double pendulum flaps to prevent false air from entering into the system.

Figure 4 depicts the flowsheet in which the PYROROTOR is introduced in between the kiln and the calciner. A controlled portion of the tertiary air is branched off to provide the required flow of air into the PYROROTOR. Depending on the type of fuel and any desirable combustion staging, the combustion process inside the PYROROTOR can be operated with varying lambda-levels, so that a pronounced pyrolysis can also be achieved for energy efficient and emissions-optimised combustion. After a beneficially long retention time inside the PYROROTOR, the ashes are dropped directly into the kiln riser duct, where they form part of the kiln inlet material feed. Combustion off-gases and entrained small fuel particles leave the PYROROTOR to create a second stage of combustion in the regular calciner. This staged concept, which can be operated within a wide range of lambda numbers, greatly facilitates energy efficiency and NO_x reduction.

Industry references

Since its first installation in 2017, seven PYROROTORS have been installed. Figure 5 shows an installed PYROROTOR and the achieved operating values. The total TSR of the calciner is 98 per cent with only a small portion of noble fuel remaining as safety. Coarse WDF with up to 300mm edge length in 3D is injected into the PYROROTOR.

Figure 6 shows a typical retrofit arrangement with a PYROROTOR into an existing preheater tower. As the PYROROTOR is placed directly over the kiln and, in most cases parallel to it, there is hardly any limitation for a retrofit as it neither requires space in the tower nor does it greatly increase the load onto it. All connections for the tertiary air ducts and the material feeds can be placed without any problems.

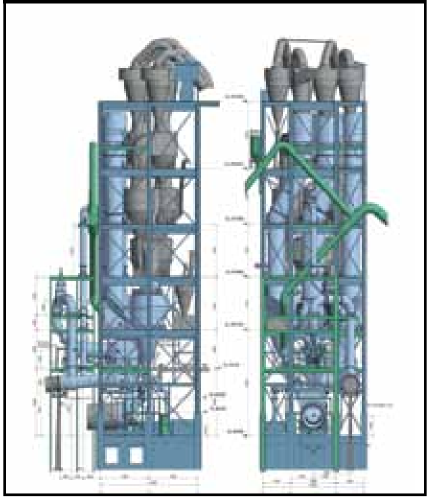
The PYROROTOR has already been retrofitted to several different types of calciners from various suppliers and can produce an even greater benefit if combined with a calciner modification at the same time. An increase in production and a reduction of emissions can be achieved alongside the increased TSR.

Summary

The versatility and robustness of the PYROROTOR are unique in the market and outperform similar systems for the utilisation of waste materials as alternative fuels. The highest AF substitution rates can be achieved with the PYROROTOR because the long retention time together with the constant mixture of the AFs with hot tertiary air ensures the complete burn-out of any fuel and the usage of almost all types of unprepared waste materials. Due to its wide range of lambda-value operability, the gasification can be intensified for highly efficient thermal conversion and effective NO_x reduction at the same time.

The PYROROTOR is a sustainable investment into a sustainable future, both economically as well as environmentally. It will allow the co-processing of any WDF that might be processed in the future without the necessity to modify the plant accordingly. Moreover, it will reduce the environmental footprint of clinker production because it uses waste materials to produce cement while reducing NO_x emissions at the same time. Hence it represents what KHD stands for best: technologies that combine sustainable and cost-efficient cement production with a cleaner environment. ■

Figure 6: implementation of a PYROROTOR into an existing preheater tower



REFERENCES

[1] MERSMANN, M AND SCHUMACHER, M (2019) 'Burn-out characteristics of lumpy secondary fuels and requirements for the design of calciners in the cement industry' in: *ZKG*, 7/8.

Figure 5: installed PYROROTOR and realised figures

	Realised figures
Plant capacity (tpd)	1900
AF thermal subsitution (%)	>98
Mass flow of AF (tph)	~12
Physical properties of AF (mm)	3D material @ 300mm
PYROROTOR speed (rpm)	0.8
Temperature at PYROROTOR inlet (˚C)	850-950
Temperature at PYROROTOR outlet (˚C)	1100-1200