Introduction

The development of rotary kiln burners for the cement industry over the past 25 years can be subdivided into two sections: the 1980s and the 1990s. At the beginning of the 1980s, the single-duct burner was often substituted by the multi-channel burner. Contrary to the blowing-in pipe of the former design, these burners allow a direct setting of the flame shape. Moreover, the primary air requirement could be considerably reduced, thereby also reducing the overall energy balance of the plant.

At the beginning of the 1990s, the utilisation of secondary fuels increasingly gained importance for burner manufacturers. To permit a reasonable combustion of secondary fuels of different chemical and physical natures, various conditions regarding the burner design had to be met. In this article, the basic features of the rotary kiln flame will be discussed and possible technical realisations introduced. KHD Humboldt Wedag AG accepted this challenge and extensively modernised the proven PYRO-JET®-burner to enable yet more efficient combustion of conventional fuels and secondary fuels.

Requirements for rotary kiln flames

Thanks to the development of preheater plants and, consequently, of plants with a secondary firing system in the calciner, the dimensions of the rotary kiln have decreased over the decades despite continuously increasing capacities. The major part of the processes concerning the heating up and calcining of the raw meal was shifted from the kiln into the preheater; the kiln, however, is still indispensable for the sintering of the hot meal to clinker. Short kilns such as the PYRO-RAPID®-kiln with only two roller assemblies require a tight, hot flame for the following two reasons:

- The energy required for sintering must be applied on a relatively short path.
- The combustion must be completed up to the kiln inlet chamber to avoid excessively high temperatures and to avoid reducing conditions in the lower cyclone stages.

High temperatures reduce the service life, in particular that of the immersion pipes; reducing conditions favour the formation of sulphur circuits, which in turn can then lead to increased accretions in the kiln inlet chamber.

Complete combustion is advantageous with regard to the suppression of carbon monoxide strands. In preheater systems without a tertiary air line, these cannot be oxidised any further and can, in particular during the dedusting of waste gases with ESPs, lead to the disconnection of the entire firing system.

The main problem with the hot flame, however, is the formation of thermal nitrogen oxides. Whereas nitrogen introduced with the fuel causes only a small degree of nitrogen oxide formation, the atmospheric nitrogen in the hot flame generates a considerable volume of nitrogen oxides. As the flame temperature increases, so does the volume of nitrogen oxide. While in a long flame, with a close to sufficient air volume, parts of the nitrogen oxide are further destroyed by the reduction already occurring at the end of the flame. This is possible only to a limited degree in the case of a short flame. In calciner plants, the nitrogen oxides can partly be reduced again by combustion in the calciner with insufficient air volume. In mere preheater plants, the nitrogen oxides, having once left the area of the flame, can only be destroyed by expensive end-of-the-pipe methods such as the selective, non-catalytic reduction with ammonia (SNCR).

Beyond these rather static requirements to the flame meeting the needs of the rotary kiln, the kiln operator must also be able to set the flame more slack or tighten it as necessary in order to melt off excessive rings or to relieve the cooler by a flame burning far into the kiln, for example.

Technical realisation

The company’s PYRO-JET®-burner fulfills the above requirements. The conception of the three-channel high-pressure burner, proven in hundreds of plants, was achieved. The main design features of this burner are the sandwich concept with an internal swirl body, one or two annular channels for pulsed fuels and the surrounding jet nozzle ring.

The most recent features are as follows:

- A discharge system optimised as regards the flowing behaviour.
- New nozzles for a still more efficient combustion of secondary fuels.
- The cooling pipe which increases the availability of the burner and simplifies the maintenance.

The low primary air portion, which is favourable in terms of saving energy and which reduces harmful matter, remains in the design.
Compared to its predecessor, the nozzle disc has been built to meet narrower and lighter specifications, which intensify the interaction between fuel, primary and secondary air. Inside the burner, slide-in pipes for ignition and oil burners, as well as special lances for secondary fuel, can be installed. Cooling the pipe that surrounds the burner results, not only in lengthening the service life of the refractory mass, but also facilitates maintenance.

The individual nozzles of the burner tip permit an optimal combustion of all fuels suitable for kiln operation. The tangential air flow generated by the swirl body results in negative pressure near the burner mouth. Hot gases and glowing particles from the kiln are sucked into the flame root and also critical fuels are safely ignited. At the same time, the swirl has a stabilising effect on the flame in the burner axis. Thanks to engineering using the most modern calculation methods, the swirl effect on the burner is optimised. An insufficient swirl causes the recirculation to collapse and hence an unstable, badly igniting flame. An excessive swirl, however, separates the flame and leads to reduced clinker quality due to non-combusted particles blown into the clinker. In the case of the PYRO-JET® burner, the swirl air volume can be matched to the operating requirements via flaps or a speed control of the fan.

The axial air emerging in the burner as individual jets from 12 - 16 nozzles ensures an intensification of the combustion by atomising the emerging coal dust cone and mixing it with hot secondary air. At the same time, the position of the flame root can be set to a certain degree via the jet air pressure. The axial air also ensures cooling of the burner shell, if this does not occur in a cooling pipe.

**Design criteria**

**Capacity - requirements and necessity**

When designing the capacity of the burner, an overall assessment of the plant is absolutely necessary. Firstly, the burner should not be designed larger than the maximum sintering zone load of the kiln. For plants with a secondary firing system, often the specific heat requirement and the distribution of the energy supply are taken as a basis and the burner is then designed with an ample control reserve of approximately 25%. Thus, the plant can be safely started and can continue to operate should a failure of the preheater firing system occur. For fuel scenarios with different pulverised fuels of different calorific values, the PYRO-JET® burner can be equipped with two annular channels. The volumes of conveying air can then be optimally matched to the respective fuel.

While the conveying air volumes are largely specified by the used fuel and the dosing system, the other primary air volumes strongly differ between the burners of the individual manufacturers.

The PYRO-JET® burner requires 6 - 10% of the stoichiometric combustion air volume including the conveying air, other types require up to 17%. The frequent argument under the term of burner momentum, i.e. that a high portion of primary air automatically leads to a more stable flame, cannot be accepted as a general statement. The facts are rather
that the fuel consumption and the energy requirement for the primary air compression increase.

When assessing primary air data, it should be clarified, whether or not the conveying air was included in the calculation. Depending on the dosing system, it is mostly 2 - 4%. Similar to other technical plants, burners should not be laid out 'with excess' which means that a certain amount of reserve should be employed. Otherwise, this will entail unnecessarily high investment costs and the large blowers will also cause high energy costs during operation. Moreover, the control behaviour is affected; in the partial load range, often only a sub-optimal operation is possible.

Secondary fuels
When buying a new burner, or when modifying an existing firing system, a frequent requirement is to permit the use of secondary fuels or to increase their portion in the fuel mixture. In terms of the great variety of secondary fuels, there is no absolute solution. The properties of the fuel must first be examined under the aspect of their conveying behaviour in the burner. The calorific value and the combustion time are of course also decisive for the suitability of the fuel. Finally, the chemical balance must also be in order, i.e. the clinker quality must not be affected by added chemicals, nor should the costs saved by the use of the cheap fuel be offset again by the high costs for a repair of the refractory material.

For the PYRO-JET™-burner, there are proven conceptions for burning liquid as well as solid fuels. In the case of used oil, for example, oil lances with compressed air atomisation are used which have a considerably higher service life compared with lances with mechanical atomisation. Also the pumping and regulating system can be designed for a clearly lower pressure. Sewage sludge and well-processed animal meal can also be fed through mixing pipes via the coal dust channel or a second annular channel. This process permits the highest substitution rates, as the requirements to the flame suitable for the rotary kiln are met in the best possible way.

Lumpy fuels such as ground domestic waste or wood chips are best blown into the flame via a central pipe. To ensure optimal combustion, the company offers special swirl bodies for blowing the fuel into the primary flame cone. For lower substitution rates or first tests, however, the existing central pipes can also be used.

The extent of substitution is fuel-specific and can vary between 10 - 100%. Well-processed sewage sludge is combusted using much the same method as for lignite, while comminuted fractions can only be fed to a limited degree without excessively affecting the flame quality. In addition, the cost/gain ratio must be estimated if the fuel is not delivered ready for use, but has to be processed in the plant.

Summary
There is no magic formula for a well functioning rotary kiln burner. For sophisticated fuel scenarios in particular, the necessary assessments do not only cover firing engineering, but also plant-specific aspects. As a plant constructor with over 100 years experience in cement process engineering and with more than 500 delivered PYRO-JET™-burners, KHD Humboldt Wedag considers itself well qualified to meet any requirement of the cement industry whether matching a replacement burner to existing equipment or supplying a complete firing system with a support and dosing unit.
PYRO-JET® Kiln Burner
Re-designed to meet customers’ present and future requirements.

Well proven properties remain
More than 500 PYRO-JET® kiln burners, sold to Cement Industry worldwide, prove profitability, reliability and environmental impact of this system:
- decreased fuel consumption as a result of a low primary air rate,
- low NOx generation because of early ignition of the fuel at the burner outlet, made possible by axial jet air nozzles and centrally located swirl air nozzle.

Good characteristics drastically improved
More than no re-designed PYRO-JET® systems, sold to the international Cement Industry in the first months after its successful launch mid 2004, prove our customers’ confidence in this up-dated product:
- Increased variability in quantity and diversity of secondary fuels - secondary fuel swirl nozzle and central channels,
- Improved process stability because of an adjustable flame for varying fuel scenarios and process conditions - internal swirl body,
- Improved reliability and service life - cooling pipe surrounding the burner,
- Increased ease of maintenance by e.g. reduced delivery time for spare nozzle system,
- Easy retrofit of all PYRO-JET® burners with the new state-of-the-art nozzle system.

Supply of a new burner or retrofit of your old one,
The re-designed PYRO-JET® is our answer.

Inner Qualities
The essential parts for securing e.g. a stable and adjustable flame shape, the use of various secondary fuels, the compliance with environmental regulations.

Front-end Solutions
Main design features – the Sandwich-Concept – with internal swirl body, one or two annular channels for secondary or other dust-like fuels and the surrounding jet nozzle ring.