Designing Solutions

Guilherme Ferreira, Luiz Felipe Pinho and Luis Filipe Fabiani, Dynamis, Brazil, explain how burner design can increase flexibility and help to overcome unforeseen problems in the kiln.

Introduction

Burners are one of the core pieces of equipment in a cement plant, dealing with one of the major operational costs of the plant – fuel. Everything from quality to kiln runtime is in some way related to how the burner operates. It can either aid smooth kiln operation, or destroy refractory lining within a mere few days of operation. A complete system accounts for just 0.2% of total plant costs and usually lasts for several years. However, fuels can change and the burner must be able to handle this. For this reason, manufacture experience and flexibility are important factors to consider when choosing a burner.

Burner characteristics

The Brazilian engineering firm Dynamis, which specialises in combustion and fluid dynamics, has installed more than 60 burners worldwide. The Dynamis burner has three separate air shaping and fuel injection channels:

- External air (used to create turbulence and to induce hot secondary air into the flame).
- Tangential air (used to create internal recirculations to promote flame stability).
- Fuel channel (fuel can be pulverised solid or gaseous. If it is both, one extra channel is added).

- Internal air (used to cool the inner channels and to supply oxygen to the core of the flame).

If wastes are injected through the main burner, then it also includes the following:

- Solid waste pneumatic conveying – central channel.
- Four small liquid waste/heavy fuel-oil/light fuel-oil/diesel-oil lances, with the latter used for heating up or in emergencies.

The Dynamis burner is built to be highly flexible, simple, easy to operate and to maintain. Its robust design can withstand the harsh conditions inside the kiln for several months of operation.

Table 1 outlines some of the parameters used in the burner design. The primary air ratio indicates how much of the stoichiometric air (minimal theoretical air flow to burn the fuel) is injected through all the channels of the burner. The higher the ratio, the larger the amount of cold air injected into the system, thereby lowering the heat recovery from the cooler. If several solid fuels are injected (such as pulverised coal/petcoke and solid waste fuel), the amount of total conveying air tends to be high. Only some gaseous fuels can be burned without primary air. As a result, depending on the fuel, a minimum amount of primary air is recommended (6% for natural gas and 12% for petcoke and waste fuels).

Figure 1. Dynamis 77 MW clinker kiln burner for petcoke, HFO and solid and liquid waste.

Table 1. Engineering parameters

Primary air ratio	6 – 12% of stoichiometric
Solid fuel conveying air ratio	2 – 4% of stoichiometric
Turbulence index	>4E-4
Tangential index	0.006 <TI <0.03
Primary air pressure	80 – 500 mbar (max.)
Primary air supply	Rotary lobe blower

Table 2. Chemical and physical parameters

	Before	After
Raw meal silica ratio	2.5	3
Raw meal alumina ratio	2.3	2
Petcoke residue at #170	14%	2.5%

Pulverised solid fuels are injected into the kiln through a pneumatic conveying line. A balance must be found between too much conveying air, which could increase the primary air ratio, and too little, which could cause the fuel to be conveyed in compact plugs (normally 2 – 4% of stoichiometric air is sufficient).

The turbulence index is defined by the ratio between the sum of the kinetic energy flow from all flows and the thermal power released into the kiln:

$$\text{Turbulence index} = \frac{½\sum \dot{m}_i \times v_i^2}{\dot{m}_{fuel} \times LHV_{fuel}}$$

The tangential index is defined by the ratio between the sum of moment of the tangential quantity of motion (or 'Linear Momentum') of all flows and the sum of the quantity of axial motion of all flows multiplied by a kiln's characteristic radius:

$$\text{Tangential Index} = \frac{\sum \dot{m}_i \times vtan_i \times r_i}{(\sum \dot{m}_i \times vaxial_i) \times r_{kiln}}$$

For Dynamis, it is not only the Momentum ($Q = mv$) that it is important, kinetic energy ($KE = ½mv^2$) also has a particular role to play with regards to turbulence. This means that the velocity is of greater importance than mass in shaping the flame and mixing the fuel with the oxidiser, which is a core concept behind Dynamis burners. It should also be noted that, 'Flame Momentum' (a quantity of motion) must not be the only parameter for burner design and should be used to compare similar burner designs. A good example is the fact that there are burners for natural gas without primary air (zero 'Flame Momentum'), using only the fuel mass flow and velocity. Of course, for such burners, flexibility is always an issue.

In the cement kiln, hot secondary air (coming from the cooler) is responsible for more than 90% of the oxygen intake. This means that the burner air, which is much colder, is responsible for less than 10% of the total air inlet, and is thus used to mix the hot secondary air stream with the fuel stream (hence why it is referred to as 'Shaping Air'). Overall, it is good practice to minimise the burner air flow to allow more heat recovery from the clinker cooler in the form of hot secondary air (maintaining the same O_2 levels at the kiln inlet).

With the Dynamis burner design and a rotary lobe blower providing the air supply, the system can work with high pressures (up to 500 mbar) at the air channels if needed, so the operator can change how the mixing of fuel and air takes place inside the kiln, effectively shaping the flame according to the process needs.

Turbulence has a significant role to play in combustion, so the burner's design focusses on how to make the best of it. Turbulence is often automatically associated with swirl, but this is not always the case. If the mix of fuel and secondary air is intense (as a consequence of high turbulence) the flame tends to be shorter. This can be achieved by increasing the overall air flow of the burner, particularly the external air pressure (and velocity and flow), ocassionally maintaining the same swirl number. On the other hand, to make the flame 'longer', one should decrease the mixing rate of fuel and air (reducing the turbulence), by lowering the overall air flow through the burner. A wider flame is formed by opening more of the tangential air (increasing the tangential index) and, likewise, a thinner flame is obtained by lowering the tangential air flow.

This flexibility is especially useful when the process takes a turn for the worse, and the operator is faced with a situation that was not foreseen in the kiln design. For this reason, it is recommended that burners are not designed for just one specific operation, but rather for a range of modes that can be used throughout the kiln's lifecycle.

Case study

InterCement, which recently took part in the acquisition of the Portuguese group Cimpor, is the cement business branch of Camargo Corrêa Group. With about 19% of the cement market share in Brazil, it is one of the country's largest industrial groups, with revenues of over US$8 billion (US$1.4 billion in the cement market alone). It has several plants worldwide, including a Brazilian site located in the town of Ijaci in the state of Minas Gerais.

The Ijaci plant started operation in 2003 and has a single 5000 tpd line. The clinker line includes a two-pier rotary kiln (5.25 m dia. x 62 m), with a double 6-stage preheating cyclone tower and SLC-D calciner. The main fuel is pulverised petroleum coke.

Kiln ring formation had been a problem at the plant since its startup, but downtime had grown significantly from 2005 with the increased co-processing of residues. Between 2005 and 2009, the kiln stopped 17 times and spent several hundred hours per year in downtime due to ring formation. Early on, it was discovered that the rings were mainly formed from sulfur compounds.

Various measures were taken by plant personnel to ensure that the process was improved (such as better control of alumina and silica ratio and finer fuel), but this was not enough to eliminate the rings or to prevent their formation.

After a thorough analysis, the plant's technical team decided that the installed burner was unable to meet process requirements as it did not offer much flexibility to adapt to the situation at hand. Dynamis was then asked to design a new burner for the Ijaci kiln.

The project commenced in March 2009 and the burner was installed in September 2009. Dynamis' approach to burner design is a tailor-made solution that takes into account several factors from process, kiln and plant. One of the main characteristics of Dynamis' burner is its flexibility and ability to shape the flame in many ways to suit the process needs.

Table 3. Burner technical data

Thermal power	78 MW
Primary air ratio	10% of stoichiometric
Conveying air ratio	3.5% of stoichiometric
Turbulence index	7.77E-4
Tangential index	0.0112
Flame momentum	1810 [% x m/s]
Primary air pressure	500 mbar
Air supply	Rotary lobe blower
Total weight	12 500 kg (with refractory concrete)
Total length	14 m

Table 4. Airflow technical data

	Pressure (mbar)	Velocity at tip (m/s)
External air	300	230
Tangential air	150	170
Internal air	90	130

Figure 2. Kiln shell thermographic analysis before modification/old burner.

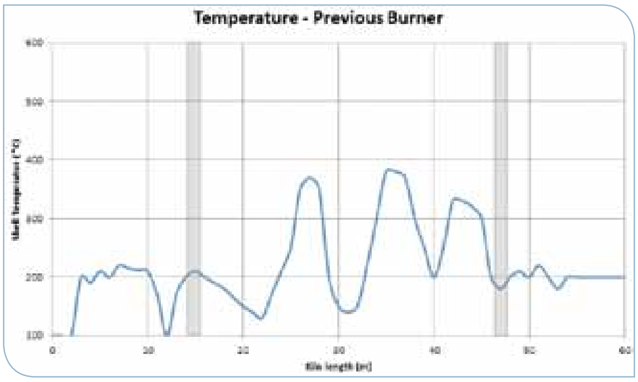

Figure 3. Kiln shell thermographic analysis after modification/Dynamis burner.

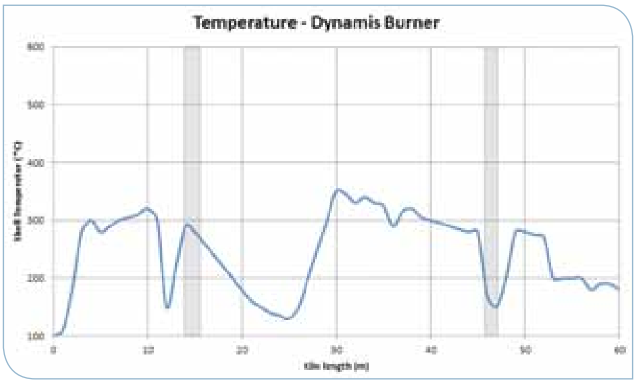

Figure 4. Burner at workshop ready to deliver before concrete.

Figure 5. Overall view of burner with maintenance car.

The Ijaci burner was built with independent air channels (3 shaping air and 1 conveying air). It was designed according to the specifications provided in Table 3.

As seen in this table, the burner prioritises injection velocity to mass flow, hence the low 'Flame Momentum' index.

In discussions with the plant's technical body, it was concluded that a liquid phase formation in conjunction with raw meal characteristics were the cause of the ring formation. In response, it was decided that the flame should be shortened and the thermal profile shifted to the kin discharge. Table 4 indicates the parameters in which the burner was operating.

Results

In conjunction with plant personnel, the kiln thermal profile was shifted to destabilise the ring formation. Together with process modifications and with the aid of the burner's high flexibility (independent channels) and high air pressure, the kiln's thermal profile was altered drastically (Figures 2 and 3).

The goal was to create a thermal profile with greater intensity at the discharge end of the kiln, in order to shift any liquid phase formation away from the zone where the rings would normally occur (around 30 m and 40 m from the discharge end). This was done by increasing two important flame parameters, turbulence and tangential indexes, shortening the flame and heating the discharge end of the kiln. Careful monitoring of the kiln scanner was carried out to ensure that the refractory bricks and coating were not being attacked by flame impingement.

Since the modifications were implemented, kiln downtime due to ring formation has been eliminated and overall availability of the kiln increased by almost 10%.

Bibliography

1. Brazilian Cement Industries Union, SNIC – Annual report for 2011/2012: http://www.snic.org.br/958AAC4E-22B6-4617-8407-020C2239CF12/FinalDownload/DownloadId-1060A56CDB7DE5D5437F9011F8B3B2E2/958AAC4E-22B6-4617-8407-020C2239CF12/pdf/snic-relatorio2011-12_web.pdf.
2. MATHIAS DE SOUZA, J., and SIQUEIRA MENDES, L., 'Formação de Anéis de Clínquer', *FICEM-APCAC Congress 2011*: http://www.ficem.org/multimedia/2011/tecnico11/6_Congresso_rev_3.pdf.