Measurement at the heart of a cement plant

Continuously monitoring gas compositions at the inlet of modern cement kilns provides safe control over firing and clinker quality. However, it is one of the most challenging tasks in industrial applications and requires reliable and robust equipment.

by Dr Henrik Alexander Noss and Wolfgang Brang, ABB Automation GmbH, Germany

The overall objective of gas analysis in a cement plant is to minimise production costs, so that the plant can compete effectively in the international market despite the current overcapacity of the global cement industry.

To achieve this objective, several steps can be taken:
- increasing plant output, which means increasing production efficiency
- minimising fuel costs by using alternative fuels with lower prices or obtaining money for firing waste
- reduce unscheduled plant shutdowns
- increase product quality.

The last does not reduce production costs but can increase a plant’s profit.

Efficient combustion by continuous gas analysis

To achieve efficient combustion, the smallest possible carbon monoxide (CO) concentration and a small excess of oxygen ($O_2$) is required. If the CO concentration is higher, the fuel’s energy use will not be optimal. If the $O_2$ concentration is too high, the plant must heat up more gas as required. The typical concentration is approximately 100ppm CO and 1.5 per cent $O_2$ by volume. Generally, reducing the $O_2$ content at the kiln inlet leads to reduced heat consumption in the range of 25-75kJ/kg clinker output. This equals between 1-2 per cent of heat consumption for modern cement kilns.

Measurement and impact

CO measurement

The presence of CO anywhere near the main flame has a negative influence on clinker quality, which is why clinker should not be burnt in a reducing atmosphere.

$O_2$ measurement

When it comes to energy efficiency, the excess air required by the main flame should be limited. Depending on the type of kiln, characteristics of the raw meal and other factors, oxygen content at the kiln inlet should range between 1-2 per cent – mostly around 1.5 per cent. Avoiding excessive oxygen content makes it possible to reduce heat consumption, as shown in Figure 1. Experience shows that the oxygen content of most kilns without inlet sampling devices hovers far above the generally recommended 1.5 per cent.

NO measurement

Nitrogen monoxide (NO) in the main flame is formed from oxygen and nitrogen contained in combustion air. The amount of NO generated depends on the temperature of the main flame, which also has a direct impact on clinker quality. A flame temperature that is too low will result in a clinker of insufficient quality. A flame temperature that is too high will lead to clinker of sufficient quality but one that is too hard and requires more energy to grind.

One of the quality criteria of clinker is its free lime content. Mill operators usually need at least two hours before they can determine it with any certainty. In kilns free lime content is in correlation with the concentration of NO at the kiln inlet.
inlet (see Figure 2). This correlation varies with individual kilns, but once established presents a perfect instant factor in determining the quality of clinker.

Producing a free lime content of one per cent is difficult with any kiln and any sudden change to even higher values results in low clinker quality. This is why cement kiln operators typically limit the free lime content of their clinker to around 0.5 per cent and less.

Most kiln operating programmes apply this correlation as a control loop, which is only possible with kiln inlet gas sampling. Kiln operations are enhanced with the following features, either manual or computer-controlled:

- reduced NO emissions from main flame
- production of softer clinker with up to five per cent in reduced energy at cement mills
- clinker production using 20-30kJ/kg less fuel, depending on the individual kilns.

Gas analysis at kiln inlet

Only direct measurement taken from a sampling device installed at the kiln inlet provides sufficient control over the production process. However, harsh conditions make up the environment of operating kilns with temperatures up to 1300°C and dust loads up to 2000g/m². Suitable gas sampling equipment is required to protect the analyser system and provide a reliable and continuous measurement gas flow. Directly exposed to these conditions, the sample probe must be of a robust design with material that is able to withstand the operating environment (see Figure 3).

In addition to the kiln’s high temperature and dust load, there is the constant danger of mechanical destruction or bending of the probe by rocks of encrusted material falling down.

Furthermore, the installation method used will decide the success or failure of the system. Good installation is the most important prerequisite for the best possible and trouble-free availability of the sampling system. Incorrect installation negatively impacts on the system’s operation as shown in Figure 4 where material falling down from the preheater has bent the probe.

Other impacts include:

- early blockage of sample gas inlets that cannot be removed
- incorrect measuring values due to non-representative sampling.

To minimise such impacts, ABB developed two types of probe systems that cover almost all operational conditions in a kiln:

- Probe 60S is preferred for applications with a known non-sticky material that behaves like sand. Cleaning of the probe is carried out by a blow-back of the filter elements. The probe has two lateral sample openings at the tip.
- Probe H is used for applications with a known sticky material that builds up encrustations on the probe. Cleaning is performed mechanically, operating like a pneumatic hammer inside the probe and followed by a blow-back of the filter element. Due to the mechanical cleaning, this probe has one central front opening at the tip (see Figure 5).

Cement industry applications

When talking to customers, it is clear that there are three key business factors: maintaining product quality, meeting the production schedule (ie, avoiding unexpected downtimes and reduced maintenance) and meeting environmental requirements. Gas analysis can support all these factors.

“If we do not deliver the right gas concentrations to control the kiln, the process colleagues give us a hard time,” said the chief engineer of a European cement plant responsible for instrumentation and analytical equipment. “No-one wants to risk a plant shut down,” he added.

“Blockages occur more since the introduction of alternative fuels. Even the best probes tend to block today. The mechanical plunger system helps to unblock the probe and enables the analyser people to deliver, what is expected from them: reliable and fast measurement values.”

A large South American cement producer decided to install gas sampling systems with Probe H to acquire knowledge of the production process to optimise the cement manufacture in different plants. Clinker quality is critical as it raises profitability.

A South European cement manufacturer replaced a 10-year old sampling system with a standard probe to new ABB system with probe H and combined it with ABB’s gas analysis system. Maintenance at the customer’s plant is now reduced by 75 per cent.
between fixed and movable parts of the probe (see Figure 6).

A significant factor in blockages of the probe inlet is the build-up of hard encrustations at the front (see Figure 7). Probe H is designed to remove such encrustations automatically. Controlled by the internal cleaning cycle, the pneumatic cylinder is activated. The plunger element is moved to the front opening, thereby breaking the encrustations, and is then retracted. During this cleaning cycle, sample gas is available for the analyser. After a configurable number of plunger movements, a back-purging is activated to remove dusty particles from the filter surface and out of the probe tube (see Figures 8A-D). The length of the probe is a further important factor in reaching a point where it is possible to get a representative sample of the gas flow. Probe H is available in lengths of 1.5-3.5m. The actual length of the probe depends on the construction of the kiln, for example its diameter.

The probe is implemented in a robust retractor system. To enable the sampling of gases exiting the kiln in such challenging environmental conditions, ABB has developed SCK, a kiln gas exit sampling system, that includes protective covers to allow for outdoor installation.

The SCK consists of two modules:
- probe retractor with pneumatic motor and a chain-driven, water-cooled probe control unit with industrial controller and menu-driven touch panel operation
- cooling unit with speed-controlled heat exchanger and cooling water circulation pump.

The retractor with its pneumatic chain drive carries the gas sampling probe in a double-beam construction. As the probe can be completely retracted, an integrated pneumatically-driven kiln flap closes the sample opening, therefore preventing the exit from the kiln of hot and toxic gases which could be hazardous for operators and machinery. A complete top cover protects the moving parts from dust.

Due to the design of the retractor, the tip of the probe is available for inspection and cleaning purposes at all times (see Figure 9). Continuous availability of measuring values is an important issue to control the process at any time. During cleaning with the plunger the sample gas flow is not interrupted.

Probe H thus offers high availability (sampling while cleaning) and reliability under the harsh conditions of the kiln, enabling cement producers to continuously monitor gas compositions and as a result, minimise production costs at their cement plant.