PRECISE COMBUSTION CONTROL

Gerald Lefebvre and Eric Hansen, EcoSource Technologies, Ronald Baker, Robert Peters and Edul Chikhliwala, EcoChem Analytics, USA, discuss how performance CEMS enable precise cement kiln combustion control.

INTRODUCTION

In cement manufacture operations, Continuous Emission Monitoring Systems (CEMS)[1] have primarily been used for regulatory reporting purposes - either for compliance with air quality regulations, or for emissions inventory purposes. Measurements from these CEMS have been used only occasionally for kiln combustion process control. Historically, tight combustion control was not feasible because of unreliable oxygen and other emission measurements, and having verified data is critical to very tight control. An additional obstacle was the cost, especially when monitoring several compounds (for example O_2, CO, CO_2, SO_2 and NO_x).

Performance CEMS contribute towards reduced emissions, improved kiln thermal efficiency, increased productivity, and better clinker quality by bringing greater kiln stability. The production rate can also be increased with the same gas flow by optimising the fuel to air ratio at all times. In the past, due to lack of reliability, plant personnel were reluctant to invest in performance CEMS although they were aware of the potential benefits. An ideal candidate for this application is the Hot-Wet multicomponent CEMS technology. This technology has evolved over three generations and two decades of experience. It has performed reliably under harsh and rigorous conditions encountered in waste-to-energy facilities and coal-fired utilities. The Hot-Wet multicomponent infrared gas analyser technology addresses past concerns regarding reliability by offering a robust, accurate and cost-effective technique.

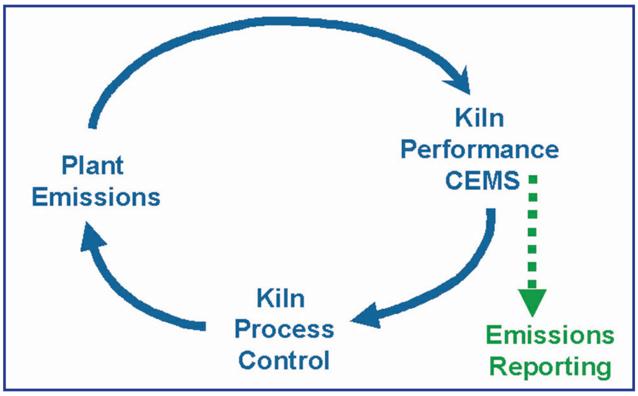

Figure 1. Application of a CEMS for a cement kiln (adapted from Jahnke[1]).

WHAT IS A PERFORMANCE CEMS?

A performance CEMS delivers high quality validated emission data for precise control of combustion. This is achieved by using a combination of optimised components (sampling system, multicomponent gas analyser and combustion control software) that monitor and control the combustion in a cement kiln. This CEMS has dual application - meeting regulatory requirements and providing inputs that can be used for process control (Figure 1). Some of the benefits of a reliable and accurate performance CEMS for the cement kiln application include:

- Better combustion control with an aim towards reducing the excess oxygen leading to higher kiln production without an increase in emissions. Hansen[2] provides an example of a cement kiln where a 1% reduction in average excess oxygen can result in a 5% increase in production throughput (Figure 2).
- Performance CEMS are equipped with combustion control enhancement software that minimises excess air while maintaining compliance and control of fuel, feed and the ID fan to ensure maximum production (Figure 3). Better combustion control achieved through a performance CEMS results in emissions minimisation. The air-fuel ratio can also be controlled in relationship to multiple emissions (NO_x, SO_2, CO).
- Performance CEMS can assist in fulfilling emission standards. This is particularly applicable in many countries like the USA where regulations such as the US Environmental Protection Agency's Portland Cement Maximum Achievable Control Technology (MACT) and long standing regulations of 40 CFR Part 60 have to be met.

RELIABLE AND VALIDATED MEASUREMENTS

In order to obtain a reliable measurement the limitations of an historical CEMS must be addressed. CEMS used for cement kiln monitoring consisted of an array of discrete analysers utilising a cold-dry sample conditioning system (a system of gas coolers remove the water moisture from the sample stream and provide clean dry flue gas to the analysers). These systems were inherently troublesome leading to maintenance nightmares for plant operating personnel. Taking note of the difficulties encountered by plant personnel, the Hot-Wet multicomponent gas analyser technology was

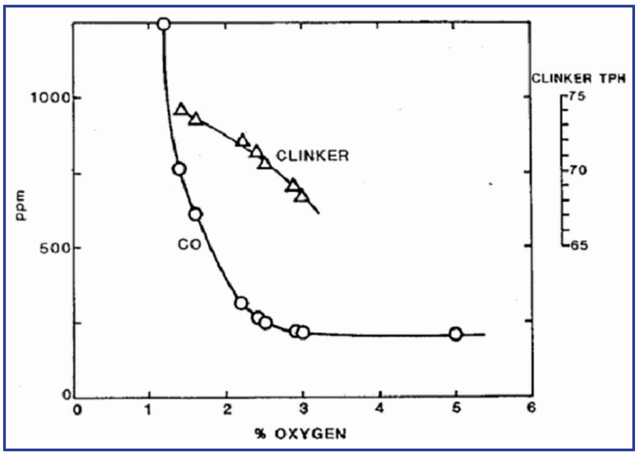

Figure 2. Kiln production as a function of excess oxygen[2].

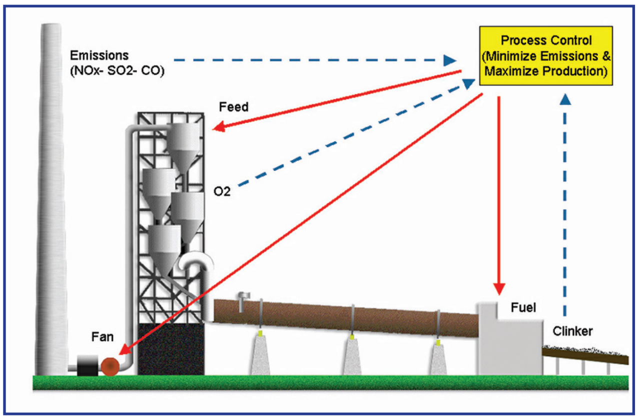

Figure 3. Advanced kiln control strategy [3].

developed where appropriate systems are matched and operating variables are optimised to maximise reliability. The advantages of this type of gas analyser over a collection of discrete analysers using the traditional cold-dry sampling approach include:

- In the cold-dry approach, sample gas coolers typically have condensates and encounter loss of reactive and water-soluble gases like SO_2, NO_2, HCl and NH_3. The Hot-Wet approach eliminates gas coolers and maintenance of the sampling system is often significantly reduced.
- A multicomponent IR gas analyser enables direct measurement of relevant gases (NO_x, CO, SO_2, CO_2, HCl) in one compact instrument (Figure 4). In addition, a zirconium oxide sensor is integrated within the analyser to provide an O_2 measurement. Thus the cement plant gets all the necessary emission data from a single analyser with one power supply, motherboard, temperature-controlled oven and I/O interface.
- Since the same analyser is measuring all gases, real-time correction for quantifiable interfering compounds using computerised algorithms is possible. This results in accurate data with high reliability.
- Due to reduced parts count, the maintenance effort for the analyser is reduced. A single source lamp, pump, flow meter, detector, power supply and optical bench replace the redundant components found in each analyser.
- Through the use of common components, the Hot-Wet multicomponent performance CEMS has a significantly lower purchase cost.

LOW-MAINTENANCE SAMPLING SYSTEM

In order for a performance CEMS to function as desired, it must be configured to deal with the harsh environment and complex chemistry of alkalis, chlorides and sulfates encountered in the cement manufacture process. The application engineering aspect may be one of the most important parts and it is in sampling systems where that is most critical.

The primary key is to keep the system as simple as possible while dealing with four primary concerns: particulates, corrosion, condensates and reactive gases. This is accomplished in the Hot-Wet (HW) sampling systems by using specially designed components. The system maintains a high temperature throughout the sampling and analysis process (for measurements of reactive compounds such as SO_2, HCl or NH_3 the entire sample system will be heated up to 450°F or 230°C). In the HW system only four parts are in contact with the flue gas, as defined below.

Probe assembly

The probe assembly provides specific functions needed for reliable sampling of flue gases while closely maintaining temperatures at elevated levels. Those functions are probe-back purge with instrument air, calibration gas injection, and failsafe inert gas protection of the system from corrosion if loss of temperature control should occur.

Heat traced sample line

The heat traced sample umbilical will maintain the gases at an appropriate temperature all the way from the probe assembly to the analyser enclosure. The sample umbilical bundle will contain one or more tubes for the sample gas and may contain additional tubes for instrument air and calibration gas. It may also have conductors and control wires for other functions needed at the probe assembly. PFA-Teflon is typically the material used for the sample tube.

Heated sample pump

A key in reactive gas sampling is minimisation of the residence time in the sampling system and that is achieved by using a custom-engineered high capacity heated pump. A three-layered Teflon diaphragm is used.

Analyser sample cell

The analyser sample cell may be of straight or folded path construction depending on the gases to be measured and range of analysis. An integral zirconium oxide oxygen sensor is also included. The entire sample cell along with the oxygen sensor is temperature controlled and a single sample exhaust is vented to the atmosphere.

ACCURATE MEASUREMENTS FROM A MULTICOMPONENT GAS ANALYSER

In order to understand the operation of the multicomponent analyser, here is a summary of the important aspects of its functioning:

Analysis techniques

The multicomponent IR gas analyser can measure different gases using techniques like gas filter correlation or the single beam dual wavelength[1,4]. Sophisticated mathematical algorithms are implemented which allow the computation of multiple gas concentrations while properly taking into account associated interference effects during each measurement cycle (which is usually completed within 10 sec).

Construction

The gas analyser is specifically designed for continuous service and the optical bench, sample cell and control components are all integrated into one convenient, and easily serviced compact enclosure (Figure 4). The analyser uses a folded path sample cell that is achieved by a specialised mirror configuration. In particular, the integrated design allows the photometer source and detector to be housed in the same temperature controlled housing which significantly improves stability. A solid-state detector is located on its own subassembly but in the temperature controlled housing.

Programmable logic controller (PLC)

A PLC controls the entire CEMS (sampling system and multi-component analyser). A commonly used industry standard PLC is deployed. The PLC can be re-programmed in the field using a touchscreen display. Using the PLC, the set points (e.g. sampling line temperature) and other crucial parameters (e.g. time values associated with a calibration sequence) can be defined.

COMBUSTION CONTROL SOFTWARE

Borrowing from standard CEMS practice, data validation and quality assurance is done on a continuous basis. Measurements are crosschecked with other flue gas constituents indicative of excess air levels (for example, the O_2 measurement that is used in control logic would be constantly validated against simultaneous CO, SO_2 and NO_x values to verify the credibility of the measurement). With this validated data, control strategies can be aggressively pursued. Algorithms for modelling the heat and mass balance in a cement kiln (Figure 5) along with process control loops implementing fuel and oxygen trim are incorporated in the software. Other potential enhancements include model-based predictive controls and strategies that prioritise emissions control[3].

CONCLUSION

The benefits of cement kiln combustion control are numerous. Hot-Wet sampling eliminates the problems associated with condensates and significantly increases the reliability of the CEMS. Coupled with a multicomponent analyser it is now possible to obtain verifiable emissions data that is continuously crosschecked. Hot-Wet multicomponent CEMS technology is an ideal candidate for a performance CEMS. It is a cost-effective and low-maintenance approach for obtaining high-availability emissions data. By virtue of the robust design and accurate data, the Hot-Wet multicomponent CEMS applied to the cement kiln industry can result in minimising emissions, improved thermal kiln efficiency, increased productivity and better clinker quality through greater kiln stability.

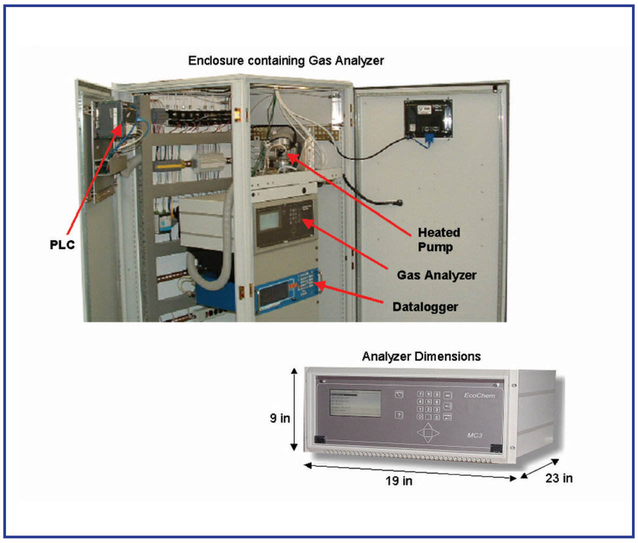

Figure 4. CEMS enclosure and typical dimensions of a multicomponent gas analyser.

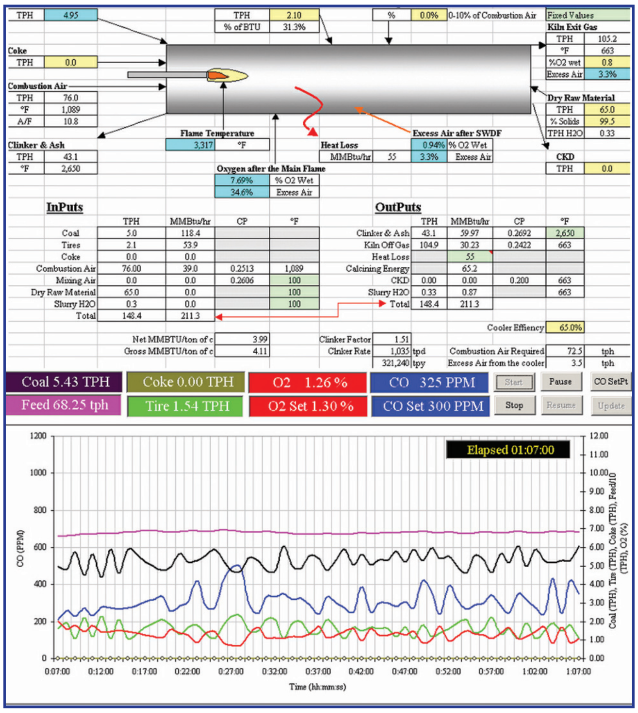

Figure 5. Process control software incorporating heat and mass balance of a cement kiln with fuel and oxygen trim loops.

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