On-line Mineral Analysis

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Dr Peter Storer, Technical Manager, FCT ACTech Pty Ltd, Australia, explains how COSMA XRD analysis can provide timely feedback for process control.

Introduction

The cement manufacturing process produces a specialised blend of minerals from a wide range of raw materials. These raw materials include traditional cement raw minerals (Figure 1), traditional fuels and increasingly, alternative fuels. There can be significant economic benefits in using alternative fuels, which can range from woodchips to shredded tyres and in some cases even negative calorific value materials such as waste water. All the materials used in cement manufacture are subject to variability in composition and calorific value, so a substantial amount of effort is put into processing the raw materials to minimise variability, and controlling the pyroprocessing to ensure uniform quality and optimum cement properties. After the pyroprocessing stage the raw materials are converted into cementitious minerals, so a method of measuring mineralogical composition is desirable. COSMA XRD provides on-line mineral analysis.

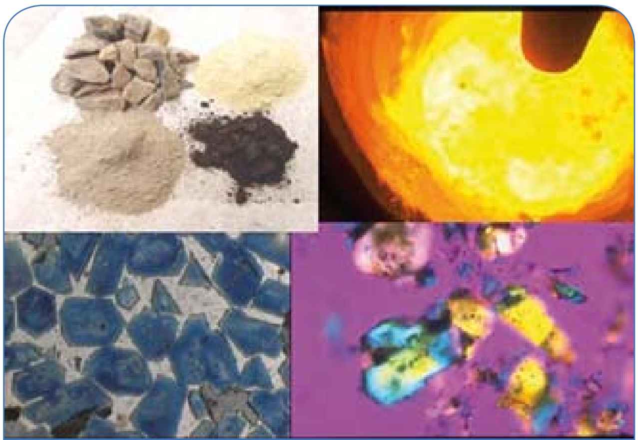

Figure 1. Raw materials such as limestone, shale, silica and iron are pyroprocessed to the clinker minerals as a part of the cement production process.

On-line analysis

On-line material analysis technologies exist for each stage of the production process to help reduce variability. These include PGNAA at the stockpile building stage, PGNAA or XRF at the raw mix/raw meal stage, COSMA XRD for clinker and COSMA XRD and laser particle sizing at the cement grinding stage (Figure 2). Using on-line technologies helps to reduce variability by minimising the time lag between the materials entering each stage of the process and the analysis of those materials, which in turn reduces the time lag between deviations in quality and the corrective action required to bring the analysis back on target.

The COSMA XRD system provides cement producers with a continuous real time direct measurement of the complete mineralogy at various points in the process stream. COSMA uses the combination of a specialised sample presentation system, a full range stationary position sensitive X-ray detector and Rietveld X-ray diffraction analysis software to directly measure mineralogy, including the major phases and polymorphs of alite, belite, aluminate and ferrite and many minor phases including free lime, portlandite, gypsum states and additives such as limestone. X-ray diffraction provides the only means of directly measuring mineralogical composition.

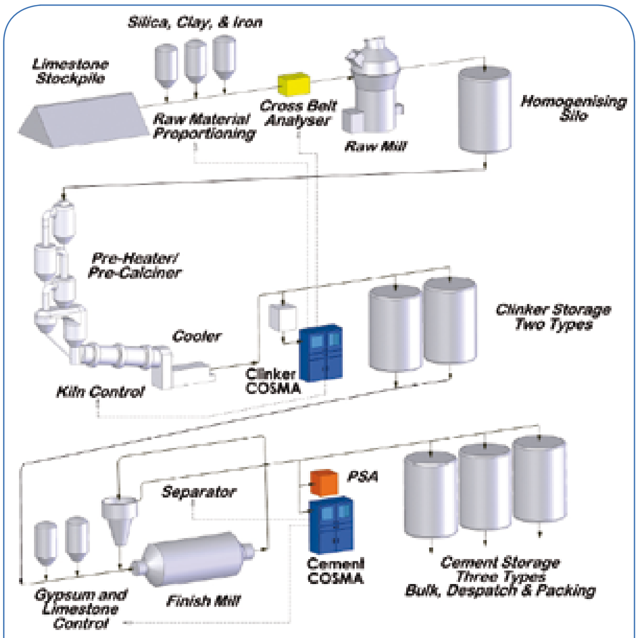

Figure 2. Examples of analysis equipment for process control in cement production.

Installation

Installation of COSMA XRD is relatively straightforward,

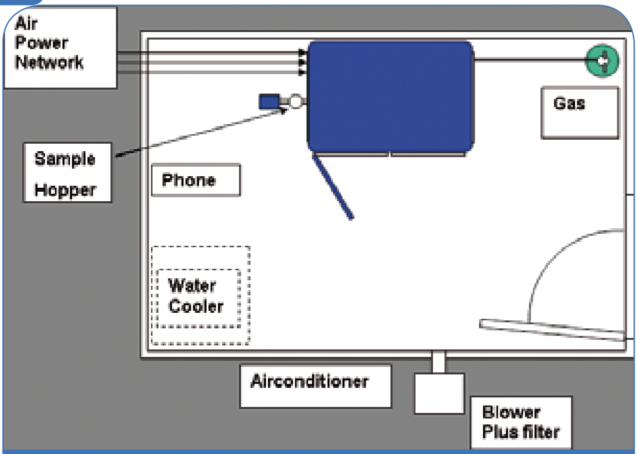

Figure 3. A schematic of a COSMA enclosure, showing the utlities required: air, water, power, network and detector gas.


Figure 4. COSMA room installed under the product conveyor exiting the finish mill building at Ash Grove Cement, USA.

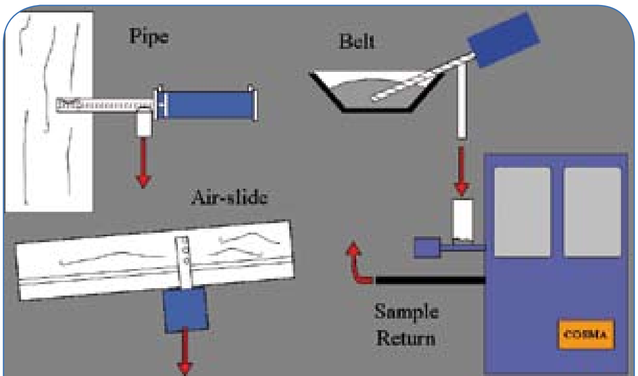

Figure 5. Three examples of cement samplers for COSMA, to deliver the sample to the COSMA feedhopper. Sample is returned pneumatically.

and can usually be performed without interrupting production. As an operational unit, COSMA can be installed in a small enclosure, out in the plant near to the process stream, as shown in Figures 3 and 4. The enclosure size is typically a small room of 2.4 m x 3.6 m, although smaller spaces can be used, down to a minimum of about 1.6 m x 2.4 m. This room houses the COSMA unit and provides a temperature controlled environment for maintenance, and for batch sample testing. Connections to COSMA include plant air for pneumatic sample removal, electrical power, ethernet for remote access and data communications, water for cooling the X-ray tube and a gas mixture for the position sensitive X-ray detector. The network connection provides status information to the plant control mimic screens and analysis data to the plant process control server.

Sampling

Sample supplied to COSMA must be ground to about 50% passing 45 µm. The sample delivery rate is about 100 g per minute. In the case of cement analysis the cement direct from the finish mill is much finer than this and can be sent directly to COSMA for analysis. The sample can be extracted from the process via a suitable means such as a feedscrew, pneumatic piston or airslide sampler (Figure 5).

COSMA has a sample feed hopper which has capacitive level sensors that determine the hopper sample level and request samples directly from the process as required. Samples are moved from the hopper onto the patented internal sample presentation stage via a feedscrew, which in turn moves a fresh bed of sample continuously past the analysis zone. Accumulated data is periodically analysed using Rietveld software that provides the mineral analysis of the material direct to the plant every minute via ethernet using a Modbus protocol.

For a clinker analysis application the sample must be pre-ground to better than 50% passing 45 µm. There are a number of sampling systems available. Figure 6 shows an example of a system where sized clinker is extracted from the cooler via an under-grate sampler and conveyed pneumatically to a grinder. The grinder continuously presents ground clinker to the COSMA hopper on an as-needed basis. In this example the trigger for requesting material from the under-grate sampler is controlled by the low level sensor in the COSMA hopper. In both the cement and clinker examples, the analysed sample is simply blown back to a point in the process that is under neutral or negative pressure, such as a nearby dust collection hood.

Control of the burning conditions

It is well known that the cost of burning cement is related to the percentage free lime in the clinker. For each 0.1% of extra free lime in the clinker the plant can save about 1% in fuel consumption. In addition the clinker grindability and reactivity improves up to a certain limit, usually about 1.5% free lime. However, most plants burn their clinker much harder than necessary, in part to avoid the risks of producing expansive cement, such as will occur if the free lime exceeds about 2%. With COSMA XRD providing continuous feedback to the plant control system, the free lime set point can be raised to the optimum level with significantly less risk of loosing control, due to the rapid feedback of information to the kiln system.

The COSMA continuous mineral analysis provides significantly more than just free lime, which in turn allows the control system to properly account for excursions of free lime that arise due to different causes. The cause of high free lime may be due to either under burnt clinker or excess lime saturation in the mixture. If the clinker is underburnt, the excess free lime will be accompanied by a drop in alite (C_3S) and an increase in belite (C_2S), as shown in Figure 7. On the other hand, an increase in free lime can be seen if the lime saturation is too high in the mixture, as shown in Figure 8. In this case the increase in free lime is accompanied by an increase in alite, and harder burning in this case will not significantly reduce the free lime. In extreme cases, attempting to burn over-limed mixture to a low level of free lime could lead to severe refractory damage.

Cement production control

For cement production COSMA can be used to control the addition of limestone and gypsum. The limestone measurement is a direct measurement of the calcite that is added to the cement. COSMA also measures quartz that may be found as a contaminant in the limestone and presents as insoluble residue. A scripting engine in the COSMA software allows the user to perform calculations with the mineralogical data, so the elemental oxides in the cement can be calculated. This provides a calculation of SO_3 for control of gypsum addition and provides for a calculation of the loss on ignition (LOI) for the cement at various temperatures, based on the hydrate and carbonate losses from the cement. In some cases it may be advantageous to control the addition of limestone indirectly by controlling the LOI.

Grinding in the cement mill induces changes in the gypsum states that can be directly measured by COSMA. In particular the gypsum ($CaSO_4.2H_2O$) is heated and decomposes to hemihydrate ($CaSO_4$. ½ H_2O). These changes can affect the setting time of the cement. Typically, production systems attempt to control this dehydration by cooling the finish mill with water sprays controlled according to the cement exit temperature. However the actual dehydration can be affected by other factors such as the temperature of the clinker that is entering the mill. In these cases COSMA provides a direct meaure that can be used to optimise cement dehydration.

In both the cement and clinker cases the COSMA can be used to feedback to the control of raw mixture, since the complete mineralogy of the clinker is directly measured. In this case deviations due to drifts in other analytical equipment or changes in the fuel ash composition can be compensated.

Conclusion

Modern methods of cement manufacture require modern process control techniques, due to the customer demand for a quality product and the sometimes conflicting economic demand for minimum cost of production. The best method of ensuring quality in a variable production environment is to implement real time continuous on-line analysis methods. COSMA XRD analysis is one such method that provides the cement manufacturer with timely feedback for process control while providing detailed insight into problem resolution. COSMA XRD allows the cement manufacturer to control the production process based on directly measured mineralogical composition.

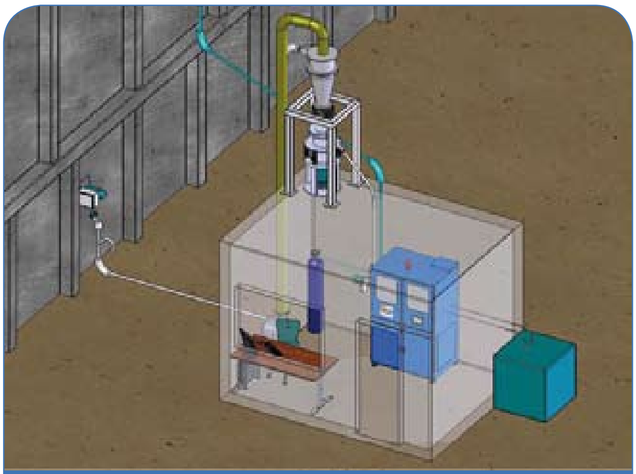

Figure 6. Schematic installation of COSMA for clinker analysis, where the clinker is extracted by an undergrate sampler and conveyed pneumatically to a grinder before the COSMA sample hopper.

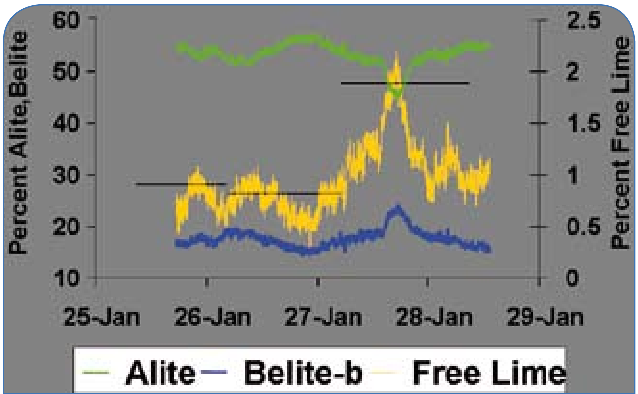

Figure 7. Trend of COSMA results showing the decrease in alite and increase in belite that accompanies excess free lime when the clinker is underburnt.

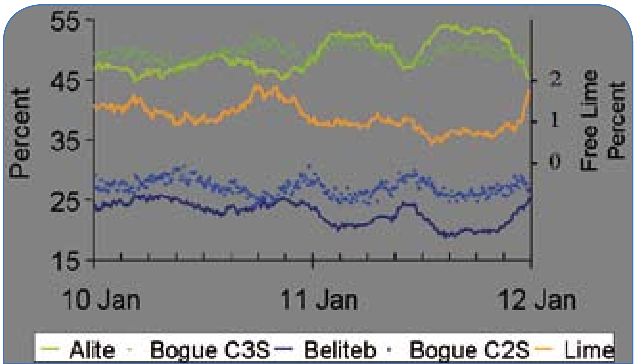

Figure 8. Trend of COSMA analysis showing an increase in free lime due to excess lime saturation in the raw mixture.