Online QUALITY CONTROL INSTRUMENTATION

Anis Haider, ITECA, France, discusses the installation of online quality control instrumentation at the Jayajothi Cement plant, India.

Introduction

Traditionally, instrumentation and control at a cement manufacturing plant has been carried out by taking samples from different processing points and analysing them in a central laboratory, either manually or in some cases automatically.

In 2008, when designing its new plant, Jayajothi Cement management decided to install online measurement systems that present a number of advantages over the traditional methods – notably in terms of higher frequency and more timely controls, resulting in energy savings and better, more stable product quality. These instruments also have the advantage of being cheaper and simpler to operate compared to central automatic laboratories.

This article provides a brief description of each of the control instruments as they were implemented at the Jayajothi plant, their installation, effectiveness in the process control and cost justifications. The four major areas covered in the article are raw mix control, precalciner control, clinker control and cement control.

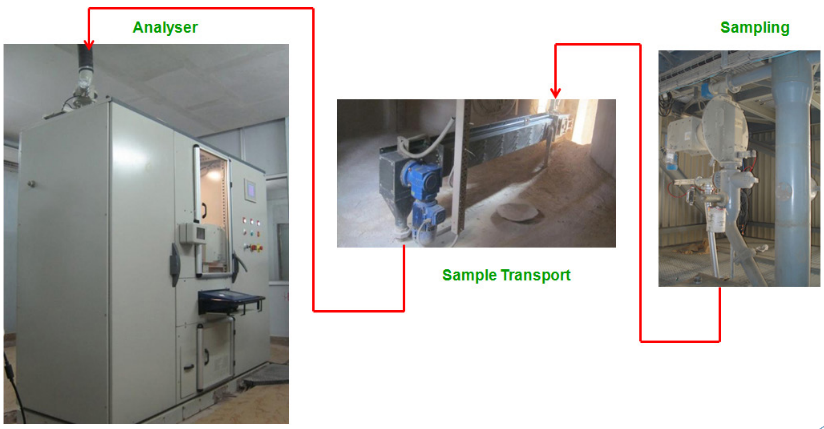
Raw mix control

A stable raw mix with the right concentration of each of the four major oxides (CaO, SiO_2, Al_2O_3

Table 1. **Data comparison between at-line analyser and laboratory data for the same period**

	Raw mix analyser (FX-3500)				Raw mill lab XRF (Bruker-S4)				Kiln feed lab XRF (Bruker-S4)				Clinker analysis in lab XRF (Bruker-S4)			
	24 hour	LSF	SM	AM	24 hour	LSF	SM	AM	24 hour	LSF	SM	AM	24 hour	LSF	SM	AM
Minimum		0.94	2.06	1.01		0.96	2.07	1.05		0.96	2.16	1.06		0.92	2.09	1.2
Maximum		1	2.33	1.19		1	2.34	1.2		0.99	2.21	1.12		0.93	2.17	1.24
Average		0.97	2.21	1.1		0.97	2.24	1.12		0.97	2.18	1.08		0.92	2.13	1.22
Standard deviation		0.01	0.06	0.04		0.01	0.07	0.04		0.01	0.02	0.02		0	0.03	0.01

Figure 1. At-line raw mix analyser.



and Fe_2O_3) is essential to ensure the stability of the kiln operation and the quality of the finished product. Fluctuations in the composition result in a harder to burn raw mix requiring higher energy consumption. The clinker produced is often of poor quality with lower strengths and it needs to be ground finer to achieve the required strengths – leading to even more energy consumption.

Traditionally, a raw mix sample is brought back to the laboratory to be analysed every 1 to 2 hours and the results of the analysis are used to correct the component mix. However, with the online instrumentation the analysis is carried out onsite every 5 minutes and the corrections to the mix can be made automatically.

It is advantageous for an analyser to be installed after the raw mill. One of the main benefits of an analyser installed after the raw mill is that it analyses the whole composite that will be going into the blending silo, including, where possible, all the fines returning from the dust collection system. These fines can vary considerably in quality as well as quantity and typically have a chemical composition significantly different from that of the intended raw mix. Therefore, unlike an analyser installed before the mill control, it would be possible to adjust the weigh feeders on the additives depending on the nature of the fine dust return.

Components of the system

Figure 1 shows the various components of the raw mix control system.

Sampling system

A highly representative raw mix sample is collected in a chute after the separator using a screw sampler. The collected sample is stored and mixed for a predetermined time and the mixer is then emptied. A volumetric sampler then collects the material to be analysed at the discharge of the mixer and the sampled material is transported using a short mechanical conveyor before dropping by gravity into the analyser. The excess material is returned into the material flow. The whole system is airtight and is not affected by pressure fluctuations in the chute.

Raw mix analyser

A 25 g sample of raw mix is ground using a high-efficiency grinder. The average particle size of the ground powder is less than 3 µm, ensuring an accurate analysis. An accurate material analysis is essential to design a raw mix that is able to produce a clinker (and cement) of intended chemical composition and physical characteristics.

The prepared sample is then analysed using an automatic at-line analyser installed near the sampling point and the results of the major oxides compositions (SiO_2, Al_2O_3, Fe_2O_3 and CaO) are output to the plant control system. The results are then used to adjust the weigh feeders on the materials, as well as on the additives.

As can be seen from the data presented in Table 1, over a 24-hour period the plant is able to control the LSF on a very tight band, despite having various outside raw material sources. The standard deviation achieved on the LSF at the outlet of the raw mill is the same as the one achieved after the blending silo. In addition, the average LSF results between the raw mix analyser, raw mix and kiln samples, collected manually and analysed in the laboratory using a Bruker XRF, are the same.

Precalciner control

Knowledge of the degree of calcination of raw feed at the kiln inlet is essential in controlling the firing conditions in the precalciner, subsequently optimising the fuel consumption in the precalciner as well as in the kiln. A more complete calcined kiln feed requires less thermal input in the kiln and leads to improved production. Traditionally, a grab sample is collected manually at considerable risk to the operator and brought back to the laboratory to be analysed every 8 to 24 hours. However, with the at-line instrument the analysis is carried out onsite every 30 minutes.

Components of the system

Figure 2 illustrates the major components of the online sampler and analyser of samples from the precalciner. The sample is collected from the calciner chute leading to the rotary kiln.

Sampler

The sampler is located at the precalciner discharge end of the kiln inlet chute. The air-cooling quenching mechanism is mounted immediately below the sample discharge.

The sample is collected automatically from the kiln inlet chute. The material is air-cooled to freeze the calcination reaction and is then conveyed to the analyser, located near the sampling point. The cooling air does not come into contact with the sampled material. Samples are typically analysed for an ignition loss at 975 ˚C to determine the degree of calcination.

Ignition loss analyser

In order to determine the degree of calcination of the raw mix from the precalciner to the kiln inlet, the loss of ignition at 975 ˚C is determined automatically at regular intervals. The sample is introduced into a special stainless steel alloy crucible where it is weighed, heated to 975 ˚C for 25 minutes and weighed again (Figure 5). The loss in weight gives the following degree of calcination of the material:

- Calcination (%) = (wt. loss of material from calciner/wt. loss of actual raw feed) x 100.

The plant operators use the calcinations data and the temperature information to adjust the fuel supply to the precalciner in order to enhance its thermal profile and optimise its efficiency.

Clinker control

It is critical that the phase composition of the clinker is correct in order to produce cement of acceptable chemical and physical properties. Although the composition of the clinker is directly related to the composition of the raw mix, it is the pyroprocessing of the raw mix in the kiln that plays a similarly critical role in achieving the targeted clinker phases. For instance, an underburned clinker from even a correctly prepared raw material can have a high free lime content and low alite phases. The percentage of free lime in clinker decreases as the burning zone temperature in the kiln is increased. High free lime content in cement can cause concrete to expand, resulting in cracks and flakes in the concrete structure. Therefore, determination of free lime is an essential element to characterise the quality of Portland cement.

Free lime analysis

Traditionally, to avoid excessive free lime, kiln operators are instructed to operate the kiln so as to have an average free lime value significantly lower than the specified level. The free lime is determined by a laboratory technician, on a frequency of once an hour to once a shift. The clinker sample in such cases is taken manually on the pan conveyor after the cooler discharge and analysed in the laboratory using a titration method after glycol or glycerol extraction.

With the online instrument, the analysis is carried out onsite every 15 minutes and the corrections to the firing conditions in the kiln can be made automatically. It is therefore possible to operate the kiln in the optimum

Figure 2. At-line precalciner control system.

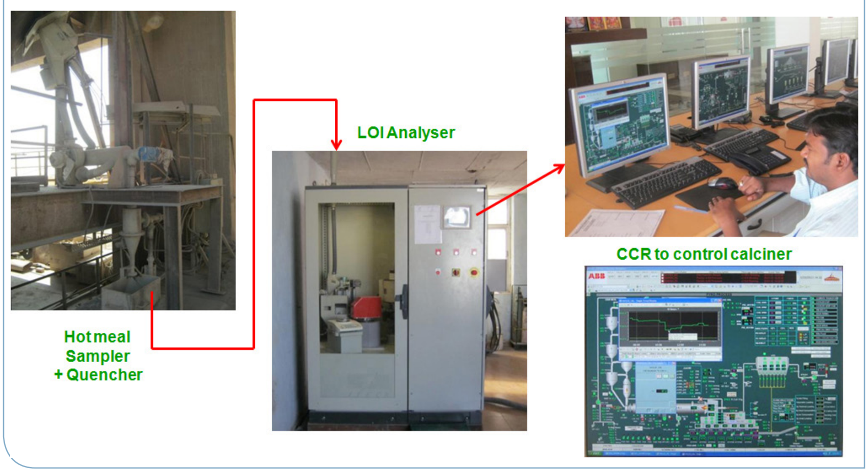


Figure 3. At-line free lime analyser.

range of free lime, saving costs on the burning process as well as on the grinding process, as hard burnt clinker is also more difficult to grind and may produce cement with disappointing early strength.

Components of the system

The basic components of the online free lime analyser are shown in Figure 3. The clinker sample is collected and transported to the analyser, located near the sampling point, where the sample is ground and analysed for free lime content.

Sampling at the kiln outlet

The sampling system is installed in the throat of the cooler next to the rotary kiln outlet.

Clinker is collected at the fall of the kiln using an air-cooled refractory steel beam. The beam is pushed into the material stream using a pneumatic actuator. Approximately 300 g of material is collected. The beam is retracted and the sample is removed from inside the beam.

The advantage of taking the sample directly at the kiln discharge is that the reaction time to a process change in the kiln is drastically reduced and corrective action may be taken immediately.

Sample transport equipment

The 300 g sample is transported to the analyser, which is generally located in close proximity to the cooler in an air-conditioned location, using a bulk pneumatic transport system.

The free lime analyser

Clinker is ground using a disk mill. The ground clinker and the glycol are weighed using an electronic scale and then fed into a reaction beaker where the solution is heated and stirred. Once the free lime is dissolved, the electroconductivity of the solution is measured and the data is converted into a free lime value shown on the front display panel and sent electronically to the central control room. The whole process, from sampling to sending the results to the CCR, takes less than 12 minutes.

Kiln control strategies using an online free lime analyser

Online measurement and kiln operation data

The graphs in Figure 4 show the data obtained at the plant. It can be seen that the plant managed to stabilise the free lime value at a relatively high level and with a low standard deviation.

It must be understood that free lime, as measured by the online analyser, is an absolute number that is not dependent on factors that may otherwise affect the control parameters normally used for kiln control purposes. For instance:

- Kiln amps, the most widely used parameter for kiln control, are typically affected by buildup in the kiln and are very slow indicators to a change in free lime content.
- Burning zone temperature measurement may be influenced by a change of concentration of dust or a buildup between the pyrometer and the clinkering zone being measured.
- NO_x can be influenced by several factors, including quality of the fuel or the accuracy of the gas sampling system at the back end of the kiln.

Figure 4. Free lime data.

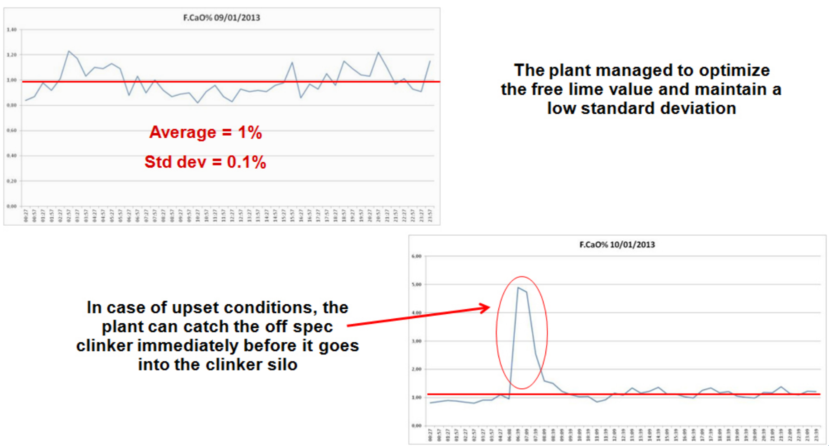
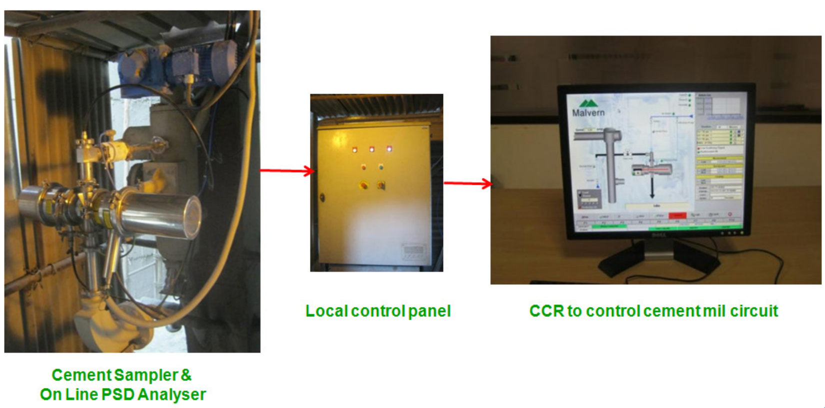


Figure 5. Online particle size analyser.



Possible kiln control strategies

Based on the information outlined above, the following control logic can be identified:

- Incremental instantaneous control is based on NO_x, BZT, kiln amps or a weighted combination of these factors around given set points.

- Free lime is measured automatically at a high frequency (typically every 10 to 20 minutes in order to see the trends forming). The clinker is sampled as close as possible to the clinkering zone to reduce the lag time between the free lime result and the kiln operational data. The free lime result is then used to update/correct the set points for each of the factors.

The data in Figure 4 also shows the advantage of having an at-line free control very early on in the production cycle, as the system is able to identify a quality problem as early as possible. As the clinker is sampled directly at the kiln discharge, the free lime result is known at least 15 minutes before it exits the clinker cooler and can therefore be bypassed into the off spec clinker storage without jeopardising the quality of the clinker stored in the good clinker silo.

Cement control

When producing Portland cement, the main parameters normally evaluated to determine both the physical qualities of cement are:

- Blaine analysis: a traditional method that uses air permeability to characterise the fineness of the cement.
- Particle size distribution (PSD) analysis: a newer technology that gives a complete grain size distribution of the finished cement and has now replaced Blaine measurement as the de-facto control method in modern plants.

Traditionally a cement sample is brought back to the laboratory to be analysed every 1 to 2 hours and, if needed, the results of the analysis are used to correct the process.

Fineness control

Figure 5 shows the various components of the system as installed in the plant. Around 150 kg/h of cement sample is collected continuously using a highly representative screw sampler in a chute at the discharge of the separator. A bypass/dilution system is used to extract a portion of the flow, pass it through the instrument and then back into the primary flow line. This system incorporates a near isokinetic tap that is driven by a venturi edutor. This allows around 30 kg/h of cement to be analysed.

The sample is then fed into an optical head and real-time sampling interface of the PSD measurement system. Particles pass through an air-purged flow cell, which supports a fixed alignment laser transmitter and a solid-state detector based on the classical ensemble laser diffraction technique. As particles pass through the laser beam, light scattered in the forward direction is collected by the receiver lens and focused onto a log-scaled annular ring detector. The detector is then scanned at high speed, recorded and digitised for continuous real-time analysis.

Using the online PSD analyser, which gives a real-time continuous measurement, it was possible to dynamically control the speed of the separators and the mill draft at the finish grinding mill. Therefore the fineness of the product was optmised, saving on the cost of the energy required for grinding and stabilising the quality.

Conclusion

Over the last 20 years, developments in the technology of cement manufacturing have provided a quantum leap for hardware and software tools in both the control room and the laboratory. This new concept has been installed at Jayajothi Cement to control the cement manufacturing process, provide more stable control, improve product quality and reduce energy costs.

This concept is a hybrid system utilising the latest developments for process control and the laboratory. This new distributed architecture brings online analysis and control into the four main control areas of a cement manufacturing line: raw meal control, hot meal control, clinker control and cement control.

By placing the analysis and control modules in direct proximity with each process, significant improvements in frequency of analysis and the availability of real-time data allow for both immediate and automatic process corrections. It is important to note that these control modules were installed prior to installing any automatic process control software – the objective being to provide reliable, pertinent, valid and proven data to any future control system that may be implemented by the plant. The principal benefits for such systems include:

- A more consistent raw mix.
- A lower temperature with higher free lime content.
- More stable kiln operation.
- Significant savings on fuel.
- More reactive, softer clinker for easier grinding.
- Considerable savings on electrical energy.
- Improved separator control for more consistent cement particle size.
- Distributed in-process area modules, which provide significant cost savings over centralised location systems.
- Payback is typically less than one year.

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