Castle's on-line analysis

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Castle Cement's Padeswood works in North Wales produces around 500,000tpa of cement. Two ball mills are used at the site to grind cement to the required specification, with six different grades being produced. During 2003, Castle Cement took the decision to investigate the use of on-line particle size analysis with the objective of improving mill control and product consistency. The outcome was the installation of a Malvern Insitec on-line particle size analyser at the Padeswood Works. In this article the reasons behind this decision are examined, and key aspects of the design and use of the system are reviewed. The benefits obtained by Castle Cement are described in detail.

Cement gains compressive strength as a result of hydration reactions that occur when water is added. These reactions are governed by the chemical composition of the cement and the size of the specific surface area of the particles, described conventionally within the industry as fineness. Chemical composition depends on the raw materials used to make the cement and these are selected primarily on the basis of cost. Composition is therefore not normally manipulated to deliver product properties. This leaves specific surface area as the key variable for controlling product quality. At the Padeswood Works six different grades of cement are commonly produced, five of which are identical in chemical composition and differ only in terms of their fineness.

Blaine is a numerical measurement for fineness. It is measured by recording the time taken for a given volume of air to pass through a bed of constant mass and depth. The number produced has the units of m^2/kg and is an averaged measure of specific surface area. It indicates nothing about the distribution of surface areas between the particles. The limitations of Blaine number become evident from Figure 1 in which two samples are shown, each with the same area but, in effect, a different particle size distribution.

If these two samples were cement then they would each have an identical Blaine number, however their behaviour would differ significantly. Particles in the first sample would hydrate in a very consistent manner whereas those in the second sample, having a different diameter, would behave with greater variability. Where two cements have the same Blaine number/specific surface area the one with the narrower particle size distribution will have the higher compressive strength as a result of more consistent hydration. Particles larger than 50µm in diameter will react so slowly that they will not be fully hydrated even after long curing periods, and an excess of particles smaller than 3µm causes the cement to cure exothermally, resulting in cracking.

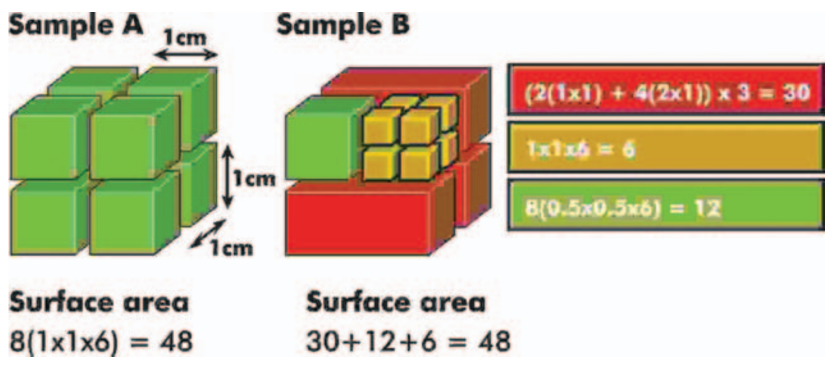
Off-line analysis

For the past seven years a laser diffraction particle size analyser has been used at the Padeswood Works in place of the standard Blaine technique to produce measurements of fineness, and in addition particle size distribution data. The results obtained using the analyzer can be closely correlated with conventional Blaine number, but are produced more consistently and rapidly. Off-line particle size analysis has been used to generate valuable information about the performance of both the cement mill and separator, but is limited in terms of further investigation of the process.

Measurements are taken using composite samples of approximately 1kg extracted from the plant at two-hourly intervals; 2-3g of the sample are analysed. The composite nature of the sample means that any fluctuations in plant performance, over the two-hourly period, are not detectable. In addition, during product specification changeover the two-hourly period between analyses can result in the production of significant quantities of out-of-specification material.

The benefits of laser diffraction/laser light scattering technology were already established at Castle Cement but the potential of the off-line analyser had in effect been largely exhausted. The

Figure 1: two samples each with same area but in effect a different particle size distribution



Laser Light Scattering/Laser Diffraction

The technique of laser light scattering or laser diffraction can be used to determine particle size because the way in which light is scattered by a particle is function of its size. Small particles scatter light at wide angles whereas large particles scatter light more narrowly. If laser light is shone through a sample and the pattern produced is recorded, the particle size of the material can be back-calculated, by applying the Mie theory of light. The technique is non-destructive, very rapid and with Malvern Insitec can be used for particles in the range 0.1 – 3000µm

company decided that an on-line particle size analyser would allow further optimisation of both product and process. The key aim of the project was to use the data generated by the on-line system to reduce product variability and save energy. Sampling frequency could not be reduced as there remained a need to acquire compositional data.

Why Insitec?

Having taken the decision to install an on-line particle size analyser production staff considered the available options and then selected the Insitec from Malvern for three key reasons:

- system robustness
- strong inter-company relationship
- operational experience.

The rugged design of the Malvern Insitec has been specifically developed for on-line applications to ensure that it meets industry's requirement for reliability and minimal maintenance. Particle size data are rapidly generated using a laser light scattering technique and no calibration is required. Dust and vibration do not affect operation. A further feature of the Insitec, of particular interest to Castle Cement, is the system software which facilitates integration with most common control platforms.

Castle Cement had worked with Malvern on a previous mutually beneficial trial during which the potential of the Insitec had been demonstrated, and installations at other cement producers such as Ashgrove Cement's Leamington plant were testament to the effectiveness of the system in hostile environments.

System design/installation

The Insitec was installed on the product line which typically handles a flow of around 50te/h. The system requires a representative sample flow of 10-20kg/h and therefore an appropriate sampling loop was needed. A two-stage system was recommended, and installed in the scheduled four days. Figure 2 shows a schematic of the Insitec and associated sampling system.

The sampling system consists of a variable speed screw auger and venturi eductor. The auger is positioned across the pipeline and continuously samples the product flow. While majority of the material sampled passes directly to the product hopper a sample probe withdraws sufficient for analysis. This sample material is aspirated and propelled to the measurement zone using an air venturi.

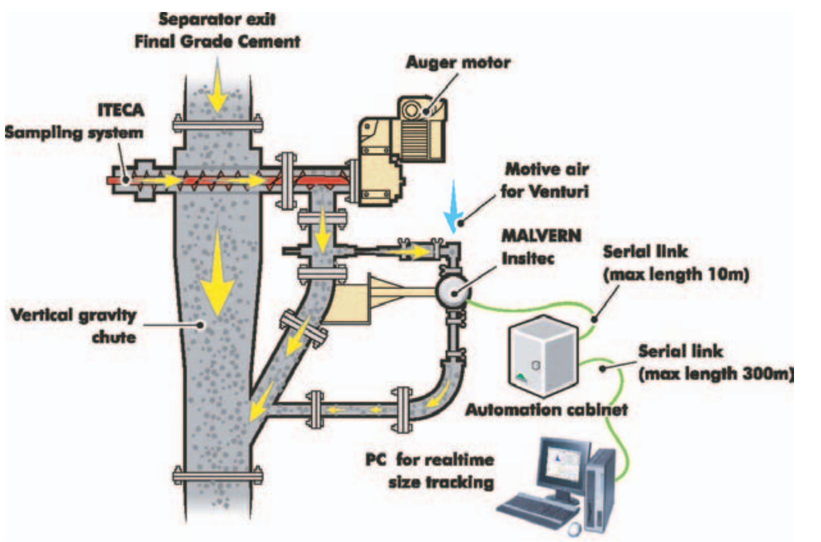
The sampling and analysis procedures are automatically controlled from three control boxes installed near the instrument which are linked to a PC in the control room. Two software packages, Malvern Link and RTsizer, installed on the PC, are used to start, stop and control the system, and manipulate and present the required data, respectively. The data presented include laser transmission, Blaine surface area, %>45 micron, %>32 micron and %< 5 micron. These parameters were selected by Castle Cement and can be changed easily. Laser transmission is monitored as it is indicative of whether sample flow through the instrument is at an appropriate level. The Insitec figure for Blaine surface area was correlated with off-line measurements and found to be in excellent agreement and therefore is routinely determined, in conventional units, for comparative purposes.

Design challenges

There was concern at the plant about the abrasive nature of the cement, and the effect that this would have on the analyser, and also the impact of dust and vibration on measurement accuracy. To combat the problem of abrasiveness the recommended technology has minimal moving parts, only the screw auger, and the measurement zone, where cement moves at the highest velocity, is ceramic lined. Flexible hoses and bends were avoided in the design. Malvern was confident that neither dust nor vibration would cause a problem, and this has proved to be the case even though the instrument is installed in an area where vibration is particularly apparent.

A further issue was a clean air supply. A clean air flow (oil/particulate concentration less than 0.1mg/m^3) is

Figure 2: typical installation of Insitec on-line particle size analyser for measuring final grade cement (cement flow rate usually 50-100tph)



Figures 3a & b: product specification change with off-line analysis

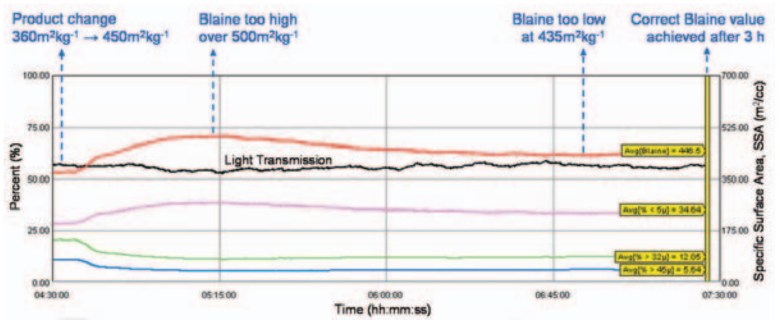


Figure 3a (above): trend chart showing optimisation of product specification using real-time particle size analysis

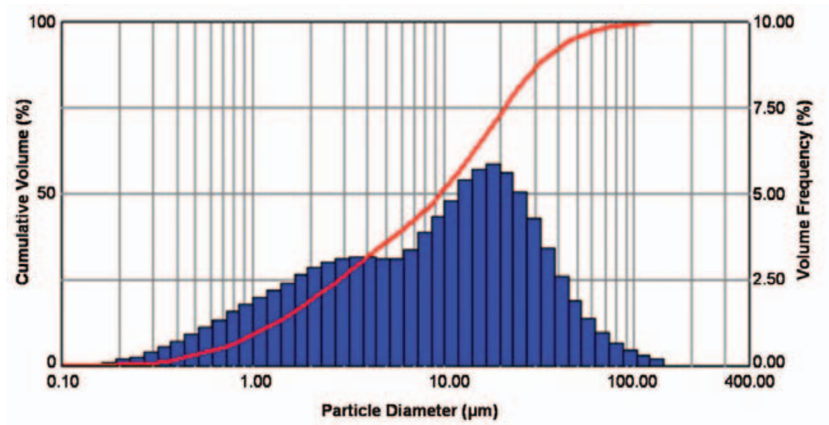


Figure 3b: particle size distribution of final grade cement measured after optimisation of product specification

required to maintain the integrity of the Insitec optical system. This air flow needs to be maintained even when the unit is shut down to prevent contamination with airborne cement particles.

To fulfil these requirements air for the analyser is taken from an auxiliary air compressor which runs almost continuously, but uses minimal amounts of energy. A drying and filtration system maintains air cleanliness.

System use

Under normal operation the PC in the control room now displays real time particle size distribution/Blaine number data which are used by the mill operator to make changes to either the separator or feed to ensure that material remains in specification.

The data are not used formally or reported on a regular basis, but have become essential process/quality control tools. Data are stored on the hard drive, transferred to CD or to another PC or simply removed. An analysis is generated every 10 seconds and therefore the amount of data handled is significant.

Benefits obtained

As a result of the installation of the Insitec system, Castle Cement has achieved improved efficiency in the form of:

- controlled operation closer to the lower end of specification
- swifter product changes
- better control during mill start-up.

More closely controlled operation

With the old analytical regime fluctuations in Blaine number were relatively frequent. As analysis was being carried out at only two-hourly intervals, and was only accurate to +/- 10 m^2/kg the mill could easily deliver a product 20m^2/kg too high or too low for the two hours between sampling. This was particularly likely when there was a change in feed from fresh to blended clinker because this is often accompanied by a change in 'grindability'. Whilst undergrinding is detrimental to product quality, overgrinding has a significant impact on energy use and hence variable cost. From regular mill efficiency tests, Castle Cement has estimated that milling to 380m^2/kg rather than 360m^2/kg can consume as much as 10 per cent more power, and 20m^2/kg variations affect compressive strength at two, seven and 28 days. More erratic operation therefore leads directly to product variability. Using the information-rich data stream from the Insitec, mill control has been significantly improved. Running the mill more tightly, closer to the required specification is allowing Castle Cement to significantly reduce variability, minimise energy costs and optimize product consistency.

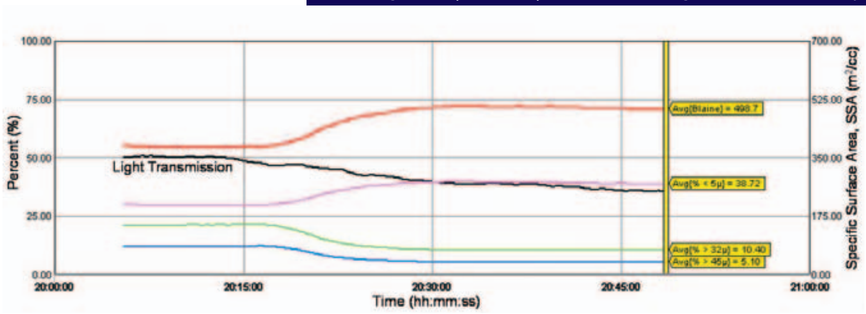
Rapid product changeover

Control of the mill during transient operation has also been improved, reducing both waste and energy usage during mill start-up and product changeover. Examining a change of specification in the presence and absence of the Insitec clearly illustrates the benefits obtained.

Figure 3 shows a change at Padeswood from Ordinary Portland Cement (OPC) to Rapid Hardening Portland Cement (RHPC). The change is being carried out under manual control without the benefits of data from an on-line analyzer. OPC has a Blaine specification of 360m^2/kg whereas the specification for RHPC is 450m2/kg. To change the specification the operator makes a change to the mill settings discovering the results of this change at 05.00 when a sample is taken and analysed. The specific surface area has increased by too much and has reached more than 500m^2/kg. Further changes are made to the mill settings and another sample taken at 07.00. This time the Blaine number is slightly low and therefore further small adjustments are made. At 07.30 material of the required specification starts to be produced, three hours after the initial changes were made. In effect the time taken to make the change has resulted in the loss of three hours production of RHPC, approximately 100t of cement – five bulk loads or 4000 bags.

Figure 4 shows an analogous change from OPC to a different product, Castle Xpress, which has a Blaine number of 500m^2/kg. The change is still being carried out under manual control but this time the operator has the benefit of on-line data. The shape of the transition is very similar but the timescales are significantly different. Changes to the mill are initiated at 20.15, and by 20.45

Figure 4: product specification change with on-line analysis



steady production of in-spec material has been achieved. After only 15 minutes the material is almost within specification even after such a large change in the target specific surface area.

For the production of Castle Xpress this improvement in mill control is particularly valuable. Castle Xpress has a relatively small turnover and is therefore stored in one of the smaller silos on the site. Before installing the Insitec it could take four hours to reach the required specification and the silo would then be full. The production routine was therefore to route the material to the RHPC silo until the specification was reached, and then change. Putting material with too high a specific surface area in the RHPC silo is detrimental only to plant economics not product quality. Including material with a Blaine number close to 500m^2/kg in product with a specification of 450m^2/kg (RHPC) is hugely inefficient in terms of energy usage. This inefficiency has been completely eliminated following the installation of the Insitec as product changeover is now so rapid.

Improved process knowledge

A further benefit of on-line analysis was observed during trials to establish an appropriate method of adding limestone as a minor additional constituent. Before releasing product with limestone to the market place it was necessary to verify that it was being added in a controlled manner. The first technique assessed was the simple addition of limestone to the clinker feed hopper. Composite samples from the mill indicated that this technique was probably adequate but data from the Insitec showed that this was far from the case.

Figure 5 shows the unsteady milling which was taking place. Every couple of hours the Blaine number of the product increases rapidly and then decreases back to its original value all in the space of one hour. This dramatic fluctuation in Blaine value is not accompanied by a change in the amount of material greater than 32 and 45 micron, which remains approximately constant. The change in Blaine is being caused by a change in the amount of fines, as indicated by the increase in the quantity of material below five micron. Samples taken at the peak of these occurrences indicate that they coincide with an increase in the amount of limestone in the product. The relatively soft limestone is, in fact, being ground very finely in the mill and passing through rapidly; very little blending is taking place. An alternative limestone feed technique was developed as a result of this investigation

This example highlights an often observed feature of changing to on-line analysis - an improvement in real process knowledge. With on-line analysis the results of any changes are immediately evident and therefore systematic parametric optimisation of the process can be carried out and long standing problems solved.

The way forward

Insitec is now an established tool for product and process control at the Padeswood Works. It has more than lived up to the expectations of the plant team who now find it difficult to imagine running without it. Although it is laborious to fully quantify the cost savings achieved, the reductions in power usage continue to accrue daily and have already more than justified the initial capital expenditure.

Looking forward, the team plans to investigate the automation of separator control. A loop is planned between the Insitec and the separator, easily implemented using the Malvern software, with the aim of further tightening control at the plant. Perhaps however the plans which best illustrate the success of the Padeswood installation are those to consider further Insitec purchases for different applications on the same unit, the other cement mill at Padeswood, and other sites within the Castle Cement group.

Cement producers looking to maintain margins in the face of high energy costs and increasingly stringent environmental pressures are seeking new ways of improving process efficiency and product quality. As this case study demonstrates, on-line particle size analysis is proving to be a highly effective tool for cement manufacturers. Using the data stream produced, plant control can be tightened and product variability reduced. Savings flow from reduced energy consumption and waste. Product quality is improved. These tangible, quantifiable benefits, which result in rapid project payback times for on-line installations, are driving the uptake of on-line particle size analysis by cement manufacturers throughout the world, many of whom now view this technology as an integral part of their plant.

Figure 5: On-line analysis during limestone addition