Perfect particles

by Stuart Barton, Xoptix Ltd, UK

Measuring particle size is a key part of the quality control process and helps ensure a high-performance product in terms of overall cement strength. To handle this task effectively, grinding plant owner United Cement of China installed a new inline laser diffraction-based monitoring system.

It is well documented that cement powder performance is related to its composition and its 'fineness'. If it is clear that the chemical composition of the cement is critical for its performance, then it also follows that the fineness is also so.

By necessity for its performance, cement is made up of a distribution of particle sizes. Measuring and controlling the particle size distribution of cement is important both to achieve the desired product performance and to control manufacturing costs. Cement particle size directly affects the setting and hardening processes, and a series of physical properties, such as its strength and flow characteristics and the physical chemistry properties of concrete.

United China Cement, Xianhshui in Jiangshu province installs a new inline laser diffraction-based monitoring system

The challenges of cement powder particle size analysis

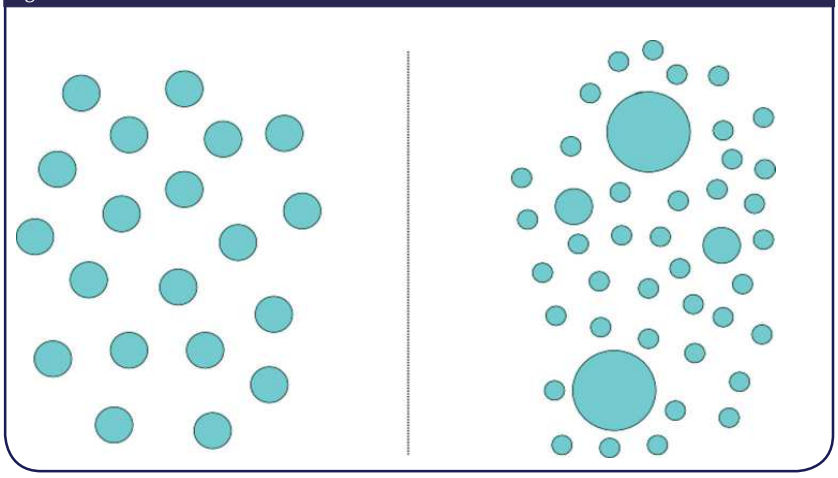
Traditionally cement fineness was measured using Blaine number (ASTM C204). This is a surface area based parameter. It is widely recognised and utilised within the cement industry. The test is a measurement of the flow rate of air through a bed of cement particles with vacuum on one side and atmospheric pressure on the other. The relationship between the air permeability of a powder and its surface area comes directly from the Kozeny–Carman approximate theory, which assumes a packing of mono-sized spherical particles. Clearly, cement particles are not mono-sized, so this value is not absolute.

Other limitations to the technique, are that it is a slow manual procedure, with less accuracy for higher Blaine values (finer speciality cements).

It has another disadvantage, in that it gives only a single parameter. What this essentially means, is that two very different size distribution cements could give the same Blaine number (see Figure 1). 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. It is well documented that particles larger than 50µm in diameter will react so slowly, that they may never be fully-hydrated even after long curing periods, even though there is sufficient water. Conversely, an excess of particles less than 3µm can cause the cement to cure exothermally, which may result in cracking.

As the cement industry continues to develop more sophisticated blended cements, a single parameter will increasingly fail to identify and hence control the real intricacies of these cements.

Figure 1: the two size distributions have identical Blaine numbers



Case study: particle sizing at China United Cement

After research and investigation into the many aspects of particle sizing of cement production, China United Cement installed the Xoptix inline particle analysis system in 2013. China United Cement worked with the Xoptix Applications Team to integrate the monitoring system into the process. The measurement principle of the Xoptix particle sizing system is laser diffraction, which is already widely accepted in laboratory analysis within the cement industry.

The Xoptix system was easily installed on the chute from the separator and uses a screw conveyor to extract product sample from the chute (see Figure 2a and 2b). Then sampling was installed on the exit tube from the screw conveyor. This ensured both that the samples are representative of the cement and that the instrument operates within its optimum range.

The impact of in-process particle sizing on production

Before the Xoptix particle sizing system was installed, the laboratory always measured the 80µm and 45µm sieve residues. There were differences between the measurements made by different operators which needed to be factored into any decisions on adjustments of the process, and additionally, there was a delay of at least 30 minutes before the results were available.

With the use of the Xoptix inline monitoring system, the impact of making minute adjustments to the milling process was seen in real time, and the operators in the central control room could see whether and how much the complete particle size distribution of the cement changed in response to these changes. Instead of one parameter every two hours (delayed in its delivery by a further 30 minutes) a full size distribution with all size parameters is available per second, thus monitoring and control is now in real-time.

Figure 3 shows the manual adjustments to the process that were made by the operators. The rotation speed of the mill selected was reduced from 59 to 57 per cent, and 15 minutes later increased again to 59 per cent. From the plot of the data captured for that period we can see clearly the changes which occurred during the period in the percentage <45 and percentage >80 curves. This was impossible before the introduction of the Xoptix instrument.

Because the 45µm sieve residue mainly reflects the percentage of medium coarse cement particle size, and the specific surface area mainly reflects percentage of medium fine cement particle size (smaller than 5µm), the customer adopted a combination of 45µm sieve residue and specific surface area to control the fineness of the cement coming out of the mill. This however, gave no real information regarding the particle distribution.

With the use of the Xoptix inline particle sizer, the Production Team could directly monitor the complete particle size distribution for the different grades of cement. From this data, rapid conclusions about whether variables in feed material

Inline particle sizer: benefits in brief

- Real-time analysis allows greater control over the rotation speed of the mills.
- Adjustments to the process can been seen instantly.
- Final cement product is more consistent.
- The mixture of materials can be optimised.
- Overall annual production cost can be greatly reduced. China United Cement has seen a reduction in annual production costs of ~US$1m.

Figure 2a: the installation of the XO inline-particle sizer on the process pipe

Figure 2b: image of the installation and movement of particles through the Xoptic Sizer

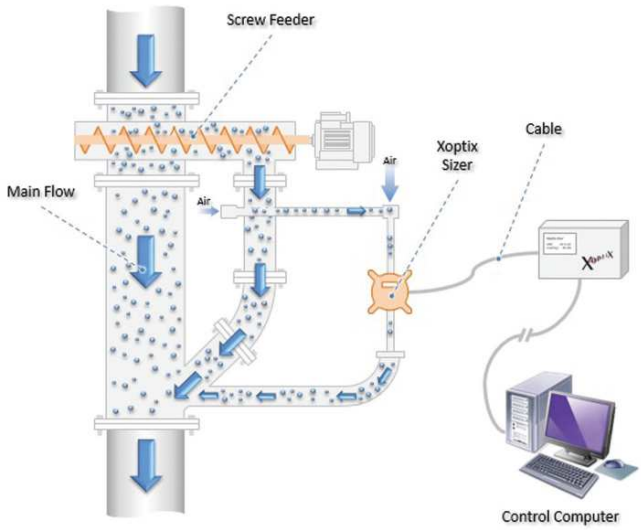


Figure 3: manual adjustments are made possible with the introduction of the Xoptix instrument

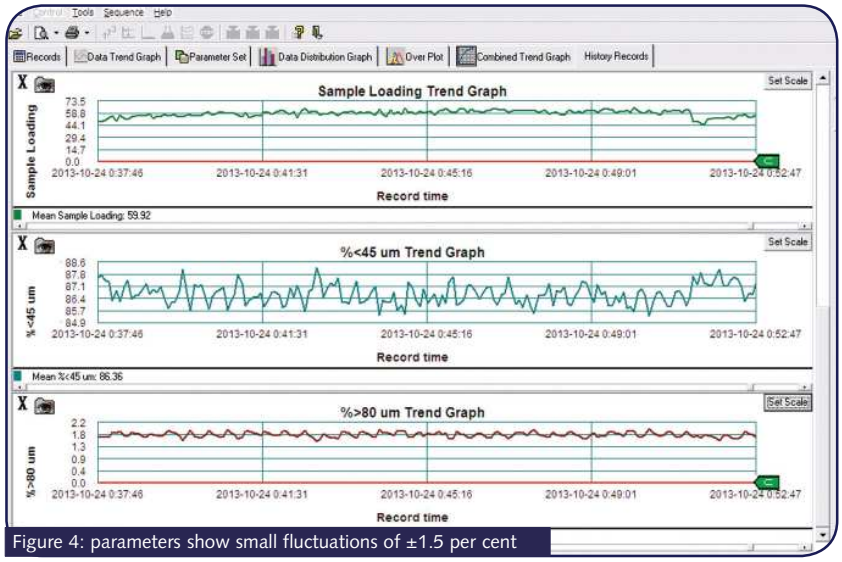


Figure 4: parameters show small fluctuations of ±1.5 per cent

were causing issues could be established.

This ability to see the results of process changes in real time gave China United Cement a powerful means of controlling the properties of its cement.

The in-process data produced by the Xoptix system correlated and tracked extremely well with offline sieve data (within two per cent), which gave the production team confidence in implementing the data to optimise the production process.

The stability of the instrument has been proven over a long period of use. Under stable processing conditions, the data for all particle size parameters reported are very consistent, with a fluctuation range of <±1.5 per cent, as shown in Figure 4. This gives the customer absolute confidence that any changes reported are due to the process, and not the instrument.

Figure 5 is a composite before and after image. It can be seen that when the separator speed reduces, particle size increases, and the particle distribution curve moves to the right.

Figure 6 shows an instantaneous distribution of the particle size. This detailed information is immediately available for every measurement, and can be recalled at any time.

The Xoptix inline particle sizer is the 'eyes' of the central control operators, and forms the basis on which operating parameters are adjusted. In real time, changes within the process are seen by operators, allowing them to respond instantly to those changes.

China United Cement purchases its raw materials for cement production from various sources. The quality of the raw materials varies widely, leading to great differences in the potential finished properties of the ground cement.

Before the installation of the Xoptix in-process particle sizer the standard deviation of the 28-day compressive strength of their product was 1.633MPa. Now the operators have stabilised the mills according to the real time data which the instrument provides, and the fluctuations in the cement have been reduced to give a standard deviation of 0.459MPa for the 28-day compressive strength of the product. The production output is balanced and stable, and meets all customer requirements.

Table 1 shows production data from before and after China United Cement used the Xoptix in-process particle sizer. Based on preliminary estimates of a production capability of 1Mta, the reduction in annual production costs reaches US$1m.

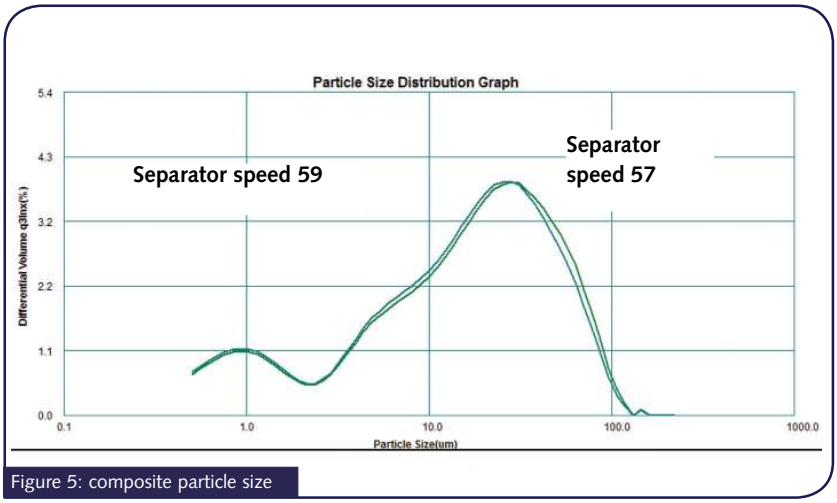


Figure 5: composite particle size

Table 1: comparison cement production before and after Xoptix XO inline particle analyser

Indicator	*Before installation*	*After installation*
Throughput (tph)	182	188
Three-day cement strength (MPa)	16.5	16.9
28-day cement strength (MPa)	38.4	39.1
28-day cement strength (SD)	1.63	0.46

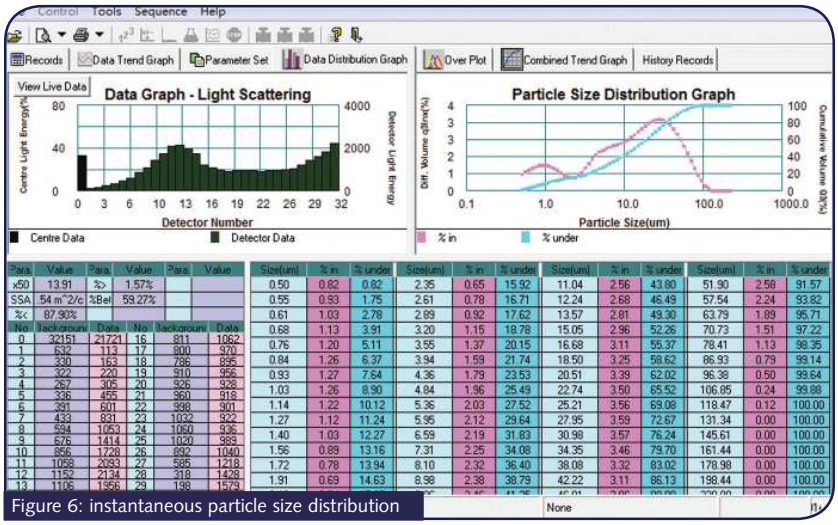


Figure 6: instantaneous particle size distribution

Xoptix in-process particle sizer optimises cement production

The installation of the Xoptix in-process particle sizer at China United Cement has had a dramatic effect on production – optimising cement production, saving time and money. The Xoptix inline particle sizer is the 'eyes' of the central control operators and forms the basis on which operating parameters are adjusted. In real time changes within the process are seen by operators, allowing them to respond instantly to those changes. They can make adjustments promptly, correctly and can see the result of those changes. Traditional offline particle sizing can never give this element of control.

For particle size distribution analyses of the content of <3µm, 3~32µm, <45µm >80µm, or indeed any parameters, process personnel can control the particle size range more precisely. This enables them to consistently produce a better product at a lower cost. Therefore the return on investment for this customer is measured in weeks, rather than months.