ON-LINE ANALYSIS – WHAT HAS BEEN DONE?

Mr P de Waal
Blue Cube Systems (Pty) Ltd

Synopsis:

The beneficiation equipment under the control of plant metallurgists exploits the differences in the physical properties between valuable and waste mineral components. In many cases, laboratory results are too late for process control and can only serve the purpose of "post" reports, the calculation of a mass balance and the issue of a quality certificate. As a result, experienced operators regularly adjust separation equipment based on the colour and texture of the various product streams in the beneficiation plant. Metallurgists quickly learn to recognise the different minerals in their ore body. The stereo microscope has been a valuable tool used by operators to quantify known mineral species. For many years it was the only practical method available for the purpose of process control and even for quality control. The modern spectroscope is far superior to the human eye and can rapidly detect a change in mineral composition. New generation optical scanners and digital signal processors can provide useful signals, related to mineral composition that can readily be applied for the purpose of process control. Successful case studies, covering dry in-line and slurry applications as well as in-plant fast spot analysers are presented.

1. Introduction

It is seldom that minerals can be mined from a deposit and then applied directly in an end application without any beneficiation process along the route. The simplest form is selective mining, just removing the high quality patches and leaving the lower quality ore behind. Usually at least one valuable mineral species is separated out of the run-of-mine ore. In many cases, more than one valuable mineral has to be separated from the waste as well as being separated from one another. In a mineral separation plant (MSP) the separation equipment consist of a large number of ingenious devices, developed over centuries by clever engineers and extraction metallurgists. Apart from chemical extraction, practically all separation processes are based on the differences in physical properties between the different mineral species in the ore. This may include one or more of the specific gravity, electrical, magnetic, particle size, surface adhesion, surface wetting and bulk density properties. In some cases it may be necessary to enhance such property before separation becomes feasible. In many cases there may be different mineral species, consisting of the same chemical elements but in different proportions, in the same ore body. A typical example is the various occurrences of the oxides of iron which can be FeO (Ferrous Oxide), Fe_2O_3 (Haematite) and Fe_3O_4 (Magnetite). They all have different physical characteristics but an elemental XRF analysis, in the presence of other minerals, can not differentiate between the species.

Analysis by XRD can differentiate but can also get confused by other mineral species having similar crystal structures. The application of the highly successful laboratory type X-ray instruments has therefore not found ready on-line application in the MSP plants. From there the question: "On-line analyses - What can be done?

2. Analytical Methods

Analytical techniques were developed for many different applications, including food and metals. The successful applications generally operate in a fairly protected environment with standardised, well-defined materials. The spark spectrometers, the flame spectrometers, the AA techniques and others, all depend on high energy molecular excitation and have all marked out a well accepted niche in laboratory applications but none of the manufacturers could produce a robust, cost effective and acceptable version for in-line mineral analysis. The reason for this is obvious. All these instruments depend on calibration by well-defined reference samples of similar composition to the test sample. The standards become transferable from one operation to the next. Large reference banks define the known elemental emission lines. These techniques can be better applied where the final product exit the MSP and start to become a "standard" product containing a single mineral species with low concentrations of impurities. Unfortunately, at the rougher end of the MSP, the operators are largely dependent on their eyesight and judgement to make the best decisions.

3. A New Approach

Minerals can not be defined by their colour alone. The presence of a small quantity of impurity can cause dramatic changes in colouration. Quarts, SiO_2, can appear as rosy, smokey or as purple (Amathyst). Standard reference "lines" are therefore not applicable. This is particularly true if different mineral deposits are compared. But plant metallurgists will recognise the different mineral species present in their ore bodies. This is so because the appearance of the minerals, in a specific mineralisation zone, is remarkably consistent. This situation made it possible to introduce "grain counting" as a recognised and accepted analytical strategy. Well-defined methods give very consistent results with a delay of about 1 hour. However, the task is monotonous, stressful on the eyes and highly dependent on the operator. Also, the technique can not be applied to minerals mixtures in motion.

Analysis of the spectra, originating from light reflected from mineral mixtures, showed that the spectra change in sympathy with changes in composition. In a structured research program, Blue Cube Systems, a South African technology company, applied this knowledge to develop and scale up presentation techniques of the minerals to the optical scanner. Transformation techniques were developed to convert the spectrum data to a quantified output, reporting the mineral composition of the sample. Each application is therefore case specific for a specific situation. The data transformation parameters are set to present the particular spectra, captured from the specific minerals occurring in that mineral stream, in a mineral composition table. Calibration is best effected by the combined effort of the plant metallurgist, defining the mineral species, the grain counter, establishing the composition, and the software expert, using the information to define the transformation parameters.
The segregation of particles in any mineral stream, wet or dry, is always a potential problem area and must be kept in mind when designing scan heads. Presentation techniques have been developed to overcome this.
Working on reflected light, the scanner can only detect the light reflected from the surfaces presented to it. For streams of moving minerals, wet or dry, representative sampling is not difficult to achieve. However as soon as the material is dumped on a heap or settled in a tank, segregation will occur. Like in any sampling application, the selection of suitable sampling positions and methods therefore remain important.

In-line analysers (the preferred term) must often be mounted in difficult places and may be exposed to harsh conditions. The product was therefore developed in a few discrete modules to be adaptable to different conditions and arrangements.

The optical scanner head is tailored for each application.

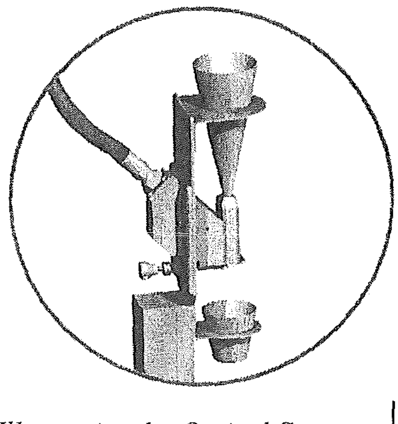

Illustration 1: Optical Scanner

There is a mineral flow channel where a dry, free-flowing mineral stream or slurry can pass through in front of an observation window. See Illustration 1. The sample is illuminated through the window and the reflected light is captured and transferred by optical fibre to an optical processor. See Illustration 2.

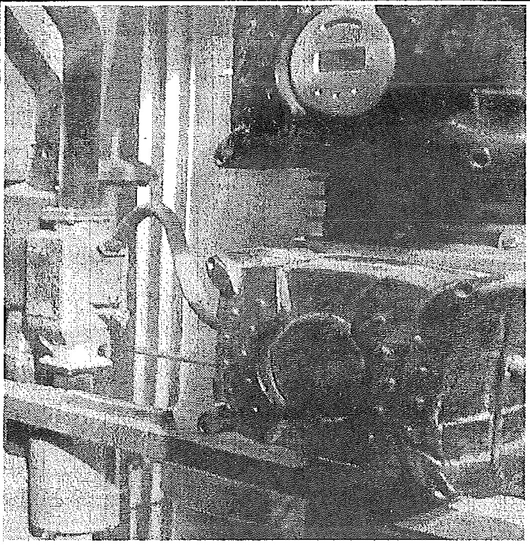

Illustration 2: The MQi installed in a harsh plant environment. Scanner head at left, Optical Processor at bottom right and Data Processor at top right

The optical processor dissects the captured light into its wavelengths, then converts the optical data to a digitised data set and transmits it to a data processor. This happens repetitively at intervals of typically 20 ms. The optical processor must be in the close vicinity (up to 2 meters) from the optical scanner. The optical processor is packaged in a robust housing, hermetically sealed, and suitable for the conditions found inside a MSP. At set intervals, typically 1 minute, the data processor integrates all the data received from the optical processor and applies the data transformation functions. The results are displayed on a local panel as mineral composition, expressed as percentages and also relayed to an interface box for transmission to the plant SCADA. Illustration 3 shows a typical example where short term trends as well as longer term trends are clearly demonstrated. The data processor and interface box are connected to the optical processor by cable and can be positioned at convenient positions.

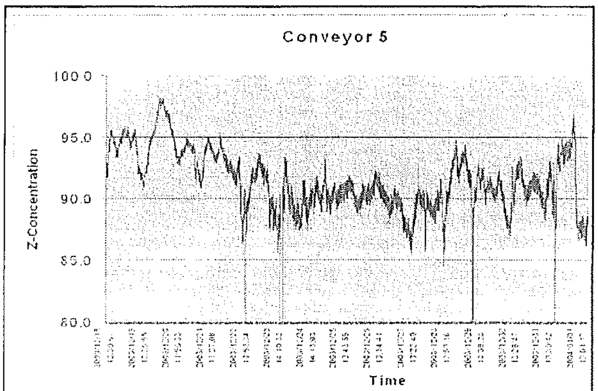

Illustration 3: Typical SCADA display captured from a MQi installation

4. Track Record

Blue Cube units have already found applications in a variety of applications.

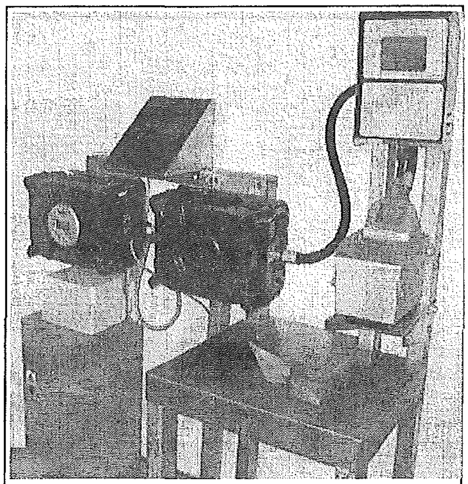

Illustration 4: MQi Spot Universal - Suitable for dry or filter cake samples. Turntable scanner on right and interface box on lower left

The first production model went into use on a heavy minerals MSP on the West coast. It was associated with a Roll Electrostatic Separator. It has since been joined by 5 further in-line units and two in-plant spot units. The spot analysers utilise the same technology as the In-line units but with a differently configured scanner head, allowing off-line samples to be scanned and sampled. The Spot analyser can be loaded with multiple calibration sets.

A spot unit is in operation in a North West Province Platinum plant analysing furnace slag, in association with wet magnetic separators.

A Spot unit is in operation at a base mineral mine in Limpopo analysing flotation feed to effect pro-active process control.

In an Australian heavy minerals MSP, two in-line units are in operation in association with electrostatic roll separators. The outputs are presently being linked to the control circuits of the separators to facilitate automatic control of grade.

5. Calibration

Calibration is effected by the scanning of mineral mixtures of known composition. The optical data is married with the composition data and the relationships are used to define the conversion parameters. Depending on the complexity of the mineral mixture and the variation thereof, the number of calibration samples may vary from 10 to more than 100 to achieve a good calibration.

The best calibrations are achieved by a team effort. The plant metallurgist or geologist will define the minerals present. The grain counter will determine the mineral compositions and the software expert will define the transformation strategy and parameters.

Every Blue Cube unit in the field is linked to the Blue Cube facilities by a GPRS (Cell phone data transmission) link. This enables fast data download, remote calibration, and upload of new calibration files. Remote supervision of field units and program updates can be effected in a fast and cost effective way.

6. Conclusion

The real time in-line determination of mineral composition is a reality. The linking of the analytical output to the control circuits of certain separation equipment can already achieve automatic control of such equipment.
The benefits are evident:

- Rapid stabilisation of plant after start-up.
- Optimised settings of separation equipment.
- Consistent and stable product grade.
- Improved recovery.
- Motivated operational staff.
- Improved financial results.

Much has been done!