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# IRON CONCENTRATOR ON-LINE ANALYZER APPLICATIONS[1]

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**Abstract**

High quality iron concentrates are produced from variable iron ore minerals using physical and magnetic separation as well as flotation. There is a significant amount of assaying required for monitoring and controlling such operations. Traditional laboratory and in some cases robot laboratories have been used to analyze samples from the process. On-line particle size analysis is rather common analysis today at medium to large size concentrators. On-line XRF elemental analysis, which is routine practice in base metal concentrators today, is not commonly used in iron concentrators. The limitations in the direct measurement of silica and other light elements have restricted its use. Some light element analyzers have been developed based on prompt gamma neutron activation (PGNAA) method but they have not performed up to the expectations. Some other methods have been tried but none of them has been used beyond some prototype installations. Operating slurry on-line light element slurry analyzer installations are very rare in iron applications. There is an economic incentive to mine lower and variable grade iron ore resources, which require concentration and removal of several impurities to produce high quality concentrates for pellet production. Monitoring such operations by on-stream analysis has significant economic benefits and there is a need to develop a practical slurry on-line analyzer for Si, Al, Mg and other light elements.

**Key words:** On-line analysis; Particle size analysis; Elemental analysis; Concentrator process control.

## APLICAÇÕES DO ANALISADOR ONLINE EM CONCENTRADOS DE FERRO

**Resumo**

Os concentrados de ferro de alta qualidade são produzidos a partir de minerais de minério de ferro variáveis, por meio de separação física e magnética ou flotação. Um número significativo de análises se faz necessário para monitorar e controlar tais operações. Laboratórios tradicionais e, em alguns casos, laboratórios robô, têm sido utilizados para analisar amostras do processo. Hoje em dia, a análise online do tamanho das partículas é bastante comum em concentradores médios a grandes. A análise on-line XRF dos elementos, que atualmente é prática rotineira em concentradores de metal base, é pouco utilizada em concentradores de ferro. As limitações na medição direta de sílica e de outros elementos leves têm restringido seu uso. Alguns analisadores de elemento leve foram desenvolvidos com base no método PGNAA - P*rompt Gamma Neutron Activation*, mas eles não têm correspondido às expectativas. Outros métodos foram testados, mas nenhum deles foi além de algumas instalações de protótipo. Instalações de analisador online de polpa de elementos leves em operação são muito raras em aplicações de ferro. A mineração de recursos de minério de ferro de menor teor e variável, que requerem a concentração e remoção de diversas impurezas a fim de produzir concentrados de alta qualidade para produção de pelotas, tem sido economicamente incentivada. O monitoramento de tais operações através da análise durante a operação traz benefícios econômicos significativos, havendo necessidade de se desenvolver um analisador online de polpa para Si, Al, Mg e outros elementos leves.

**Palavras-chave:** Análise online; Análise de tamanho de partículas; Análise dos elementos; Controle de processo do concentrador.

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## 1 ON-LINE VS. LABORATORY ANALYSIS

The performance of iron ore beneficiation processes, like any separation processes, is measured by the elemental concentrations and flows of the main process streams.
Carefully collected and prepared samples analyzed in laboratory are the reference for process monitoring, control, optimization and material balancing. The relatively high cost per assay and manpower requirements limit the frequency of such assaying to bare necessity. Shift composite sample assays describe the past behavior of the plant with some time delay but are not good for reacting to changes in the feed, alarming for equipment failures and process optimization.
An on-line analyzer offers the following advantages:

- cost of each assay is radically cheaper than in laboratory, due to automated operation and straightforward sample handling;
- automatic sampling (and sample preparation in some cases) is repeatable and less subject to human individual practices, errors and variances;
- frequent assaying reveals fast changes and variability in the process operation, giving plenty of data for process analysis, fine tuning and optimization;
- delay from sample extraction to assay available for operators and control systems is only some minutes, whereas for laboratory it can be many hours. This enables fast feedback actions by operators and closed loop control.

Laboratory automation and robot laboratories have reduced the cost of assaying and reduced assaying time delays but they are still far from on-line analyzers. Laboratory elemental analyzers are capable to measure a wide range of elements and low concentrations for quality control and mass balancing. Due to limitations in taking and measuring coarse samples and lower analytical sensitivity, these tasks are not usually carried out by on-line analyzers. The main role for on-line analysis is to produce frequent assays for process control.

## 2 ON-LINE PARTICLE SIZE ANALYSIS

A concentrator plant for high grade iron ore pellet material has typically a primary/secondary grinding circuit followed by reverse flotation and/or magnetic separation to remove gangue minerals and impurities. In many cases the concentrate is re-ground and possibly upgraded again before thickening and filtering for pelletizing (Figure 1).

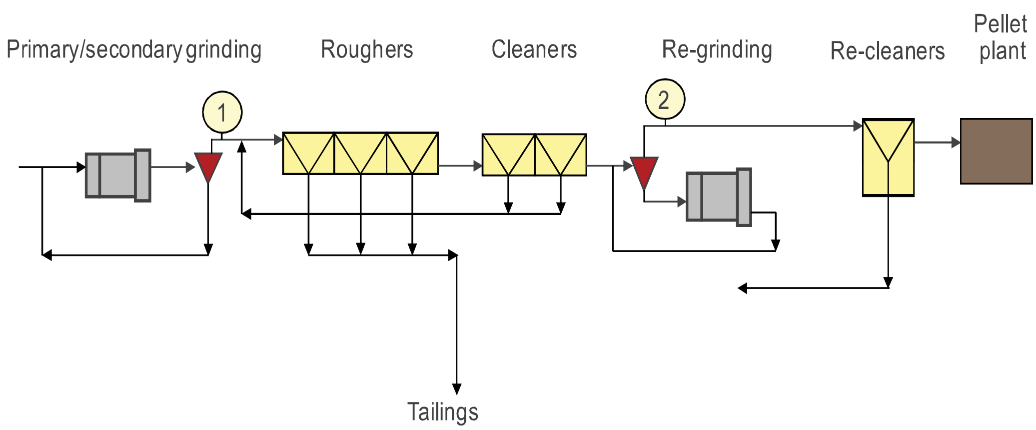

**Figure 1.** Particle size sampling points.

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## 2.1 Primary/Secondary Grinding

Particle size analysis after primary/secondary grinding is used to monitor and control particle size at secondary mill cyclone overflow. Variations in ore hardness change the particle size distribution and influence the liberation of minerals and the production of fines. Flotation reagent feed requirement is changed by varying particle size as the surface area of particle in slurry changes. Usually the average t/h feed to the grinding circuit can be increased by on-line particle size measurement and control by 5% to 10%. This has a positive effect on the cash flow of the operation. The most important particle size measure at this stage is D80, in some cases fines measurement is necessary for slimes control.

## 2.2 Regrinding

The particle size distribution of the regrinding product has a significant influence on the quality of the final product. Here the full size distribution analysis is required. On-line measurement of the specific surface area is also necessary for stable moisture control before pelletizing and pellet quality control (Figure 2).

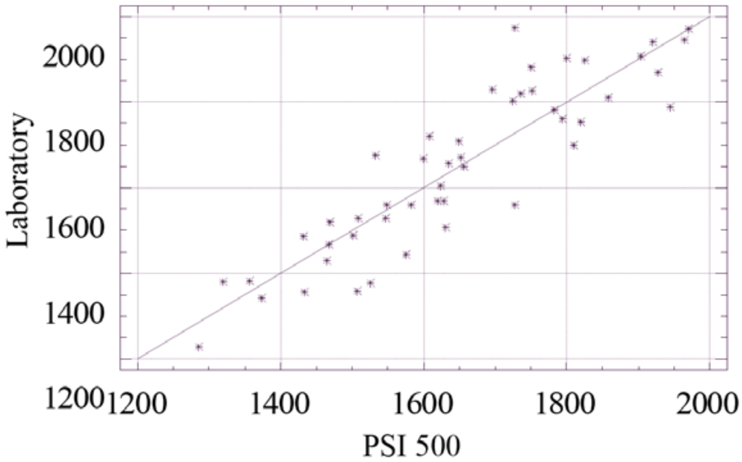


**Figure 2.** Comparison of on-line specific surface area measurement with manual laboratory measurement, unit cm2/g. Laboratory measurement repeatability is about 100 cm2/g.[1]

Magnetite concentrate particles form agglomerates, which bias the on-line measurement results to coarse side. With a typical concentrate for Fe pellet production the effect on –44 µm fraction can be as large as 5% to 10% relative as compared with carefully made laboratory measurements. This effect can be eliminated by demagnetizing the sample and subjecting it to ultrasound dispersion as shown in Figure 3.

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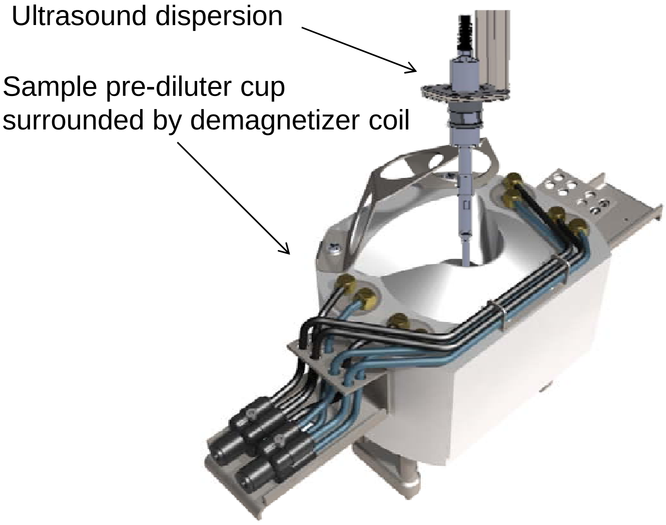


**Figure 3.** Magnetite mineral sample de-magnetizer unit for a laser scatter particle size analyzer.


**Figure 4.** Laser scatter on-line particle size analyzer for monitoring hematite concentrate particle size and surface area.[(2)]

## 3 ON-LINE FE ANALYSIS

Iron content in slurry can be measured with good accuracy directly from slurry by an on-line XRF analyzer around the process. Absolute error of 0.5% in Fe content has been achieved in some installations (Figure 8). The on-line measured Fe concentration has good correlation ($R^2$ > 0.9) with $SiO_2$ content above 3% to 5% concentrations. This has been found to be good enough for process control purposes (Figure 7). Mineralogy at a particular site has an effect on the achievable accuracy.
Typical sampling points are shown in Figure 5.

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### 3.1 Feed

Fe/silica content in the feed can be used for feed-forward control of silica removal by flotation. The disturbance caused by ore variability has to be reduced at later processing steps.

### 3.2 Rougher Concentrate

Rougher concentrate silica content can be measured indirectly by Fe measurement. Rougher area control has the most significant role of reducing the assay variability resulting from ore changes.

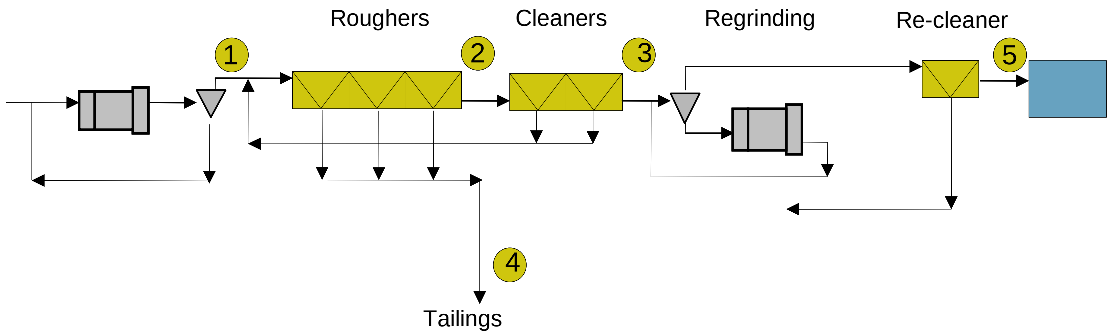

**Figure 5.** Typical iron reverse flotation assay sampling points.

### 3.3 Primary Cleaner Concentrate

Cleaner concentrate silica content can be measured indirectly by Fe measurement. The primary cleaner tailings can also be measured to assess the circulating load in the cleaner circuit.

### 3.4Tailings

Fe assay is used to maximize recovery without sacrificing product quality. With today's Fe concentrate prices and lower ore grades, recovery has a significant effect on cash flows.

### 3.5 Final Concentrate

For 1% to 2% silica content, accurate indirect measurement of gangue minerals is not possible based on Fe measurement. From process control point of view the primary cleaner concentrate grade has significant effect on the final concentrate grade.
Very similar sampling points can be used for magnetic separation circuits (Figure 6).

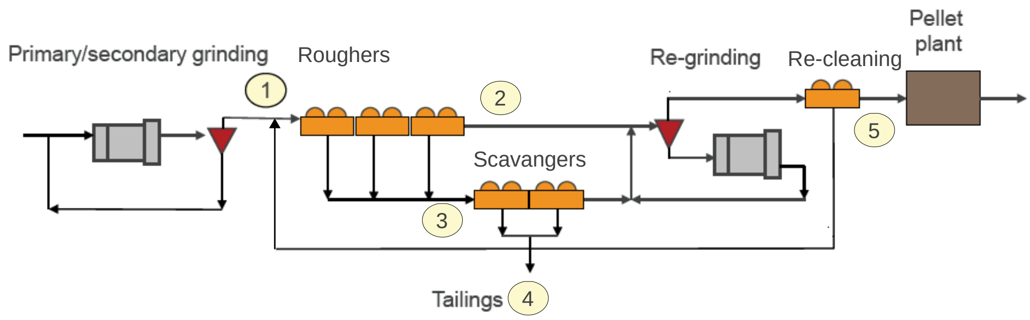


**Figure 6.** Typical sampling points in magnetic separation circuit.

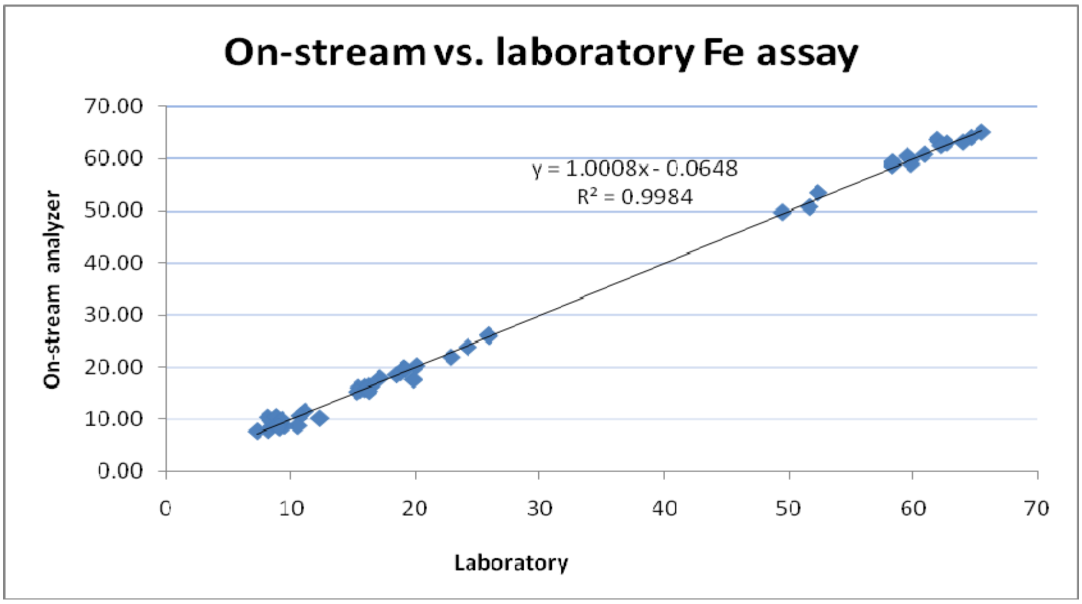


**Figure 7.**Correlation between on-stream XRF analyzer and laboratory iron measurements at a hematite concentrator tailings and concentrate samples, out of 50 samples 3 outliers were rejected.

## 4 ON-LINE LIGHT ELEMENT ANALYSIS

As described above, XRF can in specific cases provide information of the light element content of the intermediate products by indirect analysis. However, where the correlation of the element of interest with iron is poor, such kind of inference does not produce the required accuracy. For example the composition of gangue minerals may be necessary information for process operators. Technologies for direct online analysis of light elements exist, however, the application has been limited due to the challenging slurry sample matrix.

### 4.1 Prompt Gamma Neutron Activation Analysis (PGNAA)

PGNAA has been known as an analytical technique for decades, and it has had a number of successes mostly in bulk material analysis. The limiting factor of the measurement

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precision is in most cases the low frequency of the prompt gamma events, resulting in statistical variance of the measured gamma-ray intensity that can be smoothed out only by very long measurement times. In the literature minimum detection limits of 0.3% to 0.5% $SiO_2$ have been quoted for bulk solids with 10 min analysis time.In slurries an additional dilution factor, increasing the MDL needs to be taken into account. In iron ore slurry applications, another challenge arises from the fact that the analysis requires a large amount of sample solids in the sensitive volume that needs to be maintained as a representative suspension.

### 4.2 Laser Induced Breakdown Spectroscopy (LIBS)

LIBS has been under intensive research in the past decade, including a few online analysis applications. The advantage is that virtually all elements of the periodic table can be measured, and there is a good response to Fe and Si, for instance. The challenges of the technique lie in the fact that the analysis is done only in a minute amount of material on the surface, and representativeness on the very surface of the slurry in the sample representation system is critical. The statistical variation is compensated by the high repetition rate (up to 10 pulses/s) of the analysis.
In the reported online iron ore slurry application, a precision of +/-0.15% has been reached in pelletizing feed slurry SiO2 analysis.(3)

## 5 MINERAL PROCESSING PLANT CONTROL

Base level controls are essential in complementing on-line analyzers for supervisory process control.
One such tool for flotation control is a froth camera system to measure several properties of froth including froth speed, bubble size, froth stability and froth color. Also statistical data related to these variables is important. The measured froth properties, together with on-stream analyzer assays, enable expert control of the flotation circuit.

- 1 Roughers – Controlling the froth speed in consecutive rougher cells helps to balance load between the cells, which improves the overall efficiency of the operation. Froth speed control also helps to avoid pulling individual cells too hard, which would cause loss of recovery;
- 2 Cleaners – Controlling froth pull in the cleaners helps to keep circulating load under control;
- Re-cleaners – Re-cleaner operation is monitored by froth speed measurement.

## 6 PROCESS OPERATORS, THE ESSENTIAL LINK

Shift to operate a plant from infrequent laboratory assays to frequent on-line assays requires operators to understand the new possibilities with hands-on process control. This is a new situation, which is not automatically adopted by the process operators.
An efficient way to teach the operators how to operate the plant with continuous information is to use a process simulator. The simulator excercises train the operators to various options to control the process, reactions to distubances and solving unexpected problems with process equipment. Through a simulator based course it is possible to check what the operators have learned and in which issues they need more training.

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**Figure 8**. Trained process operators are key elements in process management and control.

## 7 CONCLUSION REMARKS

While the ore grade in available iron ore resources is going down and variability increases, demand for low silica concentrates is increasing. Optimizing recovery and maintaining concentrate quality within specifications at the same time requires real-time information. Concentrator automation based on on-line measurement of particle size and composition helps to maximize the economic recovery.
Successful implementation of automation is a combination of analyzer and automation equipment, process knowledge, training operators to adopt new practices and maintenance services to guarantee good availability of the system. Rewards can be significant with many percent points increase in recovery and plant capacity.

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