OPTIMUM UTILISATION OF ENERGY RESOURCES AND REDUCING CO_2 FOOTPRINT USING ON-LINE ANALYSER IN ALUMINIUM PRODUCTION PROCESS

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ABSTRACT

Production of aluminium is highly energy-intensive and classified as a significant CO_2 emitting process. Although the industry has taken many steps globally, it remains necessary to work rigorously to minimise emissions levels. To help address this, an on-line analyser can be used to monitor the desired concentration of element and phases such as fluorite, cryolite and chiolite during raw material handling, conditioning, and melting.

Australian company FCT ACTech has more than 25 years of experience in the field and has developed a number of solution-based models equipped with integrated XRD or XRF, or with combined XRD-XRF instrumentation. These models are collectively referred to as the 'X-Series', and all models within the range can be installed on-line in the manufacturing stream. Some of the major benefits of installing an X-Series on-line analyser are outlined in the following sections.

Data Availability & Reliability
The analysers provide accurate elemental data and phase identification critical for calculation of properties important for pot flux analysis, including Al, Si, Fe, Ca, S, Mg, P, K and more, due to the customisable nature of the calibration.

All analysers within the X-Series range feature a large and highly representative sample intake. The results are less variable than other off-line methods and are updated every 5-7 minutes with minimum standard deviation. The analysers feature fixed detectors for outstanding reliability and robustness, and are designed for continuous operation with up to 20 complete data points per hour.

Easy Operation
- The analysers offer ultra-fast batch or continuous operation, including full integration and automation.
- Turntable sample presentation is facilitated by continuous sample preparation robotics.
- The small footprint allows for easy installation close to the sample point for increased efficiency and consistency, since it means samples can be analysed on-line.
- The models can be highly customized according to the requirement of the specific need.
- The products can be installed at any point in the aluminium production stream starting from the raw material feed for monitoring of consistent aluminium purity.

New Opportunities
The latest analytical methodology will contribute to quality control and process improvements, as well as presenting new possibilities to utilize by-products for other industries, striving towards circular economy.

Keywords: Online analysis, XRD, XRF, Cost-effective, Plant Performance

1.0 INTRODUCTION

It is widely accepted that any plant performance, whether it is an aluminium production plant or any other production plant, can be optimized and/or increased by monitoring the quality of various processes product starting from the raw materials feed, to the intermediate product, to the final product.

In the case of aluminium production, there are several steps to get the final product. The process can be briefly described as follows.

- Mining: Bauxite is mined from the earth and is usually found near the surface in tropical and subtropical regions.
- Refining: The bauxite ore is refined to produce aluminium oxide, which is then converted to aluminium in a reduction process.
- Reduction: The aluminium oxide is reduced to aluminium in a process called electrolysis. This is done by passing an electric current through a solution of aluminium oxide dissolved in molten cryolite. The oxygen atoms in the aluminium oxide are attracted to the cathode (negative electrode), while the aluminium atoms are attracted to the anode (positive electrode). At the cathode, the oxygen atoms combine to form oxygen gas, while at the anode, the aluminium atoms are released and collect at the bottom of the electrolysis cell.
- Purification: The aluminium produced in the electrolysis cell is impure and must be purified to produce high-quality aluminium. This is done through a process called casting, where the aluminium is melted and cast into ingots or other desired shapes.
- Fabrication: The purified aluminium is then processed into various products through processes such as rolling, extrusion, and casting.

The related equations are:

Bauxite + Electricity → Aluminium + Oxygen (1)

The refining of bauxite to produce aluminium oxide (alumina) is done through the Bayer process, which involves the following reaction:

$Al_2O_3 + 2NaOH + 2H_2O \rightarrow 2NaAlO_2 + 3H_2$ (2)

The reduction of aluminium oxide to aluminium is done through electrolysis, which involves the following reaction:

$Al_2O_3 + 3C \rightarrow 2Al + 3CO_2$ (3)

Overall, the production of aluminium from bauxite involves several thermodynamically favourable reactions, but the process requires significant energy input and has a relatively low energy efficiency. Additionally, as suggested in equation-3 the process also involves in generation of sizable amount CO_2.

Issues such as significant energy consumption and generation of high amounts of CO_2 are process dependent, and vary from plant to plant. Optimisation of the process can help to alleviate these issues, hence it is necessary to monitor quality throughout the process from raw material feeding to the final product.

By monitoring the compositional and/or elemental analysis on-line, we can ensure adjustments can be made immediately, thereby reducing variability. This methodology allows operators to know and understand the properties of the materials at various points in the process.

On-line analysers can measure the elemental (X-ray fluorescence) and/or mineral (X-ray diffraction) composition of the raw materials, pot-flux and the red mud. These installations enable processes to run with minimum deviations from the target set point, resulting in a more sustainable, stable, and efficient process with reduced energy consumption at the

kiln. The models also allow for more control of what amount of NaOH can be mixed, as well as the composition of red mud.

The individual analytical modules are placed close to the material streams. Very little maintenance is required because the complete process is fully automated. The generated analytical data can be directly transmitted to state-of-the art quality and process control software to realize the biggest advantages. The analysers can be integrated into existing automated sampling solutions and the applications can easily be adapted for future requirements. The in-depth knowledge of the material stream characteristics invites the opportunity to develop the production process towards a circular economy, where by-products of other industrial process can be utilised.

2.0 APPLICATIONS

The four most important process steps for on-line material characterization are:

2.1 Raw Material Preparation

The quality of raw material has steadily been declining in recent years, which has led the utilisation of low-grade raw material with increased proportion of impurities. To achieve consistent and targeted composition of the raw material, the elemental concentration needs to be monitored. This is the first step for efficient production and constant product quality. The complete automation of the process, from sampling to the raw material control, safeguards the expected performance improvements resulting from more stable plant operation.

2.2 Analysis of Red Mud

Due to increased utilisation of low-grade bauxite, there is a possibility of increased of red mud proportion. There is also a possibility that some proportion of aluminium may go into the red mud due to the complex mineralogy of the raw material. As such, it is necessary to monitor the red mud composition to understand the gravity of waste material for further extraction of aluminium from the red mud.

2.3 Pot Flux Analysis

During pot flux analysis, samples of the aluminium bath are taken and analysed to determine the effectiveness of the fluxing agent and identify any issues or inefficiencies in the production process. The analysis mainly includes measuring the levels of various impurities such as aluminium oxide, silicon, and iron, as well as the composition of the bath, and monitoring the temperature.

Pot flux analysis is an important tool for monitoring the aluminium production process and ensuring the produced aluminium meets the required quality standards. It can also reduce the production costs by identifying and correcting any inefficiencies in the process. An on-line pot flux analyser with combined XRD/XRF system has the ability to determine the fluorite, cryolite and chiolite concentrations simultaneously, together with the full elemental composition, to achieve the best flux ratio.

2.4 Final Aluminium Quality

The final sampling position is located after the smelter to optimize the aluminium quality. Located adjacent to the smelter point, a double XRD and XRF on-line analyser can be used for process optimisation and quality control purposes. The simultaneous measurement of

the responsible phases and aluminium purity offers the manufacturer the ability to produce high quality aluminium, increase plant output, and decrease CO_2 emissions.

3.0 System Description

The described on-line analyser is a combined XRD and XRF model, which is available as part of the X-Series range. However, some other models in the range comprise only XRD or XRF. Across the range, the advantages of the systems are:

- Fast analysis with a large data set.
- Rapid switching between products and production closer to the target specification.
- A consequent decrease in standard deviation .
- Adjustable weight feeders deliver the required mix blending.
- Improved quality control and consistency.
- Reduced frequency needed for laboratory testing and sample preparation.
- Reduced fuel and energy consumption costs.
- Ability to reduce CO_2 emissions.

Table 1 outlines the different models offered for online analysis in the X-Series range.

Table-1 Different models offered from FCT ACTech

FCT Models	Analysis System		Analysis
	XRD	HRTC XRF*	
FLX	ü		Single phase
FLX+	ü		Extended phase
OFX	ü	ü	Elemental Analysis (Ca, Si, Al, Fe, S, Mg and more), single phase
OFX+	ü	ü	Elemental Analysis (Ca, Si, Al, Fe, S, Mg and more), extended phase
RMX		ü	Elemental Analysis
CMX	ü	ü	Mineral Analysis (Specific or open)

The above models can be fitted at various points of the plant stream according to the requirements of the individual plant. The models can analyse and provide accurate elemental data and phase identification critical for the calculation of properties important for pot flux analysis.

Since the sampling interval is small, a large number of data can be generated and directly connected with the plant PLC if desired, which can help the operator to monitor and accordingly adjust to the plant operating parameter almost immediately. In contrast, off-line analysis does not offer such advantages.

Due to the large data set presentation, it is possible to utilise this information for further predictive analysis.

The latest analytical methodology exemplified by the X-Series range will contribute to quality control and process improvements. The range offers new possibilities to utilise by-

products for other industries, striving towards a circular economy. Figure 1 (schematic) shows the locations in which the different models can be installed within the plant.

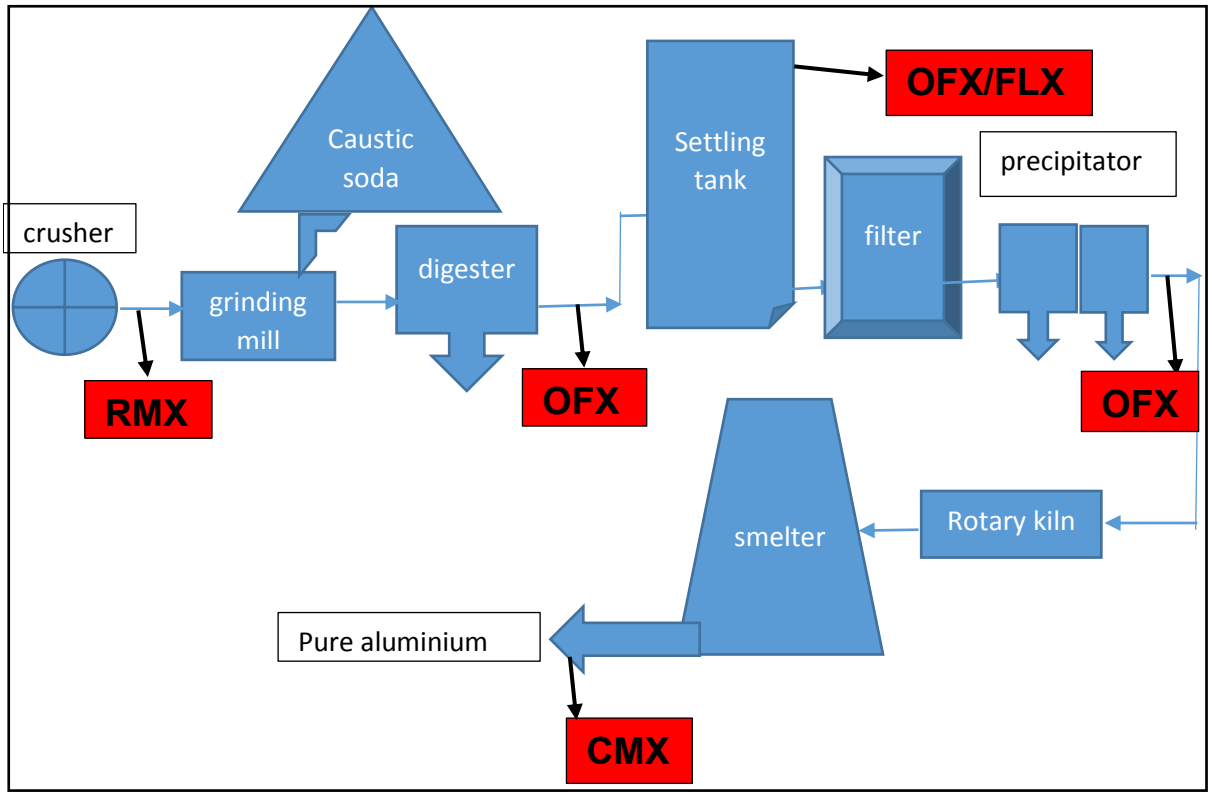

Figure-1: A proposed schematic diagram to place different models across plant stream

4.0 DISCUSSION

The X-Series range presents a variety of benefits to manufacturers in the aluminium industry. The use of an on-line XRD-XRF analyser in combination with the potflux application offers the ability to control and adjust material composition and minimise fluctuations, resulting in the following benefits:

- Frequent monitoring of phase composition in the Electrolyte bath helps to avoid solidification.
- The impurity level is controlled, and this increases Al recovery.
- The monitoring of the bath properties helps to minimise energy consumption.
- Consistent composition and quality are ensured.
- Optimal flux ratio can be achieved.
- Electrolyte consumption is minimised, and this in turn lowers CO_2 emission levels.

The quick and reliable analysis made available by the X-Series range leads to increased production and efficiency for aluminium manufacturers. The immediacy of the on-line method of analysis also offers savings in both time and cost when compared to off-line laboratory analysis. The X-Series range is designed to help manufacturers achieve the highest purity aluminium by taking advantage of the benefits as discussed.

4.0 KEY TAKE-AWAY POINTS

- FCT ACTech has developed the X-Series range of on-line analysers, which are customisable to suit the needs of manufacturers in the aluminium industry.
- The analysers are available as a combined XRD-XRF model, or as an XRD-only, or XRF-only model.
- The combined XRD-XRF on-line analyser with pot flux analysis will increase the efficiency of plant performance.
- The frequency of on-line monitoring allows for immediate adjustments to the material and assists in reducing CO_2 emissions levels.
- The resulting increase in consistency means that quality and production output are improved, and that the plant is operating more efficiently and saving energy, thereby reducing associated costs.
- Compared to off-line methods of analysis such as laboratory testing, the on-line method offered by the X-Series is cheaper and less time consuming.