Impact of remote monitoring, calibration, and maintenance of on-stream analyzer in the ore flotation process

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ABSTRACT

Courier® on-stream analyzers are very well-known equipment for mineral concentrator plants. It uses X-ray fluorescence spectroscopy (XRF) or Laser-induced breakdown spectroscopy (LIBS) technique to determine the elemental grade in a slurry on flotation process (SL model) or in hydrometallurgical process of extraction (HX model). XRF analyzers work by measuring an emitted photon with a specific energy/wavelength from a sample when it is excited by a primary X-ray source. LIBS analyzers are based on generating plasma in the slurry sample by a high-energy laser and analysis of the plasma by optical emission spectroscopy. However, measuring the grade using an online analyzer requires not only a single calibration and maintenance of the equipment as accurate real-time elemental analysis is the foremost online measurement to enhance resolutions that improve efficient flotation circuit control to achieve optimal metal recovery, presented in this publication. The remote monitoring and the active calibration services are presented too as a complement to improve the entire process. The superior utilization and the accuracy of the measuring lead to the application of these analyzers to an upper control level. Courier® analyzers data can feed any Advanced Process Control (APC) as a key variable monitored which contributes to stabilizing and optimizing the performance of the ore flotation process in terms of metallurgical recovery.

INTRODUCTION

The first commercial systems of Courier®, manufactured by Outokumpu Oy, Finland, were installed in 1967 (Kawatra and Cooper, 1986). Since 90's decade, there are two commercially available on-stream analyzers, centralized and distributed systems. In a centralized XFR system, samples of several slurry streams are transported to a common sensing unit. Such installations are generally of the wavelength-dispersive type (WDX), as this configuration allows the relatively costly and bulky equipment required for WDX analysis to be shared among several streams. This system is particularly suited for large plants where more than five or six slurry streams are to be analyzed. Based on the Courier® model, it is capable of processing up to 12 or 24 streams. Experiences gained during the last decades about automatic sampling and analysis of mineral slurries were utilized to develop an on-line analyzer that was capable of measuring elements which are essential to phosphate processing (e.g., P, Ca, Mg, Fe, Al, and Si) by LIBS principle (Köresaar et al., 2015).

On-line measuring of the grades in each step of the ore flotation process is useful not only for the operator who controls the entire process result. In an upper level on the control hierarchy, the grade in each step is a crucial feedback variable for an Optimizing Control (OC) or an Advanced Process Control (APC). This has been widely studied for copper (Rantala et al., 2014), gold (Koskinen et al., 2019) and iron ores(Köresaar et al., 2015), just to name a few examples.

This publication demonstrates the benefits of remote monitoring, calibration, and maintenance of on-stream analyzers in the ore flotation process, especially when falling grades and rising operating costs force companies to maximize equipment utilization.

METHODOLOGY

Overview of Remote Monitoring

The Metso Outotec Performance center is a 24/7 monitoring center. The center is based on a technological infrastructure with a high degree of reliability and speed of connectivity with customer sites and is designed to bring together specialists in the areas of maintenance and processes that, assisted by a monitoring dashboard platform, enables anticipation of the on-line stream failures and problems. The proposed service is designed to be remotely supported by a specialist in Courier analyzers using state-of-the-art technology of assisted reality lenses and monitoring of critical signs of the health of the equipment that will allow generating preventive alerts against deviation of the control ranges. The implementation requirements are:

a) Augmented Reality (AR) glasses, which combines computer-generated digital elements and the physical world.

b) Application software for connection.

c) Wi-Fi connection for AR glasses.

The AR system has many advantages and allows you to:

a) See the image of the client in real-time

b) Receive videos or images sent by the user, analyze them, and send instructions

c) Select area, edit, draw, write notes and send them back, to the user's view on the site

d) Send documents and images to the user (plans, procedures, etc.)

e) Guide the user with a red dot controlled by the specialist

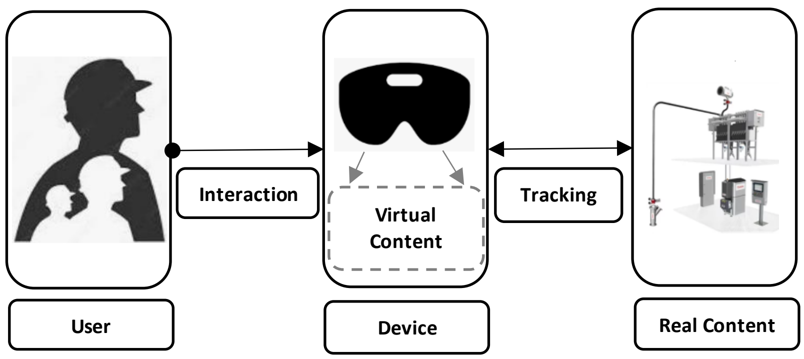

Figure 1 AR system applied to the on-line analyzer

Overview of Calibration

Remote calibration service is based on two main actions: daily monitoring of curve behavior and calibration protocol application. Figure 2 shows some examples of daily monitoring of curve behavior of a final concentrate in terms of Cu, Fe and Mo grades vs chemical analysis.

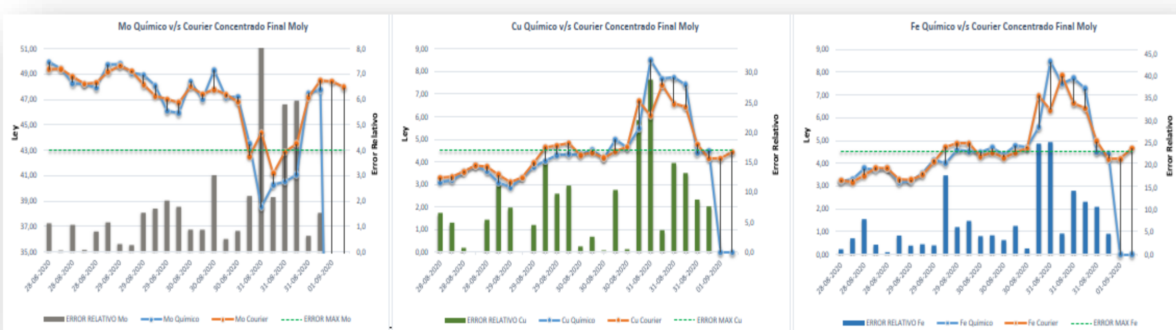

Figure 2 Cu, Fe and Mo grades vs chemical analysis

On the other hand, calibration protocol application comprises two main activities: the generation of new models and the uploading of new models with prior authorization from the end user. In that case, a new model creation is triggered by the deviations from the grades obtained from the on-stream analyzer vs. chemical assays in a block number higher than the allowed. Modelling is done with average shift data and specific survey campaigns. The two main steps previously described to carry out the calibration are complemented by the monitoring of these models and the calibration report.

Overview of Maintenance

Maintenance service includes inspection and maintenance of the following components:

a) Analyzer alarms and statuses

b) Availability of analyzer probe, X-ray tube, multiplexer units and sample lines

c) Utilization of sample system

d) Reliability of assay results vs primary samplers

e) Other internal control measurements

Service Level 1 promotes proactive maintenance and enables fast remote support in case of issues. These actions include:

a) Real-time visibility to the analyzer through online dashboards

b) Automatic alarms and notifications to the customer

c) Remote connection enables fast troubleshooting in case of sample line blockages, software malfunctions, or deviations in measurements.

On the other hand, Service Level 2 ensure the continuous improvement of our customer´s process. For this, the following predictive recommendations are considered:

a) Access to advanced analytics and world-class support, based on a joint target of continuously improving our customer’s processes. Periodic expert reviews to present calibration assessments, analyses of availability, alarms, trends, and process deviations.

b) Improved accuracy: Ensuring the customer gets realistic values from the process which enables improvements in process control and recovery optimization.

c) Increased reliability: Avoid unplanned analyzer downtime through proactive remote monitoring, alarms, and expert recommendations. Remote troubleshooting is available in case of potential failures.

Figure 3 shows the concepts of remote monitoring, calibration, and maintenance through the Metso Outotec schematic of End-to-End remote support capabilities.

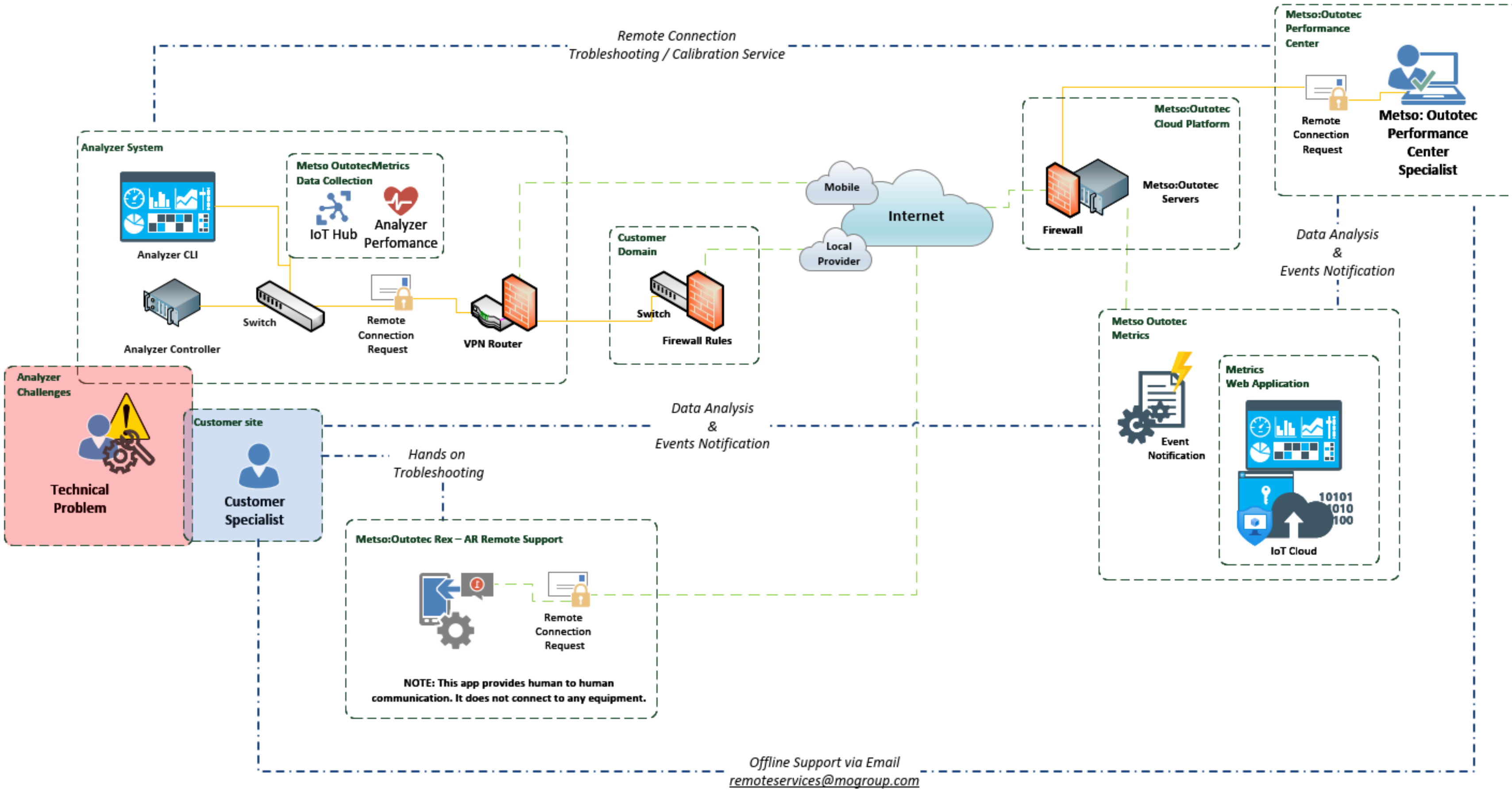

Figure 3 Metso Outotec End-to-End remote support capabilities

Additionally, Figure 3 shows, how the commitment on experienced professionals when a problem cannot be solved remotely is essential. For this, there are technology specific specialists who are capable to review the status of equipment in the field and maintenance to then build up a detailed report. Where there is no direct remote connection to the analyzer, it could be made by phone, video call or any means that helps with the general on-site troubleshooting and problem-solving.

CASE STUDY

Chemical assays and the Metso Outotec Courier® analyzer measurements of site A were used for recovery analysis. At this copper concentrator exists a full-service of monitoring, calibration, and maintenance of a Courier® 5i SL. The plant operates at full capacity, processing around 4440 tph in a circuit of rougher, cleaner and scavenger, as shown in Figure 4.

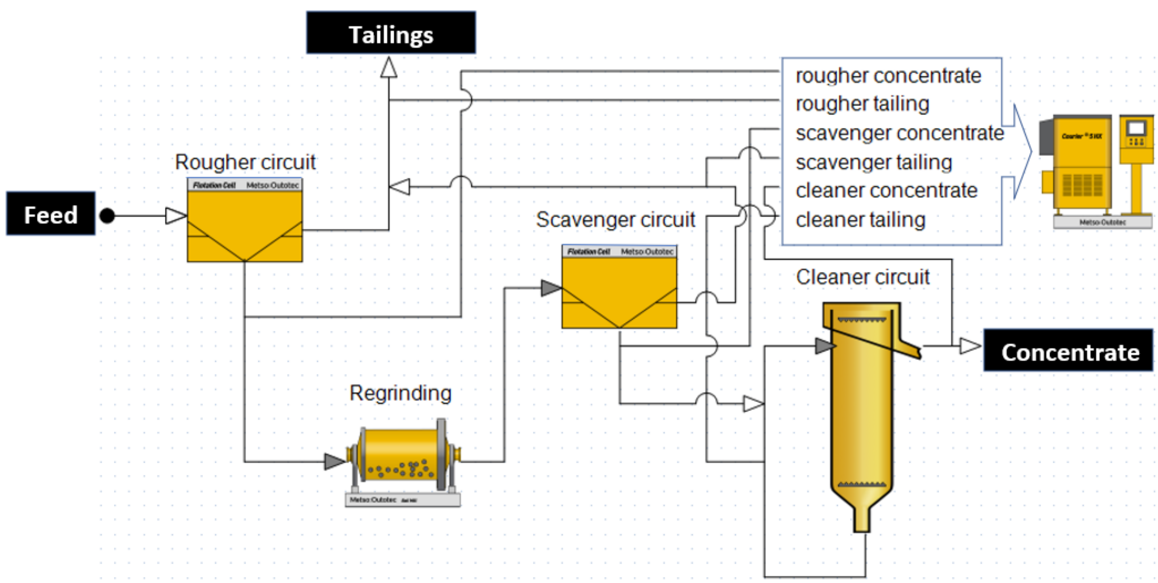

Figure 4 Three steps flotation circuit considered for the recovery analysis

Figure 5 shows the Cu rougher tail grade (%) in time. The continuous line represents the chemical assays composite which in this case, are carried out every 6 hours on behalf of the customer. The points on the graph represent the Cu grade(%) measurements recorded by the Courier® analyzer.

Before the 00:00 h —displayed as a vertical line to the center—, the on-stream analyzer measurements showed a remarkable dispersion in comparison with the 6-hour results of the chemical assays composite which is represented in the graph as a continuous line. After the new calibration model was uploaded, a better fit of the on-line measurements to the results of the chemical assays composite is observable.

As can be seen on the X-axis of the abscissas, the response time was less than 24 hours, and the calibration and adjustment were carried out quickly.

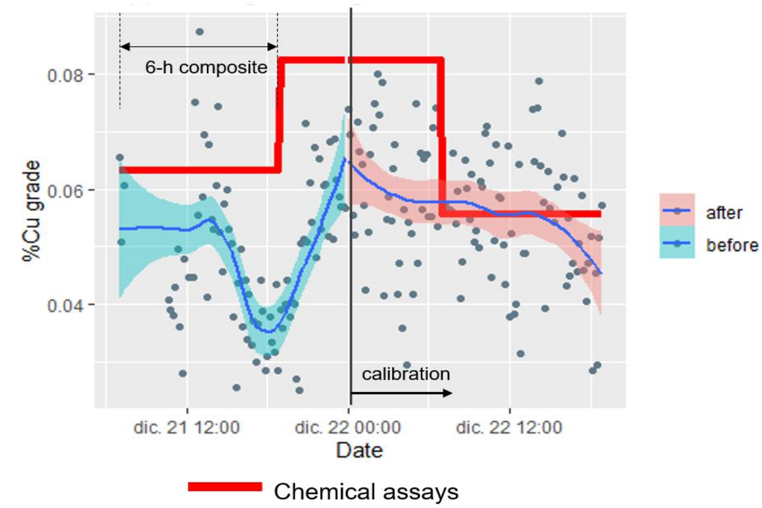

Figure 5 Cu rougher tail grade (%) in time. The graph includes 6-hour results of the chemical assays composite and on-stream analyzer measurements

RESULTS

Once the new calibration was made, the copper recovery error at the rougher stage was reduced to 2.9%, from 6.7% to 3.8%, as illustrated in the boxplots in Figure 6.

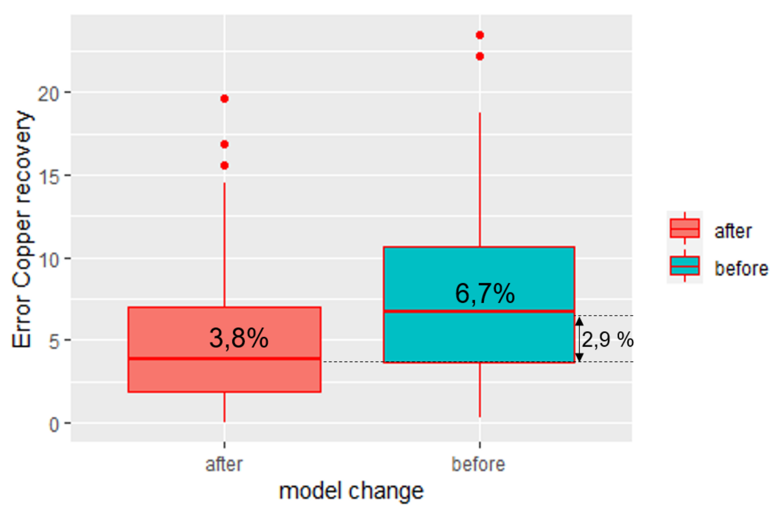

Figure 6 Error copper recovery(%) before and after new calibration

After adjusting the calibration model, the the predicted recovery with the improvements in the analyzer accuracy drops from 85.8% to 83.8%. The graph shows a 2% impact on copper recovery due to overestimation, as displayed in Figure 7. The value presented in both distributions represents the mean value (median) as the central tendency of the data. It should be noted that the shape of the real curve is not normal by default, and only in this plot is it presented in this way for purposes of graphical representation and explanation.

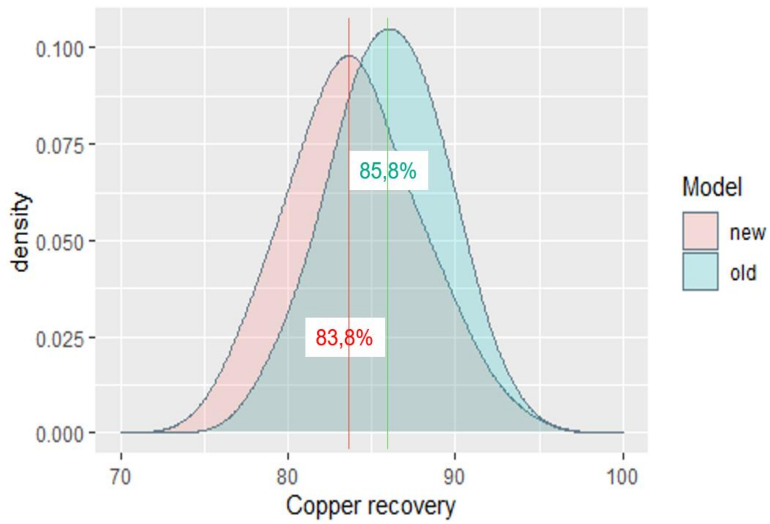

Figure 7 Copper recovery(%) before and after new calibration

The indirect benefits of maintaining an integrated plant maintenance service and remote assistance on the quality of the measurement are that all these allow a steady metallurgical control. The adjustment of the metallurgical estimation vs the real production filtered and dispatched during the shift led to improvements in the metal accounting full lifecycle: measurement, data collection, data reconciliation and reporting.

For the customer, the direct benefits to be gained from this adjustment were:

a) An accurate on-stream analysis with respect to metal accounting, and

b) Calibrated on-stream analysis allowed to take opportunistic operational decisions in real-time by APC, Digital Twins (DT), and Integrated Remote Operations Centre (IROC).

CONCLUSIONS

Remote monitoring, calibration, and maintenance of on-stream analyzers bring value, directly in the form of an increase in the equipment's availability and the reliability of the data. From this, these just-in-time decisions maximize the process efficiency. The case study brings up that the Copper recovery error at the rougher stage was reduced by 2.9%, from 6.7% to 3.8%, which translated into a recovery adjustment of 2%, from 85.8% to 83.8%. Due that, on-stream analyzers play a key role in metal recovery allowing to metallurgist and operating team to manage in real time the froth flotation efficiency and reconciliation with metal accounting based on chemical assays shift by shift. This approach transforms this technology to critical instrumentation for advance process control system (APC) and supporting digital transformation such happens in Integrated Remote Operations Center (IROC).

NOMENCLATURE

APC advanced process control

AR augmented reality

DT digital twin

IROC integrated remote operations centre

LIBS laser-induced breakdown spectroscopy

OC optimizing control

XRF x-ray fluorescence spectroscopy

WDX wavelength-dispersive X-ray

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