Minerals Engineering 124 (2018) 68–73

Contents lists available at ScienceDirect

Minerals Engineering

journal homepage: www.elsevier.com/locate/mineng

Improving grade control efficiency with rapid on-line elemental analysis

Iita Kejonen[a,*], Olli Haavisto[a], Jukka Martikainen[a], Ville Suontaka[a], Benjamin Musuku[b]

[a] Outotec (Finland) Oy, Rauhalanpuisto 9, 02230 Espoo, Finland
[b] Boliden Kevitsa Mine, Kevitsantie 730, 99670 Petkula, Finland

ARTICLE INFO

Keywords:
X-ray fluorescence
Reflectance spectroscopy
Elemental analysis

ABSTRACT

Flotation circuit control is typically based on regular on-line elemental analyses. In base metal applications the conventional assaying method is X-ray fluorescence (XRF), which has proven to be a reliable and accurate technology. However, in large flotation plants with many sample streams to be analyzed, the measurement frequency for individual assays decreases because a centralized XRF analyzer can only measure one stream at a time. This results in unnecessary delays that reduce the control performance. Nevertheless, by integrating reflectance spectroscopy measurement with the conventional XRF technology, a practically continuous assay can be obtained. In this paper the advantages of improved analysis cycle to process performance via faster automated higher level flotation circuit control are demonstrated. The presented technology enables capturing and reacting to grade fluctuations that may have been missed with longer measurement intervals. Moreover, response time to drastic changes in flotation circuit operation is significantly reduced which results in better process performance.

1. Introduction

Froth flotation is a beneficiation process where valuable minerals are separated from the gangue by benefiting from the hydrophobicity of certain particles, created by the process chemistry. The advantage of this method is that it enables economical mining of very low grades and complex ore bodies. A typical flotation circuit consists of multiple flotation stages: roughing, where the initial separation of the valuable minerals is performed; scavenging, where slowly floating particles of the rougher tailings are separated; and finally cleaning the concentrates.

Continuous changes in the feed ore and complexity of the process chemistry often demand flotation control actions to maximize the process performance. Nevertheless, the flotation control is dependent on the primary information from the process, provided by plant instrumentation, laboratory and on-stream analyzers. Elemental assays of different slurry flows are among the most valuable measurements of the flotation process. Especially flotation feed, final concentrate and final tailing concentrations give essential information on process overall performance for flotation control.

There are many different technologies for measuring elemental assays. The most utilized method for on-line elemental analysis is X-ray fluorescence (XRF), which measures the characteristic fluorescent radiation of different elements excited with high-energy X-ray radiation (Wills and Napier-Munn, 2006). Additionally, manual and automatic laboratory measurements are also very commonly used in measuring the process mineralogy. Moreover, recently also laser-induced breakdown spectroscopy (LIBS) method has been introduced to industrial uses in minerals processing, which allows measuring lighter elements than what the XRF method is capable of (Cremers and Radziemski, 2013, Köresaar et al., 2017).

Typically, on-stream analyzers are centralized and one measurement probe analyzes data from multiple slurry line locations, as this enables the use of highest quality components in the measurement probe thus enabling highest accuracy while keeping component cost reasonable. However, as traditionally one analyzer probe is only able to measure one sample at a time, in large scale systems, the measuring interval of a certain slurry line may be increased. For higher frequency, the XRF method can be complemented with reflectance spectroscopy, which analyzes the absorbance properties of the slurry in visible and near-infrared wavelength range.

The combination of XRF and reflectance spectrum analysis has been extensively studied (see e.g. Haavisto, 2009, 2010, Haavisto et al., 2016). The main idea is to utilize the good accuracy of the XRF measurements and the fast measurement rate of the reflectance spectroscopy to create a practically continuous estimate of the slurry grades. As an individual measurement device, the reflectance spectrum analyzer would need frequent laboratory assays for the calibration, which would make the system cumbersome to use and would result higher operating cost. However, with the XRF analyzer operating as a regular and automatic source of calibration, the elemental grades can be accurately calculated from the reflectance spectrum information. For example, the

* Corresponding author.
E-mail address: iita.kejonen@outotec.com (I. Kejonen).

https://doi.org/10.1016/j.mineng.2018.05.002
Received 22 December 2017; Received in revised form 28 March 2018; Accepted 2 May 2018

detection of fast grade changes and harmful process oscillations (Haavisto, 2010) benefit from the combined measurement approach.

More and more concentrator plants have increased the level of automation through advanced process control (APC) in order to stabilize the flotation process and reduce variance in process performance caused by plant operators' different perceptions. Further, APC uses large scale of data for determining its control actions, and among the most important information for this is the elemental analysis. Obtaining as accurate and up-to-date data from the process results in faster control actions and better process performance. Thus, higher frequency of elemental assay results measured by reflectance spectroscopy method may also result in faster and more reactive process control.

This paper presents potential advantages of using reflectance spectroscopy beside traditional XRF measurement to advanced higher level process control. The plant tests are performed at Kevitsa copper-nickel-PGE concentrator.

2. Materials and methods

2.1. Process description

Kevitsa concentrator treats ore in a sequential flotation process to recover copper and nickel minerals respectively. The valuable mineral is finely disseminated in the ore body requiring a fine grind of 75% passing 75 µm as feed to flotation circuit. Addition of reagents is done prior to and during flotation. Fig. 1 shows a complete flotation circuit comprising of copper, nickel and sulphur circuit.

The aim for the copper circuit is the recovering 80% of copper in feed at a Cu final concentrate grade of 23% Cu with ≤1% Ni. The roughing stage has the TC500 cell (500 m^3), which produces a rougher concentrate of about 15% Cu. The rougher tailings reports to scavenger cells for further recovery of Cu into the cleaning circuit. A grade of 4–6% Cu is targeted on scavenger cells to provide adequate feed to the HIGmill and maximize on recovery. The HIGmill is a critical unit in Cu flotation as it compensates for coarse flotation feed at high throughput by grinding mixed grains in the scavenger concentrates from F80 of 100 µm to P80 of 35 µm to unlock valuable minerals. The Cu circuit has 4 cleaning stages with Cu column being the final cleaning stage.

The main challenge in the Cu circuit is to prevent Ni contains into the Cu final concentrate with minimal impact on Cu flotation. The rougher and scavengers are operated at natural pH of about 9.5 and Cu collector is used to selectively float Cu. However, some of the Ni floats together with Cu, needing to be depressed with lime dosage at the final cleaning stage. The high concentrate target on TC500 is aimed at selectively floating most of the liberated Cu minerals and allowing mixed grains to be recovered through scavenger cells for regrind in the HIGmill. The scavenger tailings grade helps to determine mass pulling rates and collector dosage on the scavenger cells whereas cleaner 1 tailings helps determine how fine the HIGmill product should be. This implies that the rougher/scavenger concentrates grade targets are revised depending on the Cu losses to Ni circuit, whereas the HIGmill product is varied between a P80 of 35–45 µm depending on how much Ni is reporting to Cu concentrate and Cu losses through cleaner 1 tailings.

The Cu tailings are treated for Ni recovery and later on for sulphur recovery as shown in Fig. 1.

2.2. Flotation control

Kevitsa flotation plant has been utilizing an APC solution for flotation control all the way from the site startup. The system is implemented using the Outotec ACT platform and includes also grinding and dewatering plant controls, integrated into a single system. The APC solution has already been shown to provide benefits to the performance (Rantala et al., 2014), but further improvements are naturally sought after. One way to achieve better flotation control is to increase the frequency of the elemental grade measurements. The relationship of elemental assay sampling frequency and flotation circuit economic performance has been studied by Remes et al. (2007). They show that the economic performance drastically decreases if the control actions

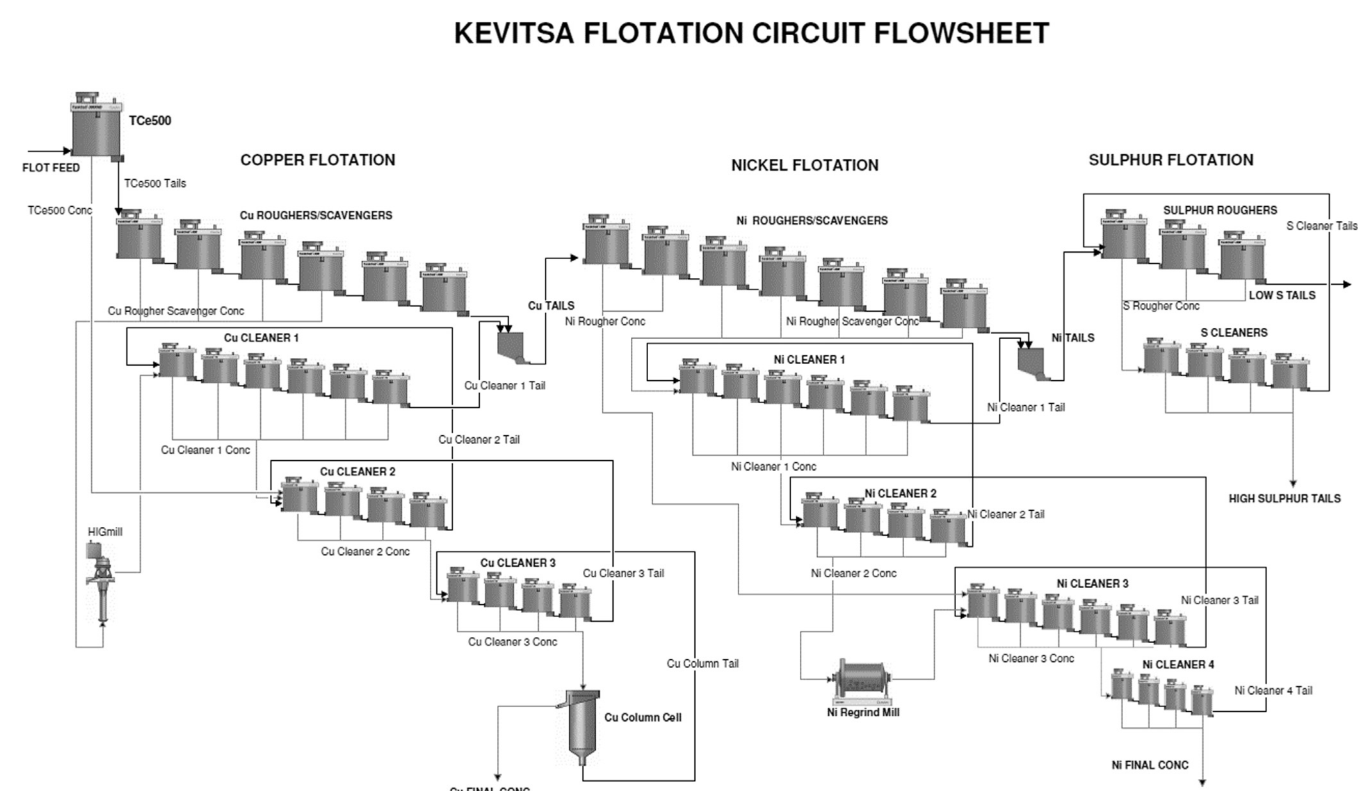

Fig. 1. Kevitsa Flotation circuit flowsheet.