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Study of process water recirculation in a flotation plant by means of process simulation

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Abstract

One of the biggest challenges with water in the mining industry is the need for water management systems that consider production-related issues when the quality of process water is subject to variations. Part of the work required to tackle this challenge is the development of simulation platforms that correlates the quality of the process water to the processing plant performance. In this paper, the application of a previously developed simulation-based approach to include the impact of process water chemistry on the performance of a flotation plant is presented. The water chemistry-dependent plant simulation is then used to investigate the implementation of a water-saving strategy to reduce fresh water requirements without impairing process performance, thus demonstrating the applicability of the previously developed approach for the simulation of large scale industrial plants.

Keywords

Flotation plant simulation, flotation kinetics, process water chemistry, water-saving strategies.

1. Introduction

The availability and efficient management of water resources is crucial for the development of mankind, so much so that the United Nations have made it one of its key Sustainable Development Goals (SDGs). For instance, SDG6 states that integrated water resources management must be implemented at all levels and water-use efficiency across all sectors must be substantially increased by 2030 (United Nations, 2015). To achieve this goal, mining companies are making considerable efforts to minimize their fresh water requirements and have become more transparent regarding their water management practices (Northey et al., 2019). The work of Gunson et al. (2012) is a great example highlighting such efforts, where the development of a mine water system model allowed the identification of water-saving strategies that could reduce water consumption by 74% or more on the mine site they investigated. However, implementing such strategies often leads to modifications of the water quality.

Where water quality is no issue for the mineral beneficiation plant, water management systems that solely focus on maximizing water reuse are sufficient. However, in froth flotation plants, water quality is particularly likely to influence the process performance (Johnson, 2003), making water management both an environmental and production-related issue (Levay and Schumann, 2006). The challenge is thus to develop a systemic approach where water quality and its influence on the processing plant performance are accounted for in the water management system. To do so, scientists and industry professionals at the EIT Raw Materials Expert Forum on “Fine particle flotation and sustainable usage of water in mineral processing” (31.01.2019, Dresden, Germany) identified at least two major requirements:

- The development of online water quality measurement methods;
- The development of a platform that links the quality of process water to the plant performance.

Great efforts are already being made in that direction, with a notable example being the EU Horizon 2020 ITERAMS project (grant agreement No 730480). Simulation platforms, which can be used as a base for the desired water management systems, have also been subjected to valuable developments in the recent years. Some of those developments were highlighted in a previous work from the authors (Michaux et al., 2019), along with a methodology to digitalize the influence of process water chemistry on the simulation of a processing plant performance. This methodology was developed using the flotation of a fluorite ore and yielded a numerical relationship between the lab-scale flotation kinetics of the ore and the composition of the process water.

In continuation of the previous work, a sampling campaign was carried in the flotation plant of the previously investigated fluorite ore. Based on this sampling campaign and the results of the previous work, the plant performance was simulated as a function of the process water chemistry. This technical note thus aims at briefly presenting the work performed to achieve such water chemistry-dependent plant simulation and its use to investigate the implementation of water-saving strategies in the flotation plant.

2. Plant sampling and digitalization in simulation platform

To create a digital twin of the fluorite flotation plant in the Outotec mineral processing simulation platform HSC Sim (Figure 1), a complete sampling of the plant was first necessary. The sampling campaign was designed to allow for the mass balancing and parametrization of the full plant in the simulation platform, and lip sampling was also performed in the different flotation stages of the process to determine the plant flotation kinetics in the roughers, scavenger, and cleaners.

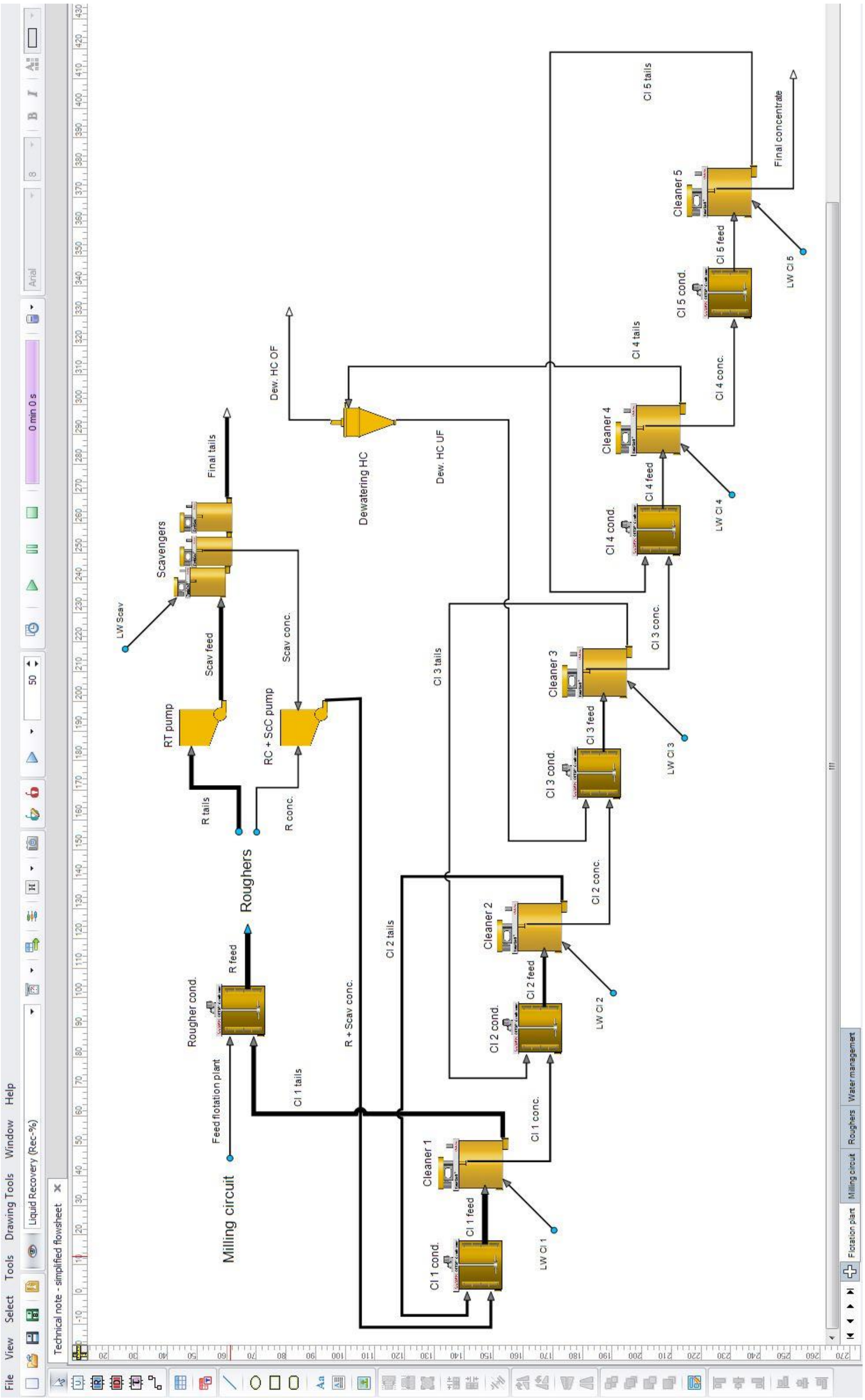

Figure 1 – digital representation of the fluorite flotation plant in the simulation platform HSC Sim. The above presented flowsheet is slightly simplified to respect non-disclosure agreements.

As is common knowledge in the industry and is demonstrated in this paper, the flotation kinetics at industrial scale are not the same as in laboratory scale (Mesa and Brito-Parada, 2019). Therefore, the determination of the plant flotation kinetics was a crucial step in order to determine the scale-up factor required to apply the lab-scale kinetic model determined in the previous work (Michaux et al., 2019) to continuous plant operations. In the previous work from the authors, a link between the composition of the process water and the flotation kinetics of the fluorite ore was determined using a so-called *three-component batch flotation model*, where the model parameters are functions of the process water composition (which are not re-defined here). This kinetic model for a continuous set-up expresses the recovery of a mineral R_m in the flotation bank as a function of the average material residence time τ in a cell of the bank as follow:

$$\boldsymbol{R_m(\tau) = m_f\left(1-\frac{1}{(1+k_f\tau)^N}\right) + m_s\left(1-\frac{1}{(1+k_s\tau)^N}\right) + m_n.0} \qquad (1)$$

Where m_f and m_s represent the proportion of fast and slow floating particles, respectively;
k_f and k_s represent the flotation rate constant of fast and slow floating particles, respectively;
m_n represents the proportion of non-floating particles such that $m_f + m_s + m_n = 1$;
N is the number of flotation cells in the bank;
$m_f = 0.76$, $m_s = 0.20$, $k_f = 1.51$, $k_s = 0.05$ under standard process water conditions.

As presented in Figure 2, the direct application of eq. (1) without applying any scale-up factor to k_f and k_s (model 1) creates a significant misfit between the measured and modeled flotation kinetics in the rougher flotation bank of the plant. To minimize the squared error between measured and modeled fluorite recovery, it was determined that a kinetic-scale up factor of 6 should be used (model 2). However, regardless of the scale-up factor being used, the shape of the measured kinetic curve cannot be satisfactorily fitted with the parameters from eq. (**1**). To tackle this problem while using the kinetic model that was determined with the lab-scale experiments, it was necessary to use N = 1 and a scale-up factor of 7 in eq. (**1**), and then to apply the resulting equation to the feed material at the entrance of every cell along the rougher flotation bank (model 3).

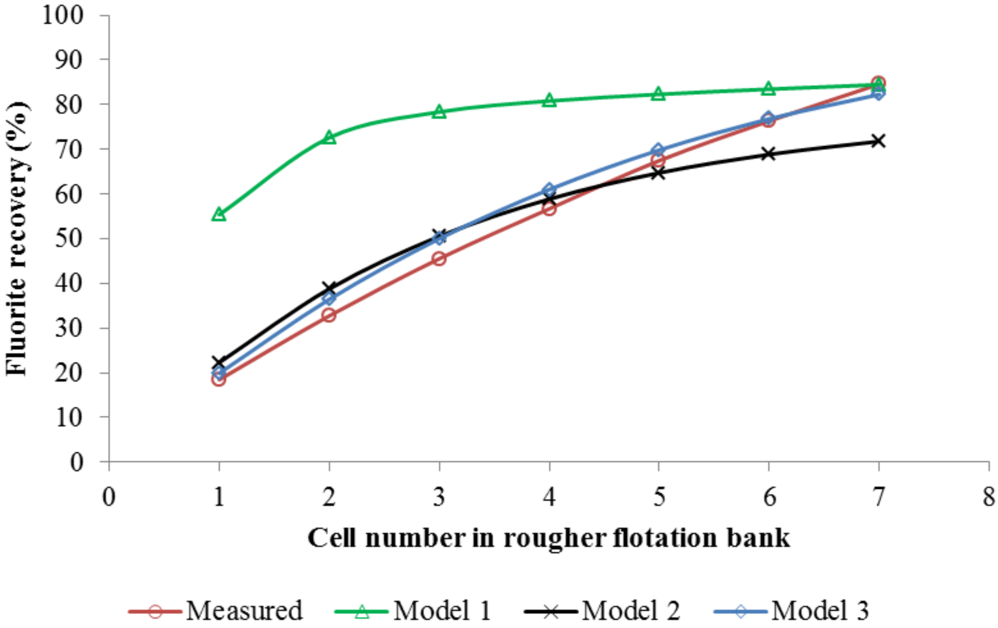

Figure 2 – determination of adequate flotation kinetic model to the plant rougher flotation bank.

The required modifications to eq. (**1**) to obtain a satisfactory fit between modeled and measured flotation kinetics would actually mean, in this specific case, that the proportion of fast and slow floating particles are the same in every cell along the rougher flotation bank. This probably implies that the flow properties inside the flotation cell are governing the fluorite recovery. In the end, this kinetic scale-up methodology steps enabled the inclusion of the previously determined water chemistry model into the digital twin of the processing plant and, therefore, allowed for the simulation of the whole plant performance as a function of the process water being used.

3. Investigation of water recirculation in the flotation plant

The inclusion of a relationship between process water composition and the processing plant performance in a simulation platform enables the investigation and implementation of water-saving strategies with consideration for the production-related issues. For illustration purposes, the impact of recirculating the water from the dewatering hydrocyclone (Dew. HC OF in Figure 1) into the milling circuit was investigated. It was determined from the sampling campaign that the amount of water withdrawn from the flowsheet through this dewatering step was sufficient to satisfy the water quantity requirements in the milling circuit, but it is also necessary to determine whether an intensive recirculation of this water stream would be detrimental to the plant performance.

To perform this investigation, the accumulation of dissolved species originating from the ore must be taken into consideration. To do so, the existing link between the simulation platform HSC Sim and the thermodynamic database of HSC Chemistry was used. With this link, the dissolution of minerals in the milling circuit and thus the enrichment in the model-relevant inorganic ions could be accounted for. As the accumulation of model-relevant species are taken into consideration with process water recirculation and the link between process performance and the process water chemistry exist in the digital flowsheet, different degrees of water recirculation from the hydrocyclone overflow could be considered. The impact of such recirculation on the process performance is presented in Figure 3.

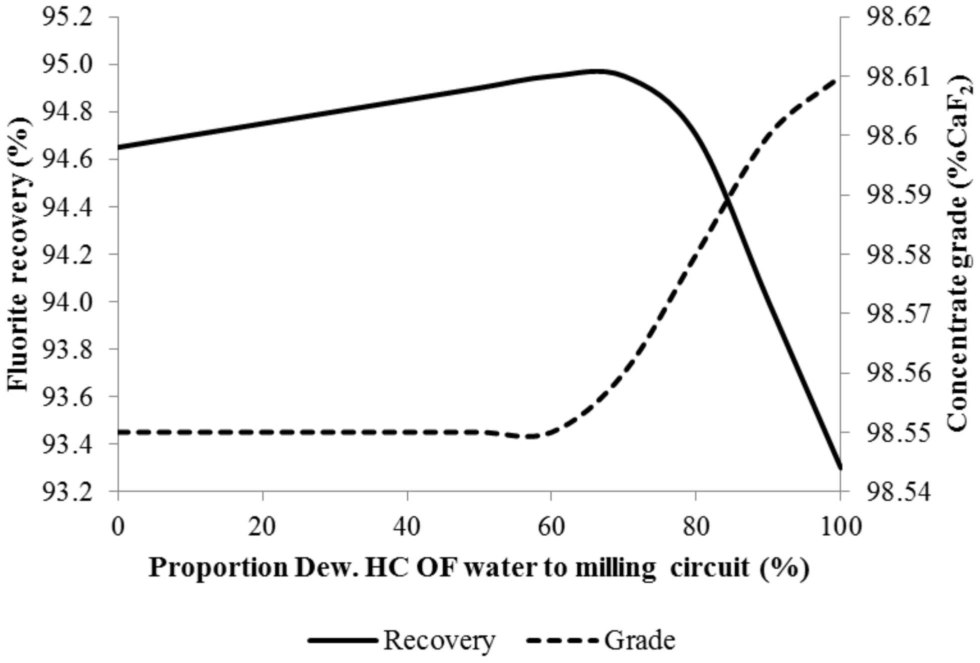

Figure 3 – impact of process water recirculation from the dewatering hydrocyclone overflow (Dew. HC OF) on the plant performance.

It can be observed in Figure 3 that recirculating water from the dewatering hydrocyclone overflow does not significantly impact the process performance. The main reason behind this observation is that the species accumulating in the process water are mostly Ca^{2+}, F^-, and SO_4^{2-}, which are not detrimental to the process performance as was highlighted in the previous work. The only species really detrimental to the process (Mg^{2+}) does not accumulate as the only source of magnesium in the ore is the slightly soluble mineral sellaite (MgF_2), and the accumulation of F^- in process water further hinders its dissolution. In addition, the concentration in dissolved species in the process water is constantly kept relatively low due to the fresh water still being used as launder water throughout the whole plant. This maintains a significant level of dilution and thus, the accumulation of dissolved species remains marginal. It must finally be noted that the downward part of the fluorite recovery curve is not related to changes in water chemistry. Since approximately 70% of the water from the dewatering hydrocyclone overflow is required to reach the target pulp density in the milling circuit, exceeding this 70% recirculation threshold leads to a dilution of the pulp density. Consequently, for a given solids throughput, the residence time in the flotation banks is slightly reduced, leading to a decrease in fluorite recovery in the plant.

It is clear that more intensive water-saving strategies could be implemented, especially if recirculated process water is used as launder water in the plant. However, such implementation would require very efficient dewatering units to avoid the clogging of the launder water spray nozzles in the plant, thus might require infrastructure modifications. The simple investigation presented here requires only very marginal modifications to the processing plant, does not noticeably impair the process performance, and yet still allows for a 20% reduction in the plant fresh water requirements. Therefore, although simple, the presented water-saving strategy constitutes a very good illustration for the application of the mineral processing simulation platform as a base tool to develop smart water management systems in the mining industry that take into consideration the production-related issues in the implementation of water-saving strategies.

4. Summary and outlook

The development of water management systems in the mining industry is crucial to satisfy the sustainable development goals set by the United Nations. Although such systems already exist and are already implemented in certain mining operations, there is a great need to account for the production-related issues when water-saving strategies are implemented. To do so, mineral processing simulation platforms that account for the role of process water quality on the plant performance were shown to be of great relevance in this paper.

Developing an efficient water management system for the mining industry is a multi-faceted issue that requires considerable efforts. This system must operate on-line to constantly adapt to water chemistry changes, availability of water sources, etc. Therefore, the development of on-line water quality control methods such as the one developed for residual xanthates by Muzinda and Schreithofer (2018) is an absolute necessity for the plant operators to have real-time information on the process water quality. This information can then be imported to the simulation and control platform of the water management system to determine the optimum water handling strategy for the minimization of fresh water use without impairing the processing plant efficiency.

Acknowledgements

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