Froth Stability Monitoring – A Route to Automatic Flotation Optimisation

The importance of control for the effective operation of float circuits is well known amongst operators of flotation concentrators. Studies have shown that **5-15 %** of the valuable minerals are **not recovered** due to sub-optimal process settings.

Mintek has been a leader in advanced flotation control, aiming to improve this sub-optimal operation, for **more than 25 years** with **96 installations** of the FloatStar system in **16 countries**. Our approach is to first ensure stability of a float circuit with improved base-layer control. Thereafter, we consider new robust technologies for long-term automated optimisation.

Flotation is strongly affected by variation in the feed mineral grade, mineralogy, particle size and density. Optimising the flotation circuit, therefore, involves altering inter-stage flows, changing the reagent dosing, manually monitoring the cell's appearance, and optimising various parameters of the feed to the circuit (e.g. density, flowrate). This optimising process requires expertise, time and manual sampling or (less commonly) online instrumentation. The optimum operating point of the plant is naturally moving faster than what can be determined manually (due to changes in the feed and other variance in the process). The effort, expertise, time and cost to carefully optimise the plant means that it is usually operated at a compromise.

Automating a component of this optimisation will therefore assist greatly in consistently achieving improved performance. Froth stability is one aspect that has been identified as a key factor in achieving optimal flotation performance. Experienced operators are able to link froth appearance to its stability and consequently the necessary control interventions. However, even these expert operators are not able to discern and diagnose subtle changes in the froth, nor are they able to control the system on a consistent basis. From this, the idea of using cameras and image processing to quantify froth stability was born. Based on the quantification of froth stability, one can optimise the flotation cells automatically.

Why Froth Stability?

The importance of froth stability in respect to flotation performance has long been recognised. Within a flotation cell, the froth phase further concentrates the collected particles by reducing the recovery of entrained gangue mineral particles. This means the froth phase influences both the recovery and selectivity of the desired minerals. Simply put: a froth phase that is unstable will not be able to hold valuable particles (resulting in their recovery being diminished). A froth phase that is 'too stable' may be immobile and trap many undesirable particles (resulting in low selectivity). An optimum is expected to lie between these two extremes. The flotation process can be optimised by using a control system that can identify, move and hold the process at this point of optimum froth stability.

How to quantify Froth Stability?

Froth stability is measured during laboratory studies using methods such as the Bikerman test[1]. Some devices such as Froth Stability Columns have been used to measure this property on industrial plants, but use part of the heavily contended space within the cell. Therefore, the idea of a machine vision (image-based automatic inspection and analysis) to quantify the froth stability was developed.

FloCam: A machine vision froth monitoring system

It has proven difficult to relate froth structure information from image analysis directly to performance indicators such as grade and recovery. Therefore, most froth monitoring systems are only able to contribute to mass pull profiling (using froth velocity as a proxy for the individual cell's mass pull rate), which is a very limited form of optimisation. A review by Aldrich et al. (2010)[2] covers the use of machine vision for flotation control. If an alternative use of the image analysis information can identify an optimum operating point, this approach might see a larger scale implementation and more sustained use in industry.

There are several promising avenues to interpret the visual froth images and produce measurements of froth stability. Some of these use aspects such as the bubble burst rate or deep neural networks to relate froth features to performance. The Peak Air Recovery methodology[3] suggests both a measure of the froth stability and a way to use this measurement directly to determine the optimum aeration rate. An approachable study on various air profile strategies is given by Maldonado et al.[4].

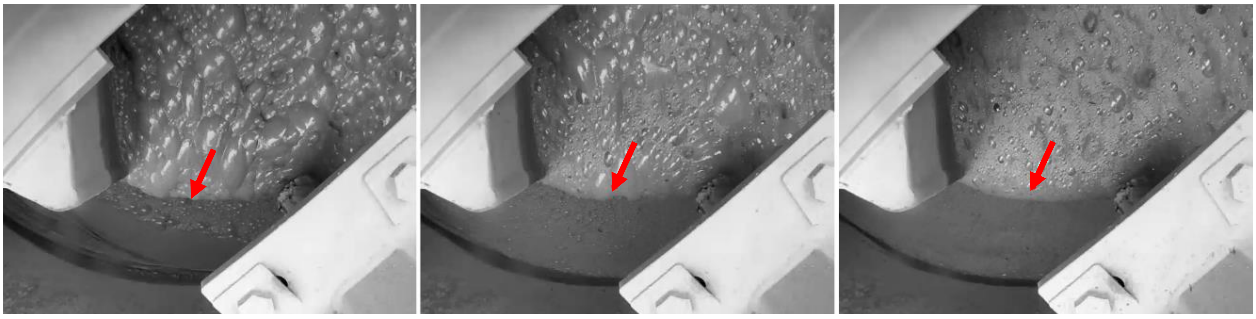
Mintek's Approach

Mintek developed a low-cost froth camera monitoring system called the FloCam. It produces both velocity and forth height measurements. It can also simply provide a remote view of the froth appearance to be used by operators without needing to go out onto the plant.

The FloCam system is able to continuously produce measures of froth stability, which can be integrated with the proven FloatStar control system for optimisation purposes.

A user's view of the FloCam System

An example of some of the information from the FloCam system is shown below (with the arrow denoting the flow direction). At low aeration rates *(A)* below the measured optimum stability (using the Peak Air Recovery methodology), the froth is high, but slow, and bubbles frequently coalesce and burst before the lip. At higher aeration rates *(C)* beyond the measured optimum froth stability, the froth is fast but low and not well loaded with minerals. Many burst before the launder lip. At conditions of measured optimum stability *(B)*, the bubbles appear to be well loaded, mobile, contain a mixture of sizes and generally do not burst until just over the launder lip.



(A) Below Optimum Stability *(B) Optimum Stability* *(C) Beyond Optimum Stability*

Mintek has a paper and presentation for the International Mineral Processing Conference (IMPC) conference (Cape Town, October 2020) which shows how the froth stability and the corresponding metallurgical performance (as sampled at a South African flotation plant) changes significantly during normal operation. The paper shows that a flotation section's **recovery can differ by as much as 8 %** between satisfactory conditions (as set by experienced operators) and optimum froth stability (identified automatically). The paper suggests ways to automatically ensure that the plant is able to stay at this continuously changing optimum froth stability point through automatic control.

Mintek is eager to discuss what we can offer in terms of automatic flotation optimisation on your plant.

This white paper has been brought to you by Mintek. Feel free to pose any questions you might have to the author at DavidPh@Mintek.co.za. To connect with Mintek Process Control experts on LinkedIn, click here.

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[1] Bikerman, J., 1973. *Foams*. s.l.:Springer.

[2] Aldrich, C., Marais, C., Shean, B.J., Cilliers, J.J., 2010. *Online monitoring and control of froth flotation systems with machine vision: A review*. International Journal of Mineral Processing 96, 1–13. https://doi.org/10.1016/j.minpro.2010.04.005

[3] Hadler, K., Cilliers, J.J., 2009. *The relationship between the peak in air recovery and flotation bank performanc*e. Minerals Engineering 22, 451–455. https://doi.org/10.1016/j.mineng.2008.12.004

[4] Maldonado, M., Araya, R., Finch, J., 2012. *An overview of optimising strategy for floatation banks. Minerals* 2, 258-271. doi:10.3390/min2040258