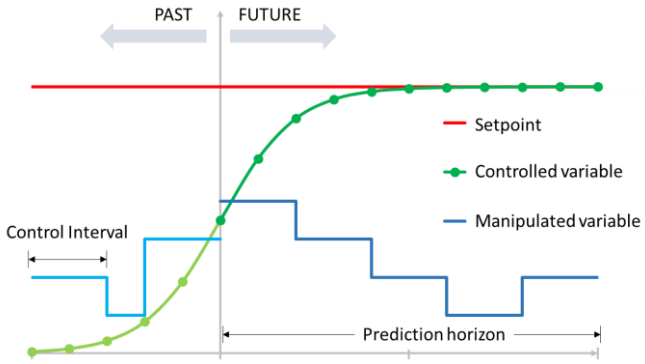
Control and Optimisation of a Gold Milling and Flotation Circuit

Improving the stability of a minerals processing circuit results in better improved recovery of the valuable mineral being extracted. The hurdles to achieving stability vary from plant to plant. As an example, the typical challenges for mill discharge control include: sump integrating dynamics, instrumentation noise, maintaining certain process variables within limits (as opposed to being controlled to setpoint), interaction between process variables, and having an unequal number of manipulated and controlled variables. For a flotation circuit the biggest challenges are disturbances in the feed flowrate and the lack of coupling between control loops of downstream cells.

Mintek has developed two independent control modules that address the obstacles around stable operation of a mill discharge and flotation circuit, namely the MillStar Model Predictive Controller (MPC) and the FloatStar Level Stabiliser. Both these systems were commissioned at Mandalay Resources' Björkdal Gold Mine. Once the desired stability was achieved at this site, flotation optimisation was also implemented on the Rougher and Scavenger banks. This paper demonstrates the benefits of these advanced systems and compares the results against regular plant control.

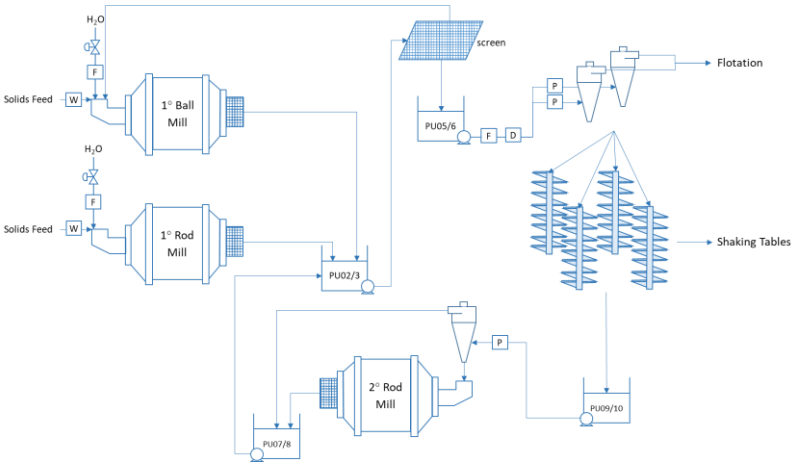
Mill Discharge Stabilisation



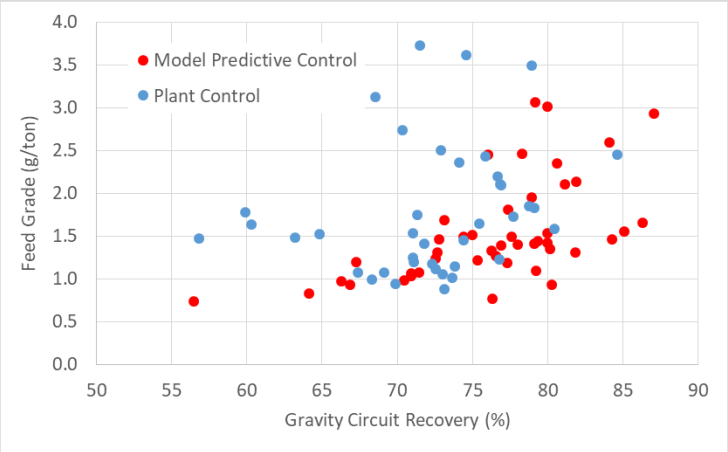
Mintek's MillStar MPC is a versatile tool that controls a process based on mathematical relationships between process variables (e.g. level, pressure) and actuators (e.g. valve position, pump speed). An objective function is formulated based on the dynamic response that is desired from the process, whether it be minimising the movement of certain actuators, setpoint tracking of specific process variables, keeping them within limits or a combination of all.

The model-based controller solves this optimisation problem in order to determine the movements of the manipulated variables to achieve the desired process response. This formulation enables it to overcome obstacles such as the interaction between process variables, and having an unequal number of manipulated and controlled variables.

The mill discharge circuit of Björkdal Gold Mine is ideally suited to an MPC solution, due to the limit handling that was necessary to accommodate the competing control objectives. The discharge sumps are integrated in a recycle through the gravity spiral separation circuit. Achieving a stable flowrate and pressure feed to the hydrocyclones, whilst simultaneously balancing the volumes between the four discharge sumps, poses a significant challenge.



The MPC strategy was implemented with the objective of allowing all sump levels to vary, buffering the change in volume through the system, so that the flowrate to the hydrocyclones could be kept constant. The controller is able to prioritise this flowrate stability, while predicting the movement of the level and, pre-emptively, slowly changes the pump speed if the level is predicted to violate a limit.

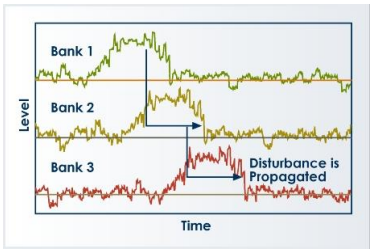


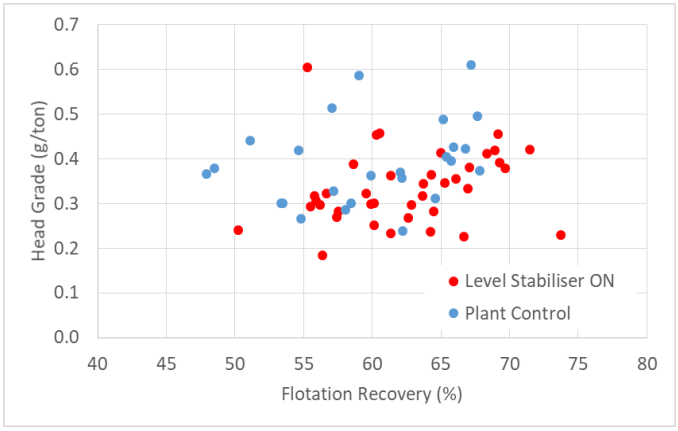
Implementation of this control strategy has improved the stability to the gravity section by 28 % as measured by the minimised flowrate and pressure feed fluctuations to the hydrocyclones. This stability enhancement in the mill discharge - gravity feed section has resulted in an average **recovery improvement of 1 %**. This improvement is in spite of lower average head grade, and the same consistent feedrate and product grade. With the assumptions[1] listed, this recovery improvement results in approximately **US$ 62,000 additional revenue per month**, which is less than the total cost of this system.

Flotation Stabilisation

Further processing of the gold ore at Björkdal includes a Knelson separator which feeds a flotation circuit. Due to the flushing cycle of the Knelson separator, the flotation circuit intermittently experiences extreme volume fluctuations. The lack of compensatory control on the flotation circuit resulted in this disturbance causing the pulp level of all the flotation cells to deviate drastically from setpoint.

Mintek's FloatStar Level Stabiliser was developed to address the instability around a flotation circuit, most often caused by varying feed flowrates. The Level Stabiliser is a model-based, feedforward scheme with stabilising Proportional-Integral-Derivative (PID) controller that allows the downstream flotation cells to pre-emptively react to a change in slurry volume that is being propagated through. This approach has the benefit that disturbances are mitigated in downstream flotation cells.





The FloatStar Level Stabiliser, with additional compensation for the Knelson separator's flushing cycle, was commissioned on all nine flotation cells at Björkdal. This implementation has resulted in a 37 % improvement in stability of the flotation circuit, quantified by the reduction in integral absolute error between the setpoint and measured level values. As a result of this improved stability and disturbance mitigation, the flotation circuit **recovery has improved on average by 2.1 %**, despite lower average head grades being processed, as summarised in the figure to the left.

This improvement results in an additional 35 g of gold produced daily from the flotation circuit. With the assumptions[2] listed, this would equate to US$ 32,700 additional revenue per month. Given the cost of the entire control system, this improvement alone would allow Björkdal to realise a **return on their investment** within only **3 months**.

[1] Production of 3,600 tonnes/day; head grade of 1.54 g/ton; market value of gold = US$ 40.75/g; concentrate sold at 90 % of market value

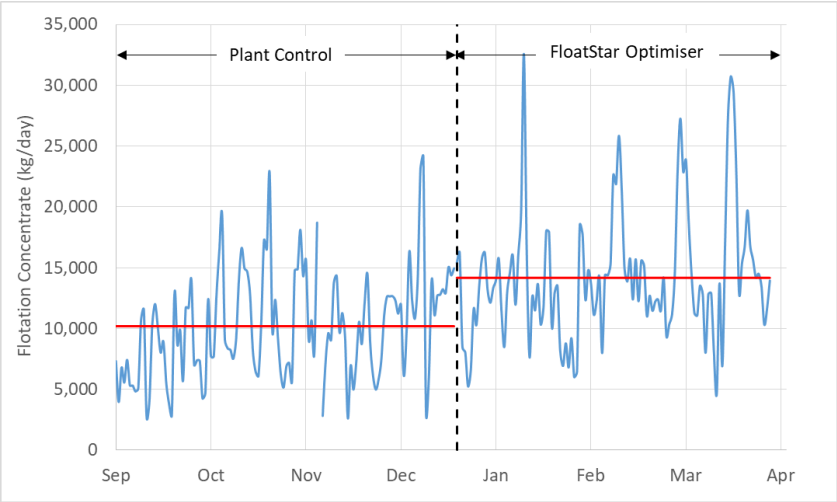
[2] Average market value of gold at US$ 40.75/g; concentrate sold at 75% of average market value

Flotation Optimisation

Once process stability of a circuit has been addressed, the opportunity for optimisation can be investigated. Concentrator plants often process different ores from various sections of their open pit or underground operations – sometimes changing on a daily basis. Floating or separating physically or chemically different material requires the operating regions to be adapted continuously. This is most important for the flotation circuit where the optimal reagent recipe, froth depth and air addition rates are dependent on the type of ore being processed.

In the absence of online grade analysers, manipulating the reagent recipe is based on visual monitoring of the froth and an in-depth understanding of the ore characteristics. Therefore, in most cases it is best that this remains within the scope of the plant metallurgist and operators. The Mintek FloatStar Flow Optimiser is ideal for finding the optimal operating region for the froth depth and air addition rates to each flotation cell, in order to achieve a desired mass pull target – all while managing concentrate sump capacities.

Processing of a different ore type that may change on a daily basis has operators and metallurgists at Björkdal constantly busy with achieving the correct reagent recipe for the flotation circuit. This means that the operational staff seldom have the opportunity to consider the adjustment of the froth depth and aeration rates. The FloatStar Flow Optimiser was therefore implemented on the Rougher-Scavenger section, in order to optimise the concentrate mass pull from these banks. The strategy uses the flowrate measurement on the combined concentrate streams to determine the optimal slurry level setpoints and aeration rates for each individual cell in the two flotation banks, in order to achieve a desired production rate. With this, the plant personnel are able to focus their attention on the reagent recipe, while the FloatStar Flow Optimiser assists in working towards the same optimal mass pull target.



Preliminary results indicate that the implemented strategy has improved the overall flotation circuit mass pull by 40 % comparing a 3.5 month period of ON and OFF data.

Björkdal is in the process of installing additional flow meters in order to expand the successful Mintek flotation optimisation system to include other parts of the plant.

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