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Evaluation of automatic polymer dosing control to optimise the performance of belt presses

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Abstract

Increasing environmental, regulatory and social scrutiny has necessitated a change in tailings management governance across the mining industry. The sector is trending towards dry disposal of tailings to reduce environmental impact, tailing dam risk exposure and to safeguard the sustainability of operations.

Common technologies employed for tailings dewatering and water recovery include thickeners and filters. A key challenge for sites employing belt press filters and gravity drainage decks is to optimise belt performance and polymer dosing control whilst treating variable ore types and clays that are difficult to dewater.

Polymer addition is critical to the efficacy of the dewatering process with dosing typically adjusted by the filter operator based on visual inspection. The practice of high polymer addition is common to achieve stable filtration over extended periods and to reduce the level of operator supervision. However, the polymer dose may not be sufficient to account for changes in sludge conditions such as flow rate and density. This may lead to a drop in cake dryness, blinding of the belt, reduced reliability and stability of the belt, increase frequency of overspills and ultimately reduced plant productivity and increased treatment costs.

Enhanced polymer dose control requires relevant, accurate and timely monitoring. Focus has been placed on developing a continuous measurement and control system, which detects the topography of the sludge on a belt and accurately adjusts the polymer dose, via proprietary algorithms, to optimise the belt performance amid changing sludge conditions.

This paper will present the advantages of automatic control compared to traditional manual techniques and corroborate these advantages by case studies.

Keywords: *belt filter press, Flocculant, dose control, gravity drainage deck*

1 Introduction

Tailings management has become increasingly more pertinent to the risk management, governance and social licence of a mine operation and the broader mining industry. In traditional wet tailings deposition methods entrainment of large quantities of water poses significant geotechnical challenges and increases risks for those facilities. Long-term industry trends indicate a decline in wet disposal systems with the adoption of best practices and technologies to dewater the tailing from a slurry to a paste in conjunction with advanced tailing storage facility (TSF) design methods. Several mining sectors such as the coal industry mix thickened paste with other coarse solid particulate waste streams to create a more consistent material with higher shear stress that may be transported safely via truck or conveyors and disposed to minimise the geotechnical risks and environmental impact.

Filtration technology such as belt press filters, which have a greater capacity to manage feed ore variability, have become a common method to dewater tailings and recover water. The addition of polymer solutions to the slurry is critical to the dewatering process. Manual operator time is required to monitor and control flocculant dosing, including on sites with proportional flux rate dosage modulation. Operators favour high polymer addition to reduce the level of necessary supervision and ensure stable belt performance during protracted unsupervised periods.

This situation provides the opportunity to develop an automatic, continuous measurement and control system that accurately adjusts the polymer dose to minimise the frequency of events requiring operator intervention, improve belt press overall reliability and stability, cake dryness, plant productivity and reduce treatment costs amid changing sludge conditions.

The development process of the control system included the following key steps:

1. Field observations of flocculant dosage dependant dewatering behaviour.
2. Formation of theoretical models based on field observations.
3. Desktop review of sensors against theoretical models and selection for field trials (Low Fidelity Piloting).
4. Field piloting of sensors (High Fidelity Piloting).
5. Development of experimental control philosophy and conformation of field observations.
6. Ongoing evaluation and continuous improvement.

Trials were conducted at a coal handling and preparation (CHPP) plant in NSW, Australia, where the process was regarded as quite variable, with no blending of incoming feed and deliveries of raw coal arriving from alternating active mine areas.

The work objective was to compare the sites existing manually controlled process to the automatic control system. The main body of work was conducted on difficult to treat ore containing high levels of clay.

2 Methodology

2.1 Field observations of flocculant dosage dependant dewatering behaviour

It is widely understood that polyacrylamide flocculant assisted agglomeration of slurries improves the mechanical retention of solids whilst also improving supernatant fluid permeability through the filter drainage mechanism.

Field observation and interviews provided video, photographic and anecdotal evidence, which demonstrated the following:

- All belt filter press equipment observed typically utilised multiple sets of rakes or ploughs. Furrows were formed post the plough, which fostered the gravity draining of supernatant.
- A tendency to overdose flocculant to improve process stability, as time constraints precluded regular monitoring and manual dose adjustment and the clean-up and loss of production associated with an underdose condition was less favourable.
- Appropriately flocculated agglomerate media retained on a filter membrane possess an overall size that does not block the drainage mechanism.
- Under dosed slurry resulted in very small agglomerated flocs that blocked the drainage mechanism, a phenomenon known as ‘blinding’. This increased the overall volume retained on the filter and swamped the furrows, hampering filtration of supernatant.
- Site investigations found similar behaviour with extreme flocculant overdosage events, where far larger amorphous flocs were formed, which blanketed the filter surface and partially inhibited drainage mechanism. These agglomerates were more rigid and tacky, often adhering to the underside of the belt leaving the compression stage.

In between these underdosed and overdosed extremities, it was noted that there was a broad stable range of predictable cake behaviours that could be controlled by fine modulation of flocculant dosage.

As polyacrylamide flocculant is hydrophilic and is predominately retained with the agglomerated cake, excessive dosage is expected to result in the retention of additional moisture. As such the minimum dosage to maintain the broad stable range of predictable behaviour was expected to yield the lowest possible moisture retained in the cake, reducing the volume of cake reporting to subsequent compression stages of the belt filter press.

2.2 Low Fidelity Prototype selection criteria

In order to conceptualise the type of data required to provide control, two theoretical models of the observed behaviour were established. The first such model was known as the 'Plateau' model, shown in Figure 1.

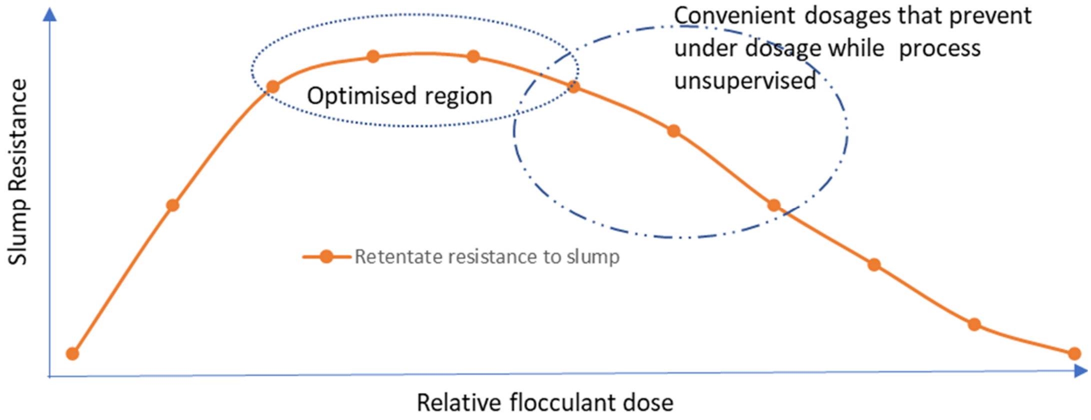

Figure 1 The Plateau model for behaviour

The Plateau represented the observed stable zone where dosage of flocculant lower than that selected by site operations was expected to yield the highest slump resistance of cake via supernatant volume filtration, whilst retaining fine particles in well formed, non-blinding agglomerates. Typical flocculant minimum adjustment resolution is 1% of the total flow capacity of the pump. The difference between the optimised flocculant dose and the convenient stable dose for unsupervised periods can vary drastically between industries and plants. It has been observed that some sites use 25–75% greater than the required, optimal dosage of polymer flocculant.

Performance of the flocculant deteriorates post the optimised region and whilst the quantity of water released and the rheology of the media is better than when flocculant is underdosed, it is inferior to that achieved when the polymer dose is in the optimised region.

The Plateau model provided a goal for a control philosophy. Observations of the cake behaviour post the rake and ploughs during underdose, optimal and overdose conditions demonstrated a correlation between flocculant dose and cake behaviour as per the Plateau model (refer to Figure 2).

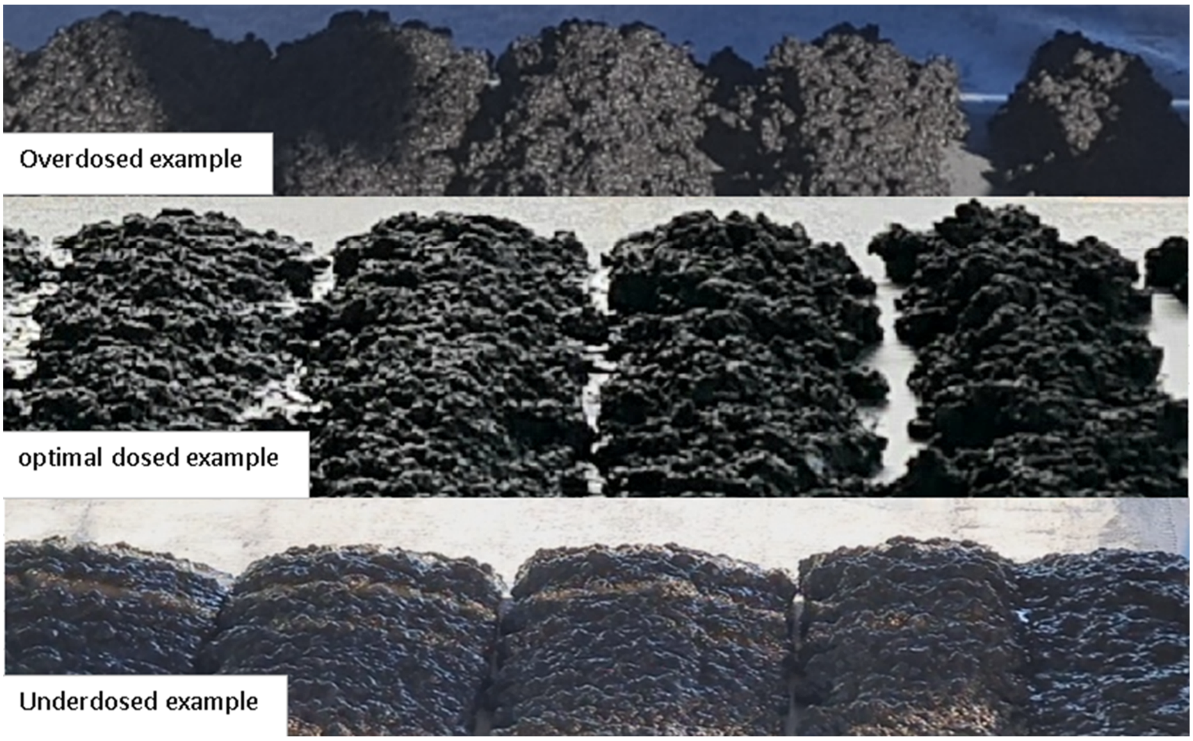

Figure 2 Plough observations in under, optimal and overdose examples

In Figure 2 the low points correspond with the location of the ploughs. The furrows offer an opportunity for additional drainage of surface water compared to furrows that are impacted by the presence of slumped media.

Underdosing results in media that is prone to slumping into the furrows and covering the majority of the filter surface due to the high volume of supernatant retained and the tendency for that supernatant to promote liquefaction. The overdose example represents moderate overdosing, where the media is more rigid due to the flocculant concentration with a larger overall cross-sectional area, from which a larger volume can be calculated over time in conjunction with the belt speed. Optimally dosed media yields distinctive furrows that allow filtration of supernatant and are not subject to being filled by liquified solids.

Sensor specifications were evaluated on their capacity to by any means identify the changes observed under a stable dosage condition. Of the wide range of sensors explored, cameras for pixel counting, laser time of flight geometric imaging and vertical laser triangulation geometric imaging were investigated.

2.3 Trials of sensors and selection for High Fidelity Piloting

2.3.1 Fixed laser time of flight geometric imaging

Identified as capable of scanning continuously at high frequency, time of flight laser sensors would scan a point cloud of data from the moving filter belt, providing a topographic surface. Integration of this surface would yield a vertical area consumed by solids which may correspond to the volume of retentate cake, including the volume of cake contributed by moisture. Water chemically retained by flocculant, interstitial between the smallest particles, free water within the uncompressed media and surface water would all reflect the light source to the sensor. Measuring the angle of repose or height of the furrows may provide a yield stress indication similar to a slump test.

Advantages of this method were that a single sensor in a fixed position could potentially image the topography of all the cake.

The disadvantages of this method were that low angles of incidence on wet cake may not yield a strong return signal and may suffer from signal loss on the periphery of the belt. The low angle of incidence would also result in shielding of the furrows on the periphery of the belt by the taller features, resulting in an incomplete topographic image. Finally, in the situation where light penetrates the wet surface, reflects off the solid cake and back through the wet surface to the sensor, the light would return to the sensor later due to the speed of light propagation through water versus air. In this instance, the sensor might select the first signal to return and calculate the distance, or discard the first measurement if the second, delayed measurement is received at a higher magnitude.

2.3.2 Mobile vertical laser triangulation geometric imaging

A high frequency triangulation laser, placed on a linear actuator, was identified as a reliable method of overcoming the potential for signal loss generated by wet surfaces, low angle of incidence target shielding and interference by environmental illumination.

Advantages of this method were that a single high frequency sensor could potentially image the topography of all the cake over a much shorter range, providing higher accuracy and resolution then other methods.

The disadvantages of this method were the need for a linear actuator to move the laser sensor to scan the belt filter width.

2.3.3 Cameras for pixel counting

Cameras were identified as a possible sensor that via pixel counting approach may identify a proportional control philosophy. A set point number of filter colour pixels may relate to an optimal dosage, a low number of filter belt pixels would require more dosage and excess of the setpoint number of filter-coloured pixels would require less dosage.

Advantages of this method were that simple colorimetric analysis with cheap, powered over Ethernet cameras and minimal signal processing would be relatively easy.

The disadvantages of this method were that in practice ploughs would not reliably scrape close enough to the filter belt to move enough material to leave the belt looking ‘clean’ from a colour alone stand point. This would bias the dose rate high. In addition, the method was light exposure sensitive, filter/media contrast sensitive and was always limited to giving a two-dimensional result that could not compensate for fluctuations in slurry flux rate.

Of the three forementioned methods, mobile vertical laser triangulation geometric imaging and fixed laser time of flight geometric imaging were selected for High Fidelity Piloting under field conditions.

2.4 High Fidelity Piloting of sensors

Three commercial laser triangulation sensors with similar sensor specifications, but dissimilar signal output capabilities and one laser time of flight sensor was obtained for field trials, along with a linear actuator powered by a stepper motor.

Trials were conducted over two days at a waste water treatment plant. Filtered cake on the belt filter was waste water sludge, a mix of organic by-products of the sewage treatment processes.

Sensors were installed in a location after the last row of ploughs. Scan data was recorded both passively without altering the flocculant dosage and by increasing/decreasing the dosage in a linear, cyclical manner.

On trial, laser triangulation sensors provided a clear, repeatable, low noise output signal requiring no filtering or signal post-processing to produce a useable topography. The laser time of flight sensor in contrast did not perform well, failing to measure the media height at low angles on incidence and significant noise filtering required to produce a useable topography.

Consequently, a high cycle frequency mobile vertical laser triangulation system, with higher specifications for control philosophy development, was selected for field trials and control philosophy development.

2.5 Development of control philosophy and confirmation of field observations

Passive scanning of media was undertaken to commission and calibrate a high frequency mobile vertical laser triangulation prototype (henceforth known as Flodose Enhanced Filtration Operation (EFO) prototype) under outdoor, partially shaded conditions.

Significant amounts of data were recoded over multiple non-consecutive passive scanning events. A considerable number of cyclic and random periods were identified, where the performance of the belt filter would, under the low fidelity models described earlier, be interpreted as a significant underdosage of flocculant, in spite of the measured flocculant flow rate and calculated slurry flux rate remaining unaltered.

Further investigations identified that the plant secondary dilution system was excessively dependant on the plant water pressure. As demands for water pressure across the plant changed, the pressure fluctuations would reduce the dosage of flocculant and coagulant to the belt filter press independently of the control logic.

2.6 Ongoing evaluation and continuous improvement

The Flodose EFO prototype control philosophy was developed in line with the Low Fidelity model assumptions, in order to maximise the range of vertical displacement observed in consecutive scans, by adjusting the flocculant dosage and observing the result. The Flodose EFO continuously evaluates the media and ensures the range of verticality is maintained by adjusting the Flocculant Pump Speed (FPS). Other media types and qualities are slated for future trial work.

3 Results and discussions

During field trials, the Flodose EFO prototype was put in control of a belt filter press with a reduced initial dosage of 20% (see Figure 3 marker A). The FPS was decreased in 1% steps to 17% (see Figure 3 marker B) where it remained due to a stable optimised zone being detected.

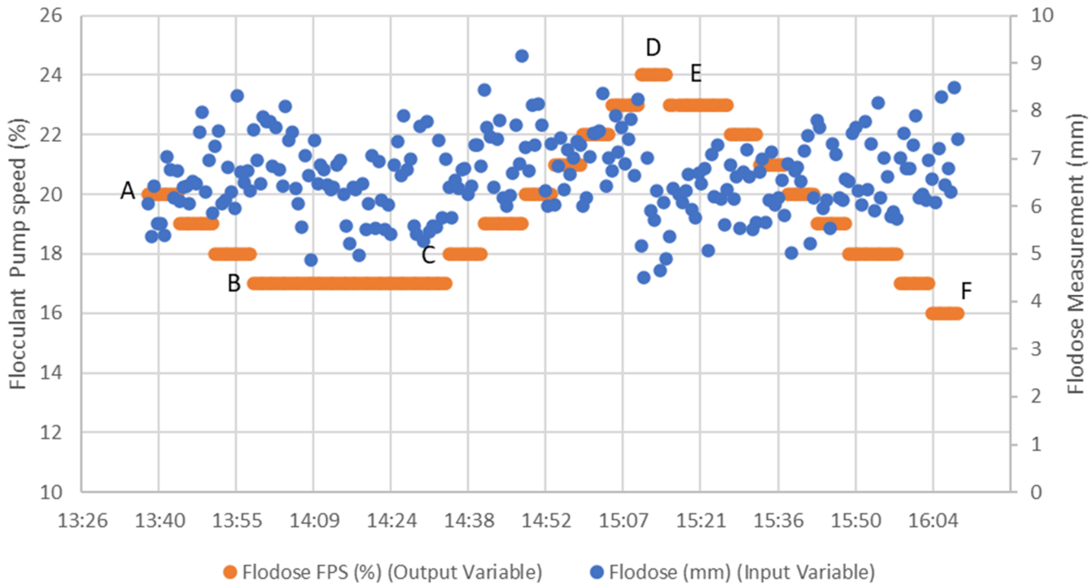

Figure 3 Raw Flodose EFO measurements of topography and Flodose EFO controlled flocculant dose pump speed

Figure 3 marker C identifies the pool of measurements leading to the control logic increasing the FPS for a protracted period. This data however is attributed to moderate underdosing. The main cause for this event was due to the secondary dilution water pressure. As alluded to previously the configuration of the secondary dilution system is subject to pressure fluctuations as demand for water across the plant changes. This event led to a lower water pressure and thus a decrease in the flocculant and coagulant dose rate to the belt filter press independently of the control logic. The Flodose EFO detected the change in topography of the sludge on the belt and correctly increased the dose to bring the system back to a stabilised optimised zone.

Figure 3 marker D with a FPS of 24% sees a dramatic decrease in the Flodose measurement and as such optimisation by decreasing dosage was implemented by the control philosophy at Figure 3 marker E) with the FPS reduced in 1% increments. At Figure 3 marker F dosage was returned to manual control to force a underdose so field samples and Flodose passive measurements could be obtained to complete Figure 4.

The Flodose EFO can be observed to alter and control the FPS in order to maximise the range of vertical displacement observed in consecutive scans at markers A through D in Figure 3.

Observing the cause-and-effect relationship between the FPS alteration and subsequent Flodose EFO measurement, the device demonstrates the ability to respond to changing plant conditions appropriately.

In Figure 4 the Flodose measurement data collected over the trial is presented as an average with standard error, alongside results of total moisture analysis from samples collected and analysed in triplicate over the trial duration. A complex but predominantly inverse relationship between the (orange series) Flodose EFO measurement and the (blue series) residual moisture in the cake media ejected from the compression stage of the belt filter press is presented. As the Flodose EFO operates under the proprietary control algorithm, it continuously finds and maintains the most beneficial media geometry to promote dewatering by adjusting the FPS.

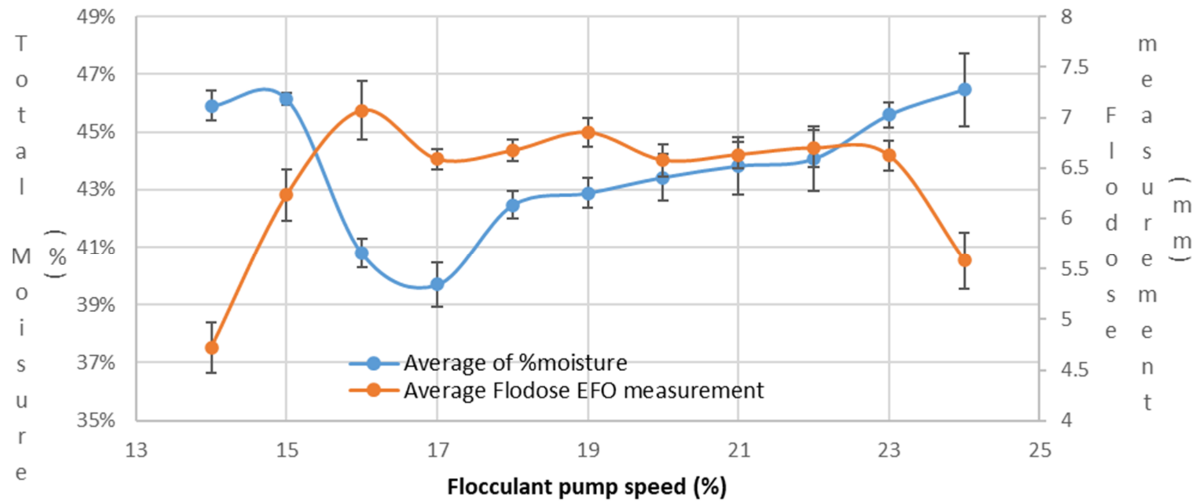

Figure 4 Sampled total moisture versus Flodose measurement for given dosage

In contrast to this approach the FPS would normally be set to a fixed manual speed by operations so the equipment can be left unsupervised. On the day of the trial the belt filter was handed over to SNF with a constant FPS of 22%.

Flodose EFO determined that at times the most optimal dosage was between 16% and 17% FPS, representing a 29–37% reduction in flocculant consumption.

Simultaneously the moisture content of the filter cake was reduced by 3–4% representing an 8–11% reduction in the moisture content.

The media when ejected from the site conveyor system stacked more vertically with drastically reduced tendency to slump. More cake could be loaded into each front-end loader bucket and the material could be loaded out for disposal without the need for blending with course reject to prevent solid liquefaction in the tray of the haulage trucks.

4 Conclusion

Flodose EFO continuously measured the sludge on a belt filter press at an operating CHPP and successfully automated flocculant dose control, via proprietary algorithms, to optimise the belt press performance. The field trial demonstrated the sensor technology's ability to provide evidence of previously anecdotal process interruptions and assist in process improvements expected to provide further performance gains in the future. The control philosophy provided responses to changes in sludge conditions without operator intervention, whilst reducing the flocculant dose rate relative to the manual, fixed-dose rate typically employed by the site. The flocculant consumption was reduced by 29–37% during the trial period, representing a significant reduction in reagent costs.

The stability and reliability of the belt was enhanced, which leads to a decrease in operation downtime and an increase in belt throughput. This coincided with improved filter cake consistency and a reduction in moisture content of 8–11%. Consequently, more filter cake could be loaded for disposal without the requirement for blending with course reject to prevent solid liquefaction in the tray of the haulage truck. This improves the ease of disposal and reduces treatment costs. Further work is underway to develop the technology from two perspectives. Firstly, to optimise the process ensuring a robust solution that continuously measures and controls flocculant dosing, enhances belt performance amid changing sludge conditions and minimises operator intervention. Secondly, broaden the application to other separation technologies such as solid bowl centrifuge, other filtration processes and secondary flocculation; with the development of a prototype for secondary flocculation well advanced.

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