LiDAR optimisation of belt press filter flocculant dosing

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Abstract The move away from tailings dams in minerals processing has led to an increase in dry tailings disposal using Belt-Press Filters (BPFs) for coal tailings dewatering, especially in Australia and North America. Typically, BPF flocculation control involves operators manually monitoring and adjusting parameters based on the filter profile via direct observation or CCTV, which can be limited by camera quality and operator availability. To reduce monitoring needs and maintain manageable filter cake, over-flocculation is common, though it raises operational costs, with estimated over-spends of $36,400 annually per filter on typical Bowen Basin coals. Optical colourimetric systems have been developed to optimise flocculant dosing by measuring the filter cake, though they have limitations such as image blinding due to sunrise/sunset and build-up on lenses. This project examined the use of 3D camera and LiDAR technologies to measure the surface profile of the filter cake on a belt press filter and identify the relationship with flocculant dosing levels. Data from these technologies can help develop a more effective flocculant dosing control strategy, minimising costs and maintaining operational efficiency.

1 Introduction

Belt press filters (BPF) are key equipment in mineral processing. A BPF is a continuous dewatering device [1] where a flocculated slurry is distributed across a semi-permeable belt. In the initial form zone a series of ploughs will create discrete rows of slurry and a portion of the water will free drain prior to the introduction of a second belt on top of the solids. The drained solids are held between the two cloths while they pass through a series of rollers in the squeeze zone. The squeeze rollers and two cloths apply pressure and some cloth shearing to further separate the slurry into a filtrate, which passes through the cloths, and a remaining solid cake.

One of the key challenges in the control of this equipment is the lack of real-time feedback on operational performance. The most common control methodology involves visually inspecting the material as it exits the form zone and prior to the introduction of the upper cloth to confirm flocculant dosing is sufficient and the cake is being dewatered appropriately.

There are several feed and machine parameters that influence the capacity and dewatering efficiency of the BPFs including feed tonnage, feed percent solids, filter cloth speed and filter cloth tension, but the main process variables to influence operation of the system are the addition of cationic and anionic flocculants. Cationic and anionic flocculants assist in the

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removal of wastewater by binding solid particles together allowing free water to drain away. The extent of dewatering will alter the appearance and physical characteristics of the dewatered material particularly as the flocculated slurry passes the ploughs and during the form zone. Filter material where the flocculant has been underdosed will resemble a mostly flat surface of wet sloppy mud due to lack of water that has been released and free drained. Material that is overdosed with flocculant will have defined upright “cornrows” due to the majority of the free water draining away and the cake holding more of a solid structure. The cornrows are formed by fixed ploughs further upstream that are designed to separate the draining solids into rows to enhance the free drainage of water to the cloth.

Although the other variables can have an impact, for the purpose of this project these variables were kept consistent and only anionic “flocculant” dosing rate was altered.

The current process for belt press filter operation involves an operator manually monitoring the belt press filter profile either in person or via a CCTV network. This process is limited by the quality of the camera feeds and the availability of the operators. To keep the filter operation in a safe state, it is common to overdose the filter feed, but this increases operational costs in terms of flocculant consumption. Over-flocculation can also increase the cake thickness and reduce the feed mobility which can lead to issues of poor feed distribution and the potential to fold or tear the cloths as they pass through the squeeze zone.

Fig. 1. Flocculant underdosed material with mud-like appearance

Fig. 2. Flocculant overdosed material with distinct and separated cornrows

Although underdosed and overdosed states are very easy to visually identify in their extremes, optimising this process is difficult due to varying plant conditions and BPF feed properties. As a result, operators will tend to overdose the material with flocculant to ensure they meet the minimum dewatering requirements. This practice of over flocculation, however, has been estimated to cost an operation up to $36,400 per annum per filter in excess flocculant consumption.

The project challenge was to quantify the state of the BPF operation using modern technology to measure the profile of the filter cake as a measure of health. A LiDAR unit and a 3D camera were trialled initially, however, the 3D camera was deemed not fit for purpose due to low precision distance measurement and operational issues, such as blinding, making the unit unreliable under plant conditions. Camera feed was, however, used to qualitatively validate the LiDAR test results.

LiDAR is a laser-based ranging technology that works on the time-of-flight principle, similar to radar units. The LiDAR unit will send out a laser in the invisible light spectrum and measure the time the laser takes to bounce off an object and return. This will then provide the system with a distance measurement.

As LiDAR technology has improved and price point reduced in recent times, it has become a viable solution for creating a virtual map of surfaces, such as the profile along the BPF. By installing a LiDAR unit above the BPF a 2D profile or "contour" across the belt could be produced. Analytical techniques could then be applied to these contours to correlate BPF performance to various process and control variables.

2 Project objective

The aim of this project was to investigate if modern sensor technology is fit for measuring a surface profile across the cake on a belt press filter and to quantify a link with flocculant dosing levels. By testing 3D camera and LiDAR technology, a 2D cake profile was developed and used to generate cake profile metrics to assist with developing a control philosophy for flocculant dosing control. Successful application of either technology as part of an operator advisory system or flocculant control system will provide industry the opportunity to optimise and potentially fully automate all aspects of the operation of the BPFs. The 3D camera was eliminated early on in field testing, with only LiDAR measurement results reported herein.

3 Methodology

A LiDAR unit was installed above a single BPF on an operating Coal Processing Plant. An industrial PC was installed in a nearby enclosure to facilitate data processing and transmitting data offsite to cloud storage. The figure below outlines the installation architecture.

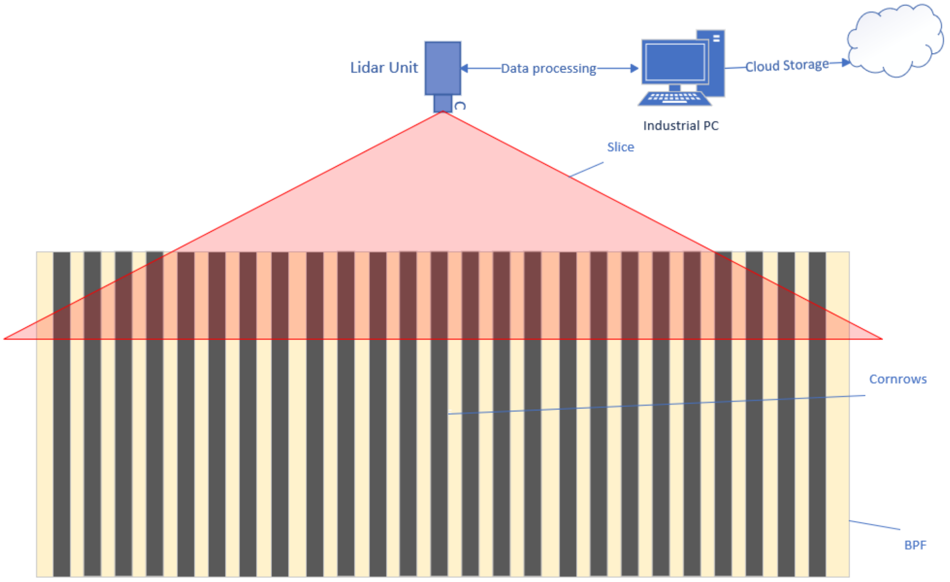

Fig. 3. Site BPF installation concept diagram

After initial installation, approximately 30 minutes of video and processed signal were captured. Over this period, an operator cycled through three rates of flocculant dosing. The operator cycled the system from a state of flocculant underdosing to a state of flocculant overdosing and then back to an optimal, or "healthy state" of flocculant dosing.

This period allowed for approximately 700 contours to be taken. These samples were saved in cloud storage so they could be analysed at a future date.

Having the 700 samples alongside 30 minutes of video allowed for confirmation of the visual appearance of the cake profile at the end of the form zone at different states of flocculant dosing during the analysis phase.

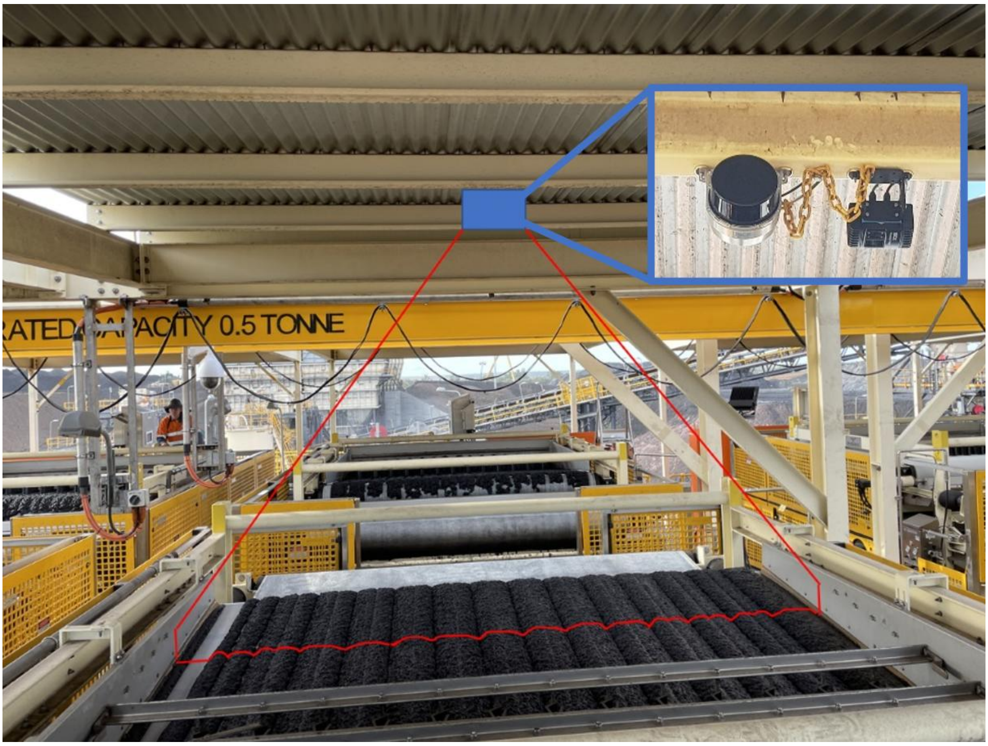

Fig. 4. Actual site BPF installation

4 Results and discussion

4.1 Initial test summary

A 50-minute test period was undertaken where the operator cycled the BPF between three states. The BPF was initially set to what the operator determined to be a "healthy" operating state, then changed to a underdosing state, back to a healthy state and then to an overdosing state. Each test was run for only for a short duration with the filter allowed to visually reach steady state between each test. During the tests the volumetric feed rate to the filter was controlled to 60 m^3/h and the belt filter speed was maintained at 60 percent speed, with a coagulant setpoint of 10 L/Hr. These were kept constant throughout the tests. The following table outlines the flocculant changes over the test period.

Table 1. Test run summary

Test	Flocculant Setpoint (L/Hr)	Visual Assessment of State
Baseline	750	Healthy
1	450	Flocculant underdosed
2	750	Healthy
3	1150	Apparent flocculant overdose, but visually not different to "Healthy"
4	1500	Flocculant overdosed

The comments under "Visual Assessment of State" highlight issues with the current procedure for operating a BPF. Operators adjust the flocculant level to what is visually assessed as being a healthy state. However, changes in feed type or other external factors can prevent the system from responding as expected. This was demonstrated during the shift from test 2 to test 3, where the operator tried to overdose the system. Despite this, the system appeared visually similar to a healthy state.

Fig. 5. Test 1 (left) & Test 4 (right)

4.2 Calculated variables

The LiDAR unit returns a raw contour across the BPF, a processing script then analyses the contour and returns four calculated variables:

- **Primary Trough** – Troughs created by the second set of ploughs. More defined as they are closer to where the LiDAR contour is taken and after any other disturbance of the cake layer.
- **Secondary Trough** – Troughs created by the first set of ploughs of the BPF. The second set of ploughs will push material to fill in these troughs under normal operations, resulting in their height being less than the primary troughs.
- **Secondary Trough to Peak Height Difference** – The distance between the secondary trough height and peak height.
- **Average Peak Height** – Peaks are considered the highest point between secondary and primary troughs. This value is an average of highest peaks across the entire belt width.

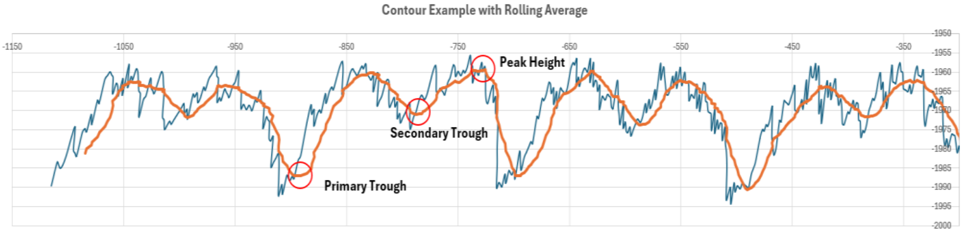

Fig. 6. Raw LiDAR contour

The calculated variables were generated and trended for the full 50-minute time period where video recording was available.

When analysing the videos, several conclusions can be made. Trough height variables are at their minimum when run at an underdosing condition. This is due to the cake having too much moisture to be able to form stable solid structures or cornrows. The sloppy cake collapses or flows back into the ploughed gaps. When the system is overdosed with flocculant, very defined primary and secondary cornrows can be observed as the material is substantially more competent with minimal slumping. When the filter is in a healthy dosing state, primary and secondary cornrows are visible; however, they are less prominent than when the system is overdosed.

4.3 Test results

4.3.1 Underdosing state results

Test 1, the operator visually identified the system as underdosed at a dosing rate of 450 L/Hr.

Table 2. Test 1 underdosing calculated variable results

Calc. Variable (KPI)	**Median**	**Mean**	**Std Dev**
Pri. Trough Height (mm)	11.98	11.87	2.57
Sec. Trough Height (mm)	7.74	3.55	4.28
Sec. Trough to Peak Height Diff. (%)	73.01	74.25	11.12
Avg. Peak Height (mm)	**30.73**	**31.83**	**3.55**

4.3.2 Healthy dosing state results

Tests 2 and 3 healthy results were combined as measurements were statistically the same. The operator visually identified the filter as healthy at a dosing rate of 750 L/Hr and 1150 L/Hr.

Table 3. Test 2 & 3 healthy dosing calculated variable results

Calc. Variable (KPI)	**Median**	**Mean**	**Std Dev**
Pri. Trough Height (mm)	14.46	14.58	5.45
Sec. Trough Height (mm)	5.93	6.51	6.09
Sec. Trough to Peak Height Diff. (%)	83.60	83.19	15.28
Avg. Peak Height (mm)	**36.52**	**35.88**	**4.56**

4.3.3 Overdosing state results

Test 4 the operator identified the system as overdosed at a dosing rate of 1500 L/Hr.

Table 4. Test 4 overdosing calculated variable results

Calc. Variable (KPI)	**Median**	**Mean**	**Std Dev**
Pri. Trough Height (mm)	16.71	16.60	1.751
Sec. Trough Height (mm)	8.57	8.69	2.45
Sec. Trough to Peak Height Diff. (%)	78.68	77.63	6.99
Avg. Peak Height (mm)	**39.49**	**39.21**	**2.05**

4.4 Discussion

The LiDAR sensor proved robust and fit-for-purpose under difficult plant conditions. The LiDAR did not succumb to image blinding from direct or reflected sunlight giving it an advantage over optical colourimetric systems currently available on the market.

The tables in the results show averaged results of the calculated variables over periods of healthy, underdosing and overdosing that were identified by correlating videos and LiDAR data results. The calculated trough measures correlated visually with the video imagery captured at the time.

Overall, it was established that the flocculant dosing rate was directly proportional to the peak height, but that apparently healthy cakes could be achieved over a range of potential dosing rates. As expected, it was observed that the average peak height is lowest when the system is heavily underdosed and highest when the system is overdosed with healthy somewhere in between. The results validated average peak height is a key indicator for identifying healthy operation and the other variables may be secondary indicators.

Tests 2 and 3 together, demonstrate that the healthy state is not necessarily at a single flocculant dosing set point. It might cover a dosing band and change based on feed type.

At the Test 4 dosing rate of 1500 L/Hr it was well accepted that this was flocculant overdosing; however, at the Test 3 dosing rate of 1150 L/Hr, it was suspected that this might be overdosing, but visually the filter cake appeared healthy or had not been given sufficient time to achieve steady state. This is the exact scenario the test work aimed to target. At this state, there is an opportunity to optimise the dosing rate, as it was already shown that similar cake conditions were achieved at a dosing rate of 750 L/Hr (Test 2).

So, by using the difference of the dosing rates from Test 2 and 3, we can calculate the annualised saving if filter efficiency could be maintained while dosing at the lower rate.

Table 5. BFP LiDAR optimisation potential (per BPF unit)

Parameter	Value (p.a.)
Site Annualised BPF Powder Usage per BPF (kg)	21,000
Proportion of Time Overdosing (@1150 L/hr)	50%
Dose Reduction (from 1150 to 750 L/hr)	35%
Potential Powder Reduction per BPF (kg)	3,675
Potential Powder savings per BPF per Year (@$3/kg)	**$ 11,025**

Table 6. BFP LiDAR optimisation potential (indicative site with 6 BPFs)

Parameter	Value (p.a.)
Potential Powder savings per BPF per Year (@$3/kg)	$ 11,025
Indicative Installation of ~6 BPF Units	$ 66,150
Labour savings (0.5 FTE Operator @ $140k)	$ 70,000
Maintenance savings (1 cloth replacement)	$ 45,000
Total	**$ 181,150**

The flocculant powder savings result of $11,025 per filter per annum (Table 5) is much lower than the value hypothesis of $36,400. However, collectively for the filter installation, considering reduction in continuous operator monitoring and intervention and preventative maintenance benefits, the total opportunity could be in the range of $180,000 per annum, or $30,000 per filter (Table 6). This does not take into account tailings deposition costs including handleability, rehandle and pit slumping costs.

5 Conclusion

The project was successful in proving that LiDAR technology was sufficient in measuring the profile of a BPF cake and inferring calculated variables that could be used as a measure of cake health and allow for automated flocculant dosing optimisation. The technology provided additional quantitative feedback to complement visual observations. The test results also validated the potential value of dosing optimisation on flocculant consumption. The next phase of this project will target the development of a suitable control algorithm from the calculated variables to control flocculant dosing. In addition, project works will look at monitoring feed tonnage control and feed distribution across each unit. This will involve extended site testing, including cake moisture analysis, and implementation of modified control logic into the flocculant control loop. Other opportunities for an “end-state” monitoring and control solution include dynamically controlled reagent parameters, reduced operator monitoring and supervision, as well as preventative maintenance opportunities by identifying cloth folds or damage in feed off conditions.

Reference

1. D. Mathewson, D. Eschebach, Belt Press Filter Handbook, ACARP Project C23040 (2015)