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UTILIZATION OF THE SMARTDIVER TO IMPROVE CONTROL OF SETTLERS, WASHERS AND TAILINGS THICKENERS

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Abstract

The key parameters for the effective control of settlers and washers are interface and mud level. Manual measurement of these is risky and labour intensive. Using Smartdiver, it is now possible to automatically track suspended solids and density within the entire profile of the vessel, providing more accurate measurement of interface and mud levels that are easily integrated with a control system.

Using this data , control strategies of varying complexity from standard feedback to feed forward and model predictive control can be employed, resulting in significant reduction in overflow suspended solids with minimum flocculant consumption.

Enhanced control of mud level can increase underflow density resulting in less liquor passing to washers in the case of settlers, whilst improving the efficiency of washers within a CCD circuit. Increased underflow density in tailings thickener will reduce the volume of slurry entering the tailings dam, subsequently increasing its lifespan.

By optimizing the performance of settlers, washers and tailings thickeners, significant cost and environmental benefits can be achieved with the use of Smartdiver.

Introduction

A gravity thickener is a vessel that separates the solid and liquid components of a slurry stream. This is achieved through the difference in density between the solids component of the slurry and the liquid component. As the solids are denser than the liquid, they will settle to the bottom of the thickener. This creates a stratum of material with a higher solids concentration than the input slurry stream. This stratum is considered to start, where the density of the slurry reaches a nominal value. This is commonly called the mud layer. A stratum of low solids concentration (hopefully zero) slurry will conversely be present at the top of the thickener. This stratum is considered to start where the solids reach a preset value, usually in grams per litre (gpl). From this point to the mud layer is commonly referred to as the interface layer. Anything above the interface level is considered to be essentially free of solids, however the closer the interface level is to the outlet the higher the risk of solids entering the overflow.

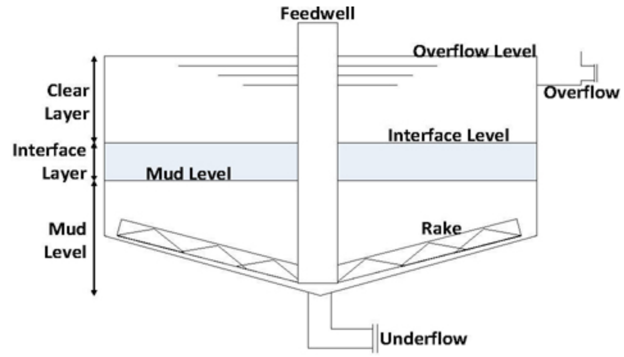

Figure 1: Cross section of a typical gravity thickener showing different settling zones.

After this separation, different processing can occur on the different streams.

Thickener underflow density is affected by a number of factors. These include the height of mud layer, tonnage of solids entering the thickener, particle size distribution and rake performance. The height of the mud layer is the only variable that can be manipulated easily online. The other factors are either results of earlier sections of the process, in the case of tonnage of solids entering the thickener, particle size distribution or mechanical devices without the ability to be manipulated online, such as the rake.

The underflow pump rate is manipulated, in order to change the mud height in the thickener. The solids input can be controlled however this is usually pre-determined by the feed entering the thickener from the previous unit operations.

Thickener interface level is affected predominantly by the dry flocculant flow rate. This can be changed by varying the flocculant concentration, or the flow rate of the flocculant, which is the most common method used.

PROCESS

Thickeners are a common unit operation in many mineral operations. There are three main applications where thickeners are utilised. The main thickener unit operations are as settlers, washers and tailings thickeners. The aim of a settler is to separate the tailings and the liquor, a washer's purpose is to reduce the concentration of reagents entering the tailings dam whilst also reclaiming these reagents if possible and in a usually related function to the washers, the aim of the tailings thickener is to ensure that the tailings are pumped away with the least entrained liquor possible.

There are two aims of a thickener. These are to have zero solids reporting to the overflow and all the solids reporting to the underflow with the least amount of liquor possible ie high underflow solids concentration. The consequence of high

overflow and low underflow solids, will determine the process and application for which the thickener is utilized.
Maintaining a high settler underflow density is vital to reducing the quantity of liquor going to a washing circuit. If excess liquor goes to the washing circuit, high reagent concentrations may result which is not desirable from an environmental perspective. It is also not desirable from a cost perspective as the reagent may possibly be reusable.
The aim of the washer is to maintain high underflow density so that additional wash water from the previous washing stage can be added due to the reduction in volume of the underflow. Again as with settlers, it is important not to have overflow solids going to the next washing stage, since flocculant, an additive to increase settling in the vessel, is expensive hence its control is vital. Excess flocculation can also cause operational issues such as 'bogging' of the underflow and poor settling.
The aim of a tailings thickener is to increase the percentage underflow solids to the highest level that can be pumped. This will increase the life of the tailings dam due to the lower levels of liquor entering it. Increasing the volume of tailings dams is a high capital cost item for mineral processing plant operators.

How is measurement achieved?

The mud and interface levels have traditionally been measured using a large tube and extracting what is essentially a 'core' of the thickener. This is then visually inspected and underflow pumping and flocculant rates are varied on this basis. This test is difficult, risky and requires multiple persons to perform it as the tube is very awkward to handle. Over the years a number of automatic methods have been devised. These include ultrasonic, radar and systems based on density and clarity. The most successful automated methods used have been based on density and clarity. In many such systems two different methods are utilised to obtain the interface and mud levels. This is why a measurement technique that will work on detecting a density difference which would be suitable for detecting the mud level would not succeed in identifying the interface level as the change would be too small to detect. Using a probe that would be suitable for detecting the interface would result in the instrument being saturated before a suitable mud level could be detected.
A system used to detect mud level can be based on a 'float' of material with a known area and density that will sink in the clear and interface layer but float on the mud layer. Anything that doesn't react with liquor can be utilised. This float will be lowered into the thickener until the tension in the wire lowering the plate is reduced. When the tension is sufficiently reduced the height is recorded and the wire is retracted. The tension in the line reduces as the plate begins to float with increasing density. This point is recorded as the mud level.
Many level switches utilise the same principle. Probably the most common example is that of the toilet. As the water level rise, a float in the toilet tank rises, forcing a valve to close. In our application the point where the plate floats is recorded rather than directly controlling a valve.
An example of a float type probe that would be lowered is shown in Figure 2.

Figure 2: Ball float utilised in various thickeners.

A system to detect the interface level is based on a clarity probe being lowered into the thickener. Once the clarity hits a predetermined value the depth is recorded and this is measured as the interface level.
An example of a clarity probe is shown in Figure 3.

Figure 3: Example of a clarity probe.

As an extension of this concept the PLA Smartdiver was developed. The Smartdiver works by utilising a probe which provides a solids and interface measurement through the use of a clarity / suspended solids sensor which applies acoustic attenuation to measure density attached to a lowering mechanism shown in Figure 4. This complete unit sits on top of the settler or washer. This means that detection of the mud and interface level can be done on a single, reliable lowering mechanism which reduces maintenance and operational cost for thickener applications.

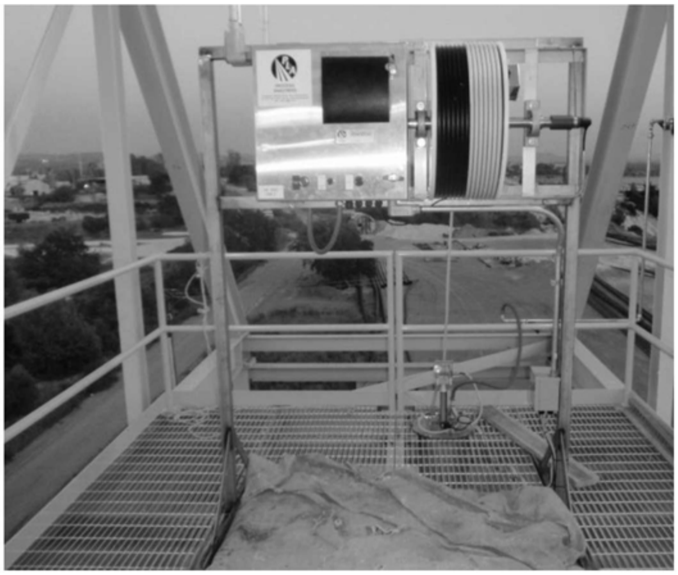

Figure 4: Retraction mechanism utilised by the smartdiver

These techniques all work on the settlers and the washers in the same way. The main difference is that the settlers will operate at a higher temperature and higher saturation level than the washers. This leads to more scaling which ultimately means more maintenance for units operating in the settlers than in the washers.
The main issue with all systems based on lowering probes into the thickeners, is that they provide semi-continuous control rather than continuous control as the probes need to be drawn back to the top of the thickener. This allows for the cleaning of the probes and for the passage of the rake without damaging the probe.
Although this is not ideal, for a thickener it is not a major issue. The reason for this is that thickeners are large vessels when compared to the inlet flow of slurry. This means that changes that do occur tend to happen slowly so this type of semi-continuous control works well as long as it's taken into account in the control strategy.

Methodology

The simplest form of control is feedback control. Feedback control mitigates the effect of a disturbance by measuring the effect on the process variable and adjusting the manipulated variable accordingly (Erickson K.T, Hedrick J.L 1999).
Once this control is established, this can be enhanced with feed forward or model predictive control. Feedforward control measures the disturbance and changes the manipulated variable in the order to counteract the disturbance before it affects the process variable (Erickson K.T, Hedrick J.L 1999).
Model predictive control selects control actions which we think will lead to the best predicted outcome (or output) over some limited horizon (Rossiter J.A 2013).
Generally feedback and feed forward / model predicative control work in tandem. The feedforward controller does not introduce instability into the closed-loop system since there is no feedback loop from the process variable back to the disturbance (Erickson K.T, Hendrick J.L 1999). The feedfoward / model predictive control should create less variability in the process variable entering the system which means that the feedback control will have to change the manipulated variable less.

Feedback Mud Level Control

Mud level needs to be controlled so that the level does not go too high with the consequence of underflow pumping issues or solids to overflow the settler. Mud level is controlled through the change of the settler underflow pumping rate. The higher the level the higher the mud flow pumping rate required.
See Figure 5 for a control schematic of settler underflow pumping control strategy.

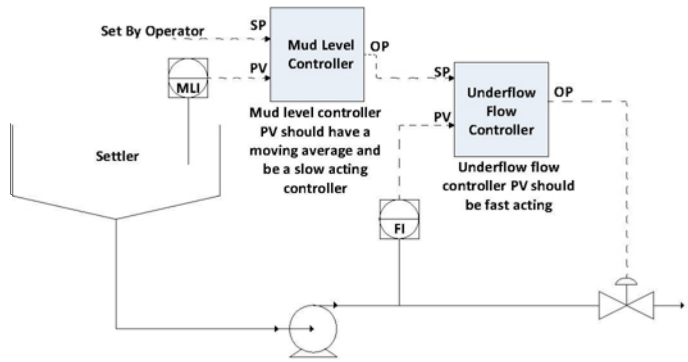

Figure 5: Mud level control utilising a PLA Smartdiver

The nature of the process means that this system is very slow moving due to the large volume of the settler compared to the flow rate entering the settler. Additionally, due to the non-continuous nature of the control some data manipulation is highly recommended. The mud level indication process variable (PV) should utilise a moving average. A moving average will take the last 'x' number of raw samples and average them. Additionally this has the effect of dampening the effect of any single erroneous dives that isn't picked up by the Smartdiver's own erroneous dive removal facility.
As can be seen in Figure 5 the level control cascades to the underflow pump flow control. In this situation the level control should be tuned so that it is a very slow acting controller. The actual flow controller (which receives its set point from the slow acting level controller) on the pump should be a fast acting flow controller. This way variation is not unnecessarily added to the washing circuit which can harm washer efficiency.
This type of control will not result in flat mud level control. This is the intention as it is preferential to vary the mud level (within limits) rather than the flow rate to the washers to compensate for any process disturbances.

Feedback Interface Control

Interface level control is utilised to ensure that the overflow solids concentration doesn't get too high whilst minimising the quantity of flocculant utilised. Interface control can be achieved in two different ways.
The first is that the interface level controller is cascaded into the flocculant flow control. This level PV would need to utilise a moving average to dampen the effect of any single erroneous dive and the level controller should act slowly. This is essentially the same control as for the mud level control however the control action should be faster as the interface level can change more rapidly than the mud level. Problems can arise with this control strategy if the mud and interface levels are close together. If the mud level rises above the interface, the interface will continue to

add flocculant which can exacerbate the issue causing the mud level to rise.

The second and preferred strategy is to utilise a differential controller. A differential controller controls the difference between the interface and mud level. For example if the mud level PV is 3m and the interface differential controller SP is 1m, the interface level will attempt to control to 2m. In a fast tuned system this may result in set point changes in the interface control which are too quick however the mud level control is a very slow acting controller so the set point changes will also be slow. This type of strategy eliminates any issues caused by the mud and interface levels overlapping.

A control block strategy is shown as Figure 6.

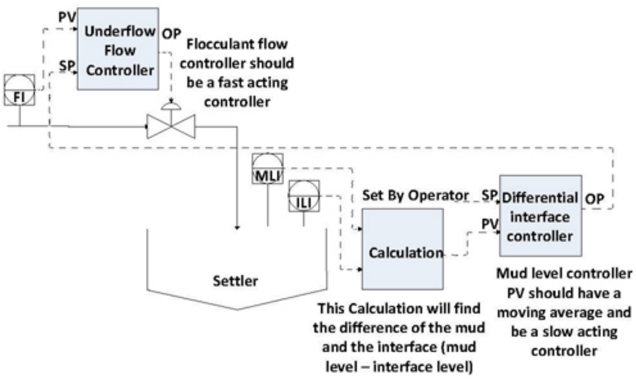

Figure 6: Interface control using the PLA Smartdiver

Feedforward / Model Predictive Control

The previously mentioned control strategies are feedback systems. It is possible to establish feedforward control on both the mud and interface level. This will work most effectively if the tonnage of solids entering the settler or washer is known. If the density is not known then it is possible to base the feedforward control on the flow rate entering the settler or washer. This will not be as accurate as if the tonnage is known however the feedback control will compensate for the variations in density.

Feedforward Mud Level Control

Mud level control can be enhanced through the use of feedforward control. By understanding what the tonnage of solids per hour entering the system this can be used to manipulate the underflow pumping rate. This is a mass balance as all solids entering the settler must exit through the underflow. The feedback control is still vital as it provides a correction for any disturbances or small time delay's in the system.

For a control block diagram see Figure 7.

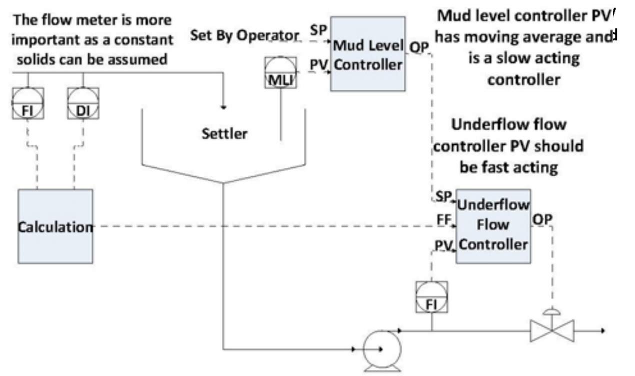

Figure 7: Mud level control with feedforward using the PLA Smartdiver

Model Predictive Interface level control

Interface control can also be enhanced through the use of model predictive control. One method of improving flocculant performance (and thus reducing consumption) is to dose the correct amount of flocculant on a per tonne of solids basis. If the solids flow rate into the settler is known (or approximated based on the slurry flow rate and a constant concentration) then the flocculant flow rate can be determined and corrected through feedback control from the Smartdiver. This is the most efficient form of flocculant dosing. This can be calculated by utilising the flow rate and concentration of the flocculant to determine how many grams of flocculant are being dosed and dividing this by the tonnes of solids which is calculated by multiplying the density (or an assumed density if a density meter isn't present) and the flow rate. This can be used in tandem with feedback control which utilises the interface level as the measured variable.

For a control block diagram see Figure 8.

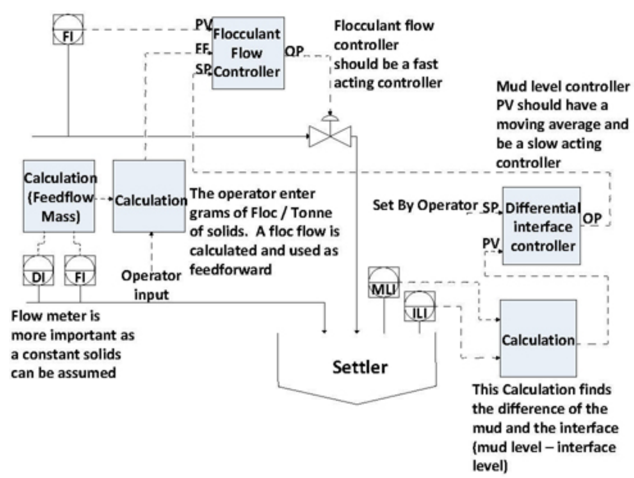

Figure 8: Interface level control with feedforward utilising the PLA Smartdiver

Control strategies for washers

All the control strategies described above are also valid for use in standard washers with some small modifications depending on the type of washer.

The advantages of the Smartdiver for use on washers revolve around reducing flocculant consumption and maintaining high underflow density that enhance washing efficiency. Improved control in the washers can result in substantial savings in flocculant and reagent consumption (as more reagents or product can possibly be returned to the circuit) and improved environmental performance as well as capital savings through the increase in lifespan of the tailings dam if this is the final stage of tailings thickening.

Control strategies for Tailings Thickeners

All the control strategies described above are also valid for use in tailings thickeners.
The advantage of the Smartdiver for use on tailings thickeners revolve around increasing the underflow density, giving cleaner overflow for other unit operations in the plant and reduced flocculant consumption. Substantial capital savings can be made by increasing the tailings density as it will increase the lifespan of the tailings dam. Maintenance cost savings can be made through lower solids being in the tailings thickener overflow. This is commonly used in other unit operations which are generally not designed for high solids which if present can cause issues. Flocculant consumption can also be reduced as the control will give more accurate dosage of the flocculant into the system.

Results

A control strategy which was implemented with documented results, utilised the feedforward control for the mud level control and model predictive control for the flocculant control. In figure 9 we see the clarity, which is a measurement of the solids reporting to the overflow. The data shows measurements before the control strategy was implemented, a transition period to allow the process to stabilise and for operations to understand the running of the control strategy. Thereafter, the control strategy ran in a stable fashion.

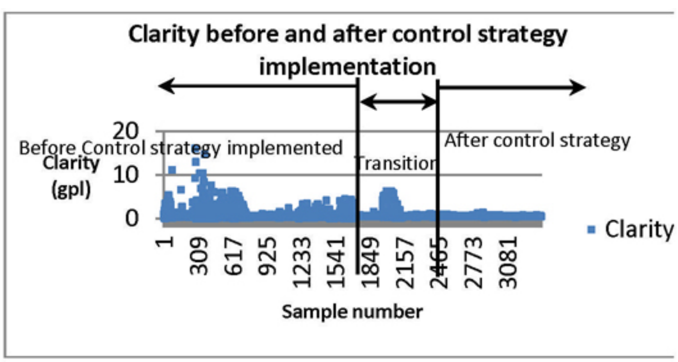

Figure 9: Chart showing clarity before and after implementation of feedback and feedforward / model predicative control

The clarity mean before the control strategy implementation was 0.94 gpl with a standard deviation of 1.2. During the transition period the clarity mean was 1.00 gpl with a standard deviation of 1.22. After the control strategy is implemented and the process is stabilised the mean is 0.58 gpl with a standard deviation of 0.087. This is a substantial improvement in performance.

Unfortunately no underflow density or flocculant consumption was recorded at the time. Figure 10 shows the change in underflow density utilising a similar control strategy. Anecdotally there has been substantial reduction in flocculant consumption.

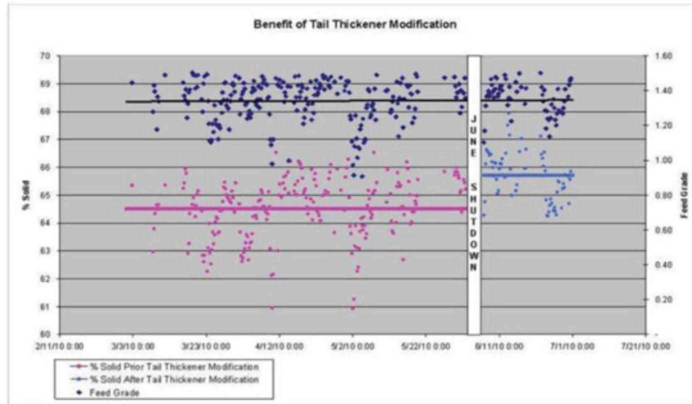

Figure 10: Change in thickener underflow density utilising a similar control strategy (Weidenbach M. and Lombardi J.)

Conclusion

In summary the Smartdiver is low capital, low maintenance option to improve thickener clarity, mud density and reduce flocculant consumption for mud circuit and CCD applications.
In settlers, decreased overflow solids % reduces the load of the wash circuit which greatly improves washer performance and efficiency.
In washers increased underflow solids % assists washing efficiency which decreases the quantity of reagent sent to the tailings dam. This increases environmental performance and gives cost savings as reagents may be returned to the process. Enhanced interface control returns cleaner overflow to the processing plant which can lead to reduced maintenance in other unit operations where the overflow is utilised. Significant cost savings through reduced flocculant consumption can also be gained.
In tailing thickeners increased underflow solids % will decrease the volume of slurry entering the tailings dam. This increases the lifespan of the tailings dam which is a significant cost saving to its operators. Enhanced interface control gives cleaner overflow back to the processing plant which can lead to reduced maintenance in other unit operations where the overflow is utilised. By integrating the Smartdiver in the control of settlers and washers, there can be significant cost savings through reduced flocculant consumption, higher throughputs and consistently higher underflow solids.

References

[1.] Kelvin T. Erickson and John L. Hedrick "Plantwide Process Control" (John Wiley & Sons, 29/04/1999).
[2.] J.A. Rossiter "Model-Based Predictive Control: A Practical Approach" (CRC Press, 2013).
[3.] Weidenbach M. and Lombardi J "Tailing Thickener Operability and Control Improvements at Prominent Hill" (11th Mill Operators' Conference 2012).