UTILISATION OF THE SMARTDIVER IMPROVES CONTROL OF SETTLERS AND WASHERS IN THE BAYER PROCESS

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Abstract

The two key parameters for the effective control of settlers and washers are the interface and mud level. In the past, the interface and mud level have been obtained manually. The process of obtaining a reading was a risky, difficult and labour-intensive process which was open to error due to the visual nature of the test. With the SmartDiver it is possible to gather suspended solids and density data of a settler or washer throughout the entire profile of the vessel, automatically and semi-continuously, through the use of an automated dive mechanism. This provides a more accurate measurement for the control of the interface and mud levels that is easy to incorporate into a control system such as a Programmable Logic Controller (PLC) or Distributed Control System (DCS).

Once an interface and mud level measurement is obtained a number of different control methods can be utilised, in which the interface level is utilised in the control of flocculant dosing and the mud level is utilised in the control of the underflow pumping. The control strategies utilised range in complexity from standard feedback control through to feed-forward and model predictive control. The end result of this improved control is the reduction in overflow suspended solids, while using the minimum quantity of expensive flocculant. The enhanced control of the mud level allows for increased underflow density. This results in less liquor (due to the higher percentage of solids being pumped) passing through to the washers in the case of a settler and improves the washing efficiency of any washers within a Counter Current Decantation (CCD) circuit.

Improving the performance of the settlers, washers and tailings thickener in this way provides significant cost and environmental benefits.

1. Introduction

A gravity thickener separates the solid and liquid components of a slurry stream. This is achieved utilising the difference in density between the solids component and the liquid component of the slurry. Solids generally being denser than liquid will settle to the bottom of the thickener. This creates a stratum of material with a higher solids concentration than the input slurry stream in the bottom of the thickener. This stratum is deemed to start where the density of the slurry reaches a nominated value. This point and below in the thickener is commonly called the mud layer. A stratum of low solids concentration (preferably zero) slurry will conversely be present at the top of the thickener. This stratum is deemed to start where the solids reach a nominated value, usually in grams per litre (g/L). 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.

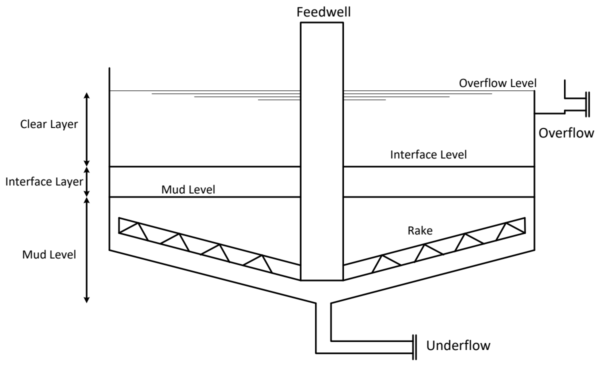

Figure 1. Cross section of a typical gravity thickener showing different settling zones

Thickener underflow density is affected by a number of factors. These include the height of the mud layer, the tonnage of solids entering the thickener, the particle size distribution and rake performance. Of these factors, only the height of the mud layer 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 and particle size distribution, or are mechanical devices which have minimal ability to be manipulated online, such as the rake.

To change the mud height in the thickener the flow rate of the underflow pumps is manipulated. The solids input can be manipulated; however the usual circumstance is that the flow entering the thickener is determined by previous unit operations.

Thickener interface level is affected predominantly by the dry flocculant flow rate. This can be changed by changing the flocculant concentration or by increasing the flow rate of the made-up flocculant, which is the most common method.

2. Process

The main thickener unit operations in the Bayer process are as settlers and washers although they are also utilised to classify product at some sites. This paper will be focusing on settlers and washers. The settler is used to separate the tailings and the liquor; the washer is used to reduce the concentration of reagents entering the tailings dam whilst also reclaiming these reagents.

Thickeners have two purposes: to achieve zero solids reaching the overflow; i.e measured as overflow clarity; and to ensure that all the solids reach the underflow with the least amount of liquor possible; i.e. a high underflow solids concentration. The application and process used with the thickener will determine how high the overflow clarity is, and how low the underflow solids are.

Maintaining a low clarity is vital for upstream operations of post digestion settlers in particular. Control of clarity is vital as a wave of high suspended solids material can dramatically affect the operations of security filtration. In the washing circuit high suspended solids reduce the efficiency of the washing process.

Maintaining a high settler underflow density is vital to reduce the quantity of liquor going to the washing circuit. If excess liquor goes to the washing circuit, high reagent concentrations may result, which is bad from an environmental and cost perspective as the caustic may be re-used.

The washer is used to try to maintain high underflow density, so that additional wash water from the previous washing stage can be added due to the reduction in liquor volume of the underflow stream. Again as with the settler, it is important not to have overflow solids going to the next washing stage; however, flocculant is expensive so it is vital to optimise the flocculant dosage. Excess flocculation can additionally cause operational issues, such as inability to pump the underflow (also known as bogging) and poor settling.

Whilst the results shown in this paper are not from a Bayer plant it is expected that similar results would be obtained in the Bayer process.

2.1 How are measurement of interface and mud bed levels achieved?

The mud and interface levels traditionally have been measured utilising a large tube to extract what is essentially a “core” of the thickener. This is then visually inspected and underflow pumping and flocculant rates are varied based on this. This test is difficult, risky and requires multiple people to perform it as the tube is very awkward. Over the years a number of automatic methods have been devised. These include ultrasonic and radar methods, and systems based on density and clarity. The most successful automated methods have been based on density and clarity. In many such systems two different methods are utilised to obtain the interface and mud levels. The reason for this is that a measurement technique that will successfully detect a density difference in the mud level would not be suitable for measuring the interface level. 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.

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. This sensor utilises acoustic attenuation to measure density, and is attached to a lowering mechanism (shown in Figure 4) which 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 cost for operations where thickeners are utilised.

Figure 4. Retraction mechanism utilised by the SmartDiver

All these techniques 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, so more maintenance will be required for units operating in the settler than in the washers.

The main issue with all the systems based on lowering probes into the thickener 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 to reset, allow for the cleaning of the probes and to allow for the passage of the rake if the probe is lowered into its path.

Whilst this is not ideal, for a thickener it is not a major issue as the thickeners have a large volume compared to be the inlet flow of slurry resulting in slow changes meaning that this type of semi-continuous control works well, as long as it is taken into account in the control strategy.

Of concern in the Bayer process is scaling for this type of equipment. The SmartDiver has an on board cleaning system to prevent scale build up which substantially reduces maintenance requirements.

3. 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 and Hedrick, 1999).

Once this control is established, it can be added onto. This can be done with feed-forward or model-predictive control. Feed-forward control measures the disturbance and changes the manipulated variable to counteract the disturbance before it affects the process variable (Erickson and Hedrick, 1999).

Model-predictive control selects control actions which are expected to lead to the best predicted outcome (or output) over some limited horizon (Rossiter, 2013).

Generally feedback control operates in tandem with feed-forward or model-predictive control. The feed-forward 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 and Hedrick, 1999). The feed-forward or 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.

3.1 Feedback mud level control

Mud level needs to be controlled so that the level does not go too high and bog the pumps, or cause solids to overflow the settler. Mud level is controlled through changing the settler underflow pumping rate. The higher the level the greater the mud flow pumping flow rate needs to be.

See Figure 5 for a control schematic of settler underflow pumping control strategy.

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 dive that is not 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 better to vary the mud level (within limits) rather than the flow rate to the washers to compensate for any process disturbances.

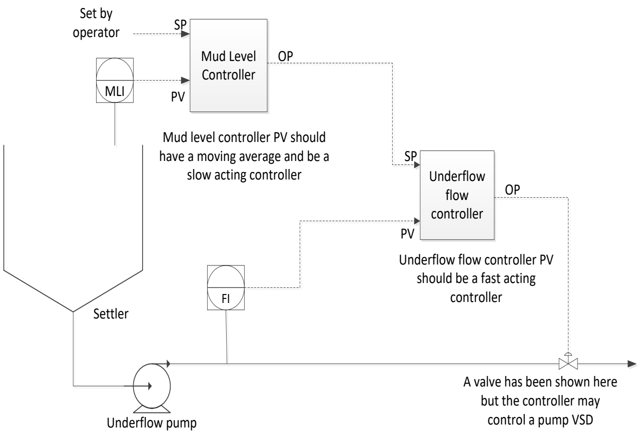

Figure 5. Mud level control utilising a PLA SmartDiver

3.2 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.

Issues can arise if the set points for the mud and interface level are incorrectly entered as the underflow pumping will control the mud level to a position which may be above the interface set point. Because the interface set point is below the mud level the control strategy will keep on adding on flocculant further compounding the issue.

The second and preferred strategy is to utilise a differential controller. A differential controller controls for the difference between the interface and mud level. For example if the mud level PV is 3 m and the interface differential controller Set point (SP) is 1 m, the interface level will attempt to control to 4 m. 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 in Figure 6.

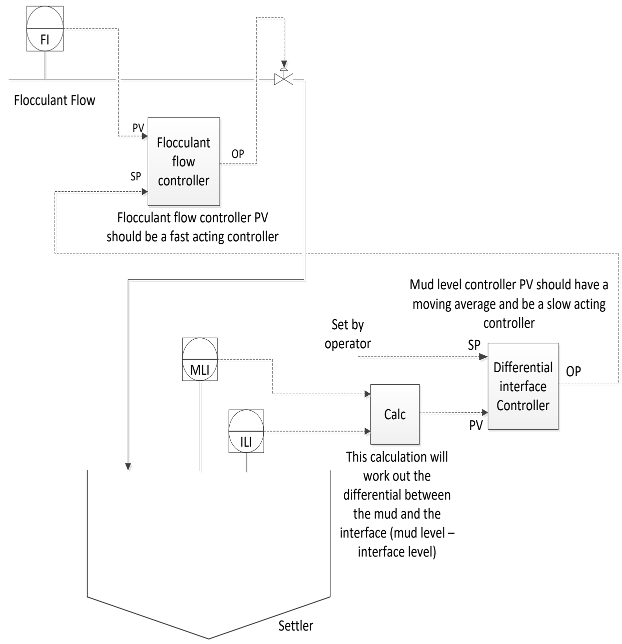

Figure 6. Interface control using the PLA SmartDiver

3.3 Feed-forward or model-predictive control

The previously mentioned control strategies are feedback systems. It is possible to establish feed-forward 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 feed-forward 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.

3.4 Feed-forward mud level control

Mud level control can be enhanced through the use of feed-forward control. Knowing the tonnage of solids per hour entering the system 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 delays in the system.

Figure 7 shows a control block diagram.

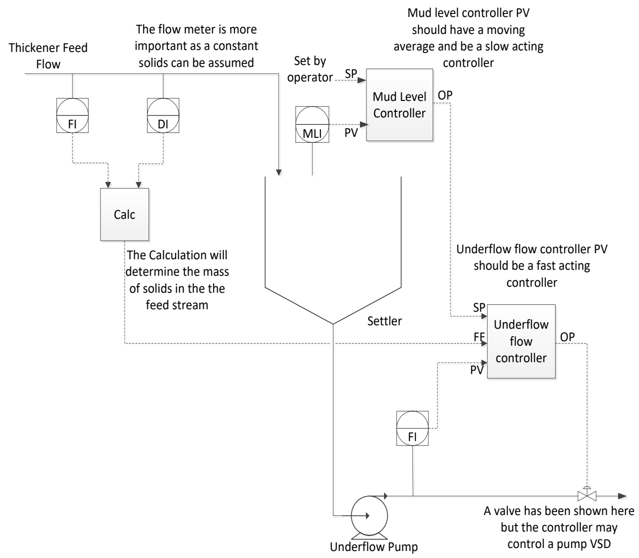

Figure 7. Mud level control with feed-forward using the PLA Smartdiver

3.5 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 solids 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 is not present) and the flow rate. This can be utilised in tandem with feedback control which utilises the interface level as the measured variable.

Figure 8 shows a control block diagram interface level control utilising feed forward control.

3.6 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).

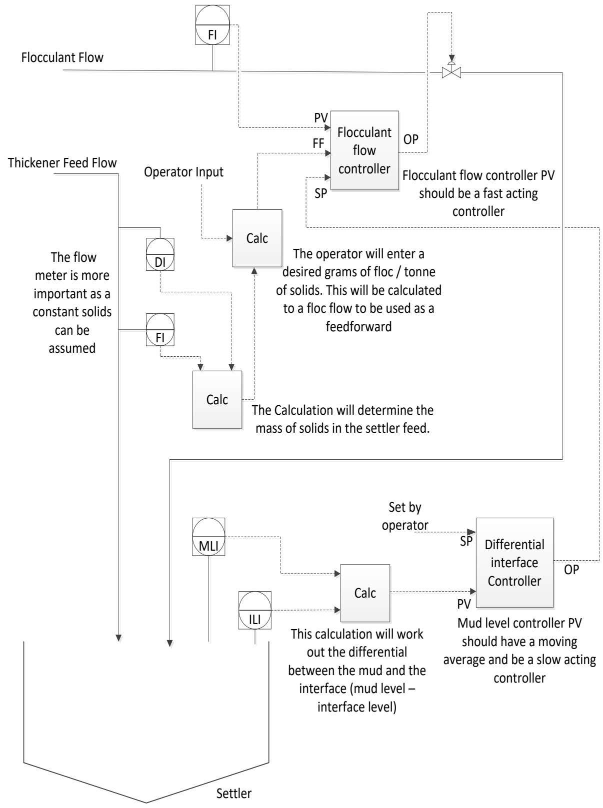

Figure 8 Interface level control with feed-forward utilising the PLA SmartDiver

3.7 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 can cause issues). Flocculant consumption can also be reduced as the control will enable more accurate dosage of the flocculant into the system.

4. Results

The control strategy which was finally implemented utilised feed-forward control for the mud level control and model-predictive control for the flocculant control. Whilst this data was not obtained from a Bayer site it is believed that similar results would be obtained within a settler or washer utilised in the Bayer process. In Figure 9 the clarity, which is a measurement of the solids reporting to the overflow is shown. Three time periods are shown in the data in Figure 9. The first period shown is before the control strategy was implemented. A second stage is a transitional stage where the control strategy was being bedded in and the third stage is where the control strategy was running as designed.

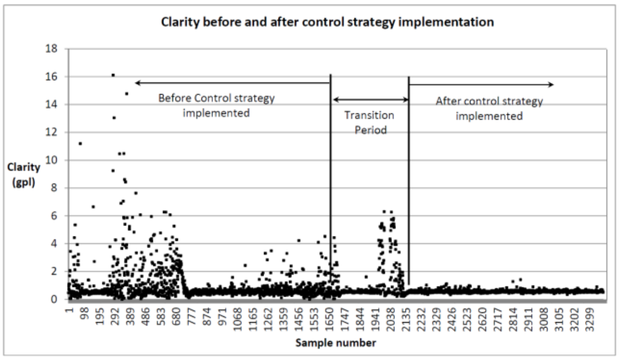

Figure 9. Chart showing clarity before and after implementation of feedback and feed-forward or model-predictive control

The mean clarity before the control strategy implementation is 0.94 g/L with a standard deviation of 1.2. During the transition period the mean clarity is 1.00 g/L with a standard deviation of 1.22. After the control strategy is implemented and the process is stabilised the mean is 0.58 g/L with a standard deviation of 0.087. This is a substantial improvement in performance for both the mean and the standard deviation. The reduction in the mean indicates an overall improvement in performance from the steady state perspective but the major benefit is the reduction in the standard deviation. A reduction in the standard deviation indicates a process in control without large disturbances which can cause large process issues especially in areas of the plant such as security filtration. In security filtration surges of solids can result in substantial process upsets due to filters blinding which can substantially reduce throughput.

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.

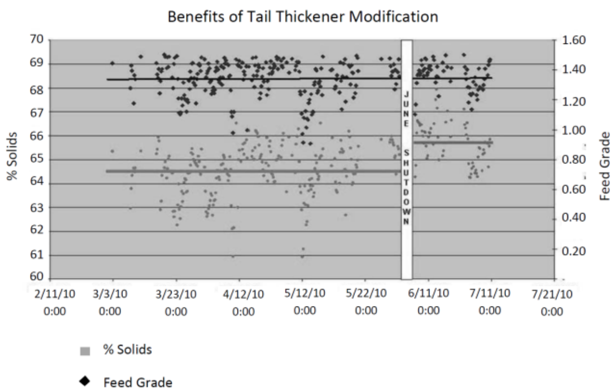

Figure 10 Change in thickener underflow density utilising a similar control strategy (Weidenbach and Lombardi, 2012)

5. Conclusion

In conclusion, the SmartDiver is a low capital and maintenance option to improve thickener clarity, increase underflow mud density and reduce flocculant consumption.

In settlers an increased percentage of overflow solids decreases the load of the washing circuit, which aids washer performance.

In washers an increased percentage of underflow solids assist washing efficiency, which decreases the quantity of reagent and or product sent to the tailings dam. This in turn decreases the environmental impact and renders cost savings, as caustic and product may be returned to the process.

Enhanced interface control gives improved clarity which can reduce maintenance and operational requirements in other unit operations such as filtration.

Significant cost savings through reduced flocculant consumption can also be achieved.

6. References

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