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Modernization of Chinalco Toromocho Copper Tailings Thickeners

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ABSTRACT

The Chinalco Toromocho copper mine uses four (4) 43-m diameter paste-type tailings thickener, each is designed to process over 1,300 dry metric tons per hour, mtph and 3,600 cubic meters per hour, m^3/h of slurry. The target non-Newtonian underflow was designed to be pumped to the tailings storage facility, TSF to be surface stacked. Difficulty has been experienced achieving the target underflow causing water balance, pumping capacity and other issues. Chinalco contracted WesTech to perform an optimization study to evaluate the benefit of retrofitting their feed system and mechanism of their thickeners with the latest advances in the market. Plant trend data was analyzed over the past 1.5 years, establishing the current operation of the site. The tailings stream variation range in dry mtph, particle size distribution, PSD, and flocculant consumption, are shown. The underflow weight percent and overflow clarity operating ranges were tracked. The analysis gives the effect these critical parameters have on thickener performance. A comparison is provided of the predicted modernization performance in response to the established operating variability. This paper provides a review of the Toromocho thickeners trend data based performance, optimization study results, and the mine's way forward to optimize their tailings thickeners.

INTRODUCTION

Chinalco, Toromocho copper mine uses four beneficiation plants with the tailings from each plant dewatered in a 43m diameter high density -type thickener. Since the installation in 2014 there have been multiply mechanical problems. There have been several tank, bridge, and mechanism failures (Valderrama, 2016). The performance of the thickener has not achieved the promised 69 wt% solids nor achieved the needed rheological character for the designed tailing storage facility, TFS management. The performance issues are the focus of this study. Chinalco contracted WesTech to conduct an optimization study of the current four tailings high density-type thickeners. The study included, a site inspection and sample collection (7 and 8 of November 2019), WesTech standard laboratory sizing tests establish the potential performance and comparison to the plant operating data trend analysis. The objective of this study was to determine if a cause of the poor performance could be identified and then give a predicted thickener performance following modernization of their tailings thickeners with the WesTech EvenFlo feedwell, mechanism, and MudMax bed level instrument.

The operating audit was conducted of the Toromocho thickeners to address the following:

- Document the current thickeners performance
- Establishes the range of stream variability to each thickener, which should be represented in the laboratory study
- A comparison between the four processing plant tailings.
- Identify if there are any process issues limiting the dewatering of the tailings.
- Level of control of the thickeners,
- Review plant efforts to increase underflow density

Data for the four tailings thickener were provided for the period of 1 January 2018 through 11 November 2019. Almost 2-years of data was received and reviewed. The sheer volume/size of the data and graphs makes it difficult to provide a general view of the plant operation. Therefore, for the body of this paper, the only plots and trends to support the process conclusions are provided. This optimization study results include, 1) high density thickener bench-scale sizing results and conclusions, 2) audit of Toromocho tailing thickeners identifying feed characteristic range and operating trends, 3) recommendations and predicted performance post retrofit.

BENCH-SCALE STUDY

Bench-scale sizing tests are designed to identify the limits associated with the process stream to first, design the proper thickener to confidently provide the customer with a robust thickener and second, to provide operating conditions to meet the dewatering needs. The design must provide hydraulic loading to have clear overflow and the solids loading to produce the target underflow character (wt%, yield stress). Flocculation and hydraulic loading tests are very similar to those used for all thickeners. Flocculant screening, optimum feed solids conditions, dosage, etc. are determined using beaker settling tests. The optimum conditions determined for flocculation were then used in 2-L settling tests to confirm an initial settling rate. The difference between the high rate-type thickener and the paste-type thickener is that the paste thickeners are designed to produce and discharge non-Newtonian underflow that has a significant yield stress and viscosity. The rheological character of the mud is used to predict the underflow solids and in turn the solids loading for the paste-type thickener.

The yield stress (defined as the pressure required to start movement in the material) is determined for a series of solid content to establish the yield stress curve for the Chinalco tailings. A Haake VT 550 viscometer was used for this study. Two methods of determining the yield stress are employed. The first is a break-through method where the viscometer slowly turns the vane and measures the resulting drag force. The second method is to produce a flow curve where the viscometer exposes the sample to a series of shear rates (vane tip speeds) in both the increasing and decreasing modes. The flow curve data is interpreted using the Bingham plastic model. A third useful method to determine the yield stress curve is the use of cylinder slumps.

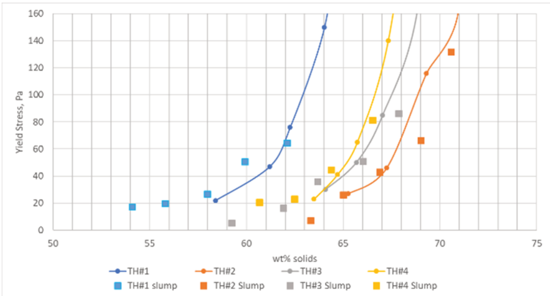
Bench-scale results

The overflow and underflow from each of the four tailing thickeners were sampled and characterized for suspended solids, particle size distribution, PSD, and yield stress. The overflow clarity ranged from 65 – 330 ppm. The underflow wt% solids and yield stress varied from 57.4 – 66.0 wt% and 5 – 34 Pa respectively. These four underflow samples were compared to the recent plant PSD trend data. The PSD curves for daily samples collected during the month of November 2019 were used to estimate the range of variation that occurs during normal operation of the Toromocho plant. The bench-scale test samples cover a similar PSD range; Th#2 was similar to the coarsest, Th#1 was slightly finer than the finest sample and Th#3 and Th#4 are in the middle of the PSD range. It was concluded that the bench-scale test will be representative of the actual production range seen at Toromocho.

The flocculant screening compared plant flocculants (labeled RP630 and Rheomax), and two other flocculants, RH 4852, and A-110. The results showed that the current plant flocculant RP630 provided excellent settling and clarity with a dosage below 8 g/t. The concentration of the solids in the stream being flocculant can greatly affect the efficiency of the flocculant. For this material it was observed that the concentration must be below approximately 10 – 12 wt%. In this range the initial settling rate was between 15 – 25 m/h for the 8 – 10 g/t dosage.

The direct, breakthrough measurement and the cylinder slump based yield stress values are provided in Figure 1. The effect of the PSD variation can be seen as each yield stress curve is shifted with respect to each other. The Th#3 and Th#4 have similar PSD and the yield stress versus wt% solids relationship is also similar. As part of the audit, Chinalco provided results from a previous yield stress study from 2018. The data was bracketed by the current study, covering a similar range. The Toromocho tailings variability was consistent for the two studies.

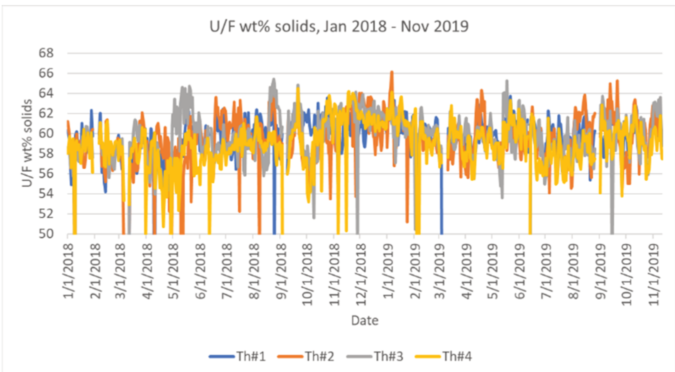
Figure 1 Rheology results for the four thickener samples



AUDIT OF TOROMOCHO TREND DATA

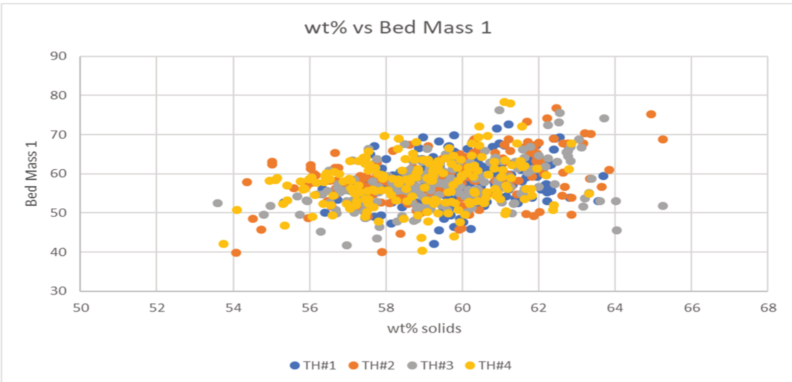
The four tailings thickeners data were provided for the period of 1 January 2018 through 11 November 2019. The trends for all four thickeners were similar depicting the same trends. The underflow wt% solids for thickener #1, 2, 3, and 4 is given in Figure 2. This trend shows the underflow wt% solids range between 56 to 64. The underflow density varied significantly day to day.

Figure 2 Toromocho four tailings thickener underflow wt% solids, 23-month trend



Improvement of the underflow wt% solids has been a focus of the plant. The approach used, was to increase the bed inventory in the thickener to give increased solids residence time. Each thickener is equipped with two bed mass pressure gauges. One is located near the bottom of the cone and the other is located at the knuckle of the tank (floor and vertical sidewall junction). The lower gauge, Bed Mass 1, provides bed inventory reported as percent of calculated pressure maximum. It is used as a relative value for control of the underflow pumps. Over the past 6-8 months, the plant has steadily increased the target Bed Mass 1 value from about 55 % up to 70 %, resulting in an increase in solids retention time of 50% or longer. During this period the operators identified that for general thickener operation, the optimum bed level /clear water interface should be maintained 3 to 3.5 meters measured down the sidewall. The corresponding Bed Mass 1 value is about 65 %. The wt% solids versus Bed Mass 1 depicts a general trend of increased wt% solids as the Bed Mass 1 value increases, Figure 3.

Figure 3 The Bed Mass 1 versus wt% solids, all four thickeners



The flocculant dosage, an important operating parameter was targeted to be minimized down to 12 g/t. The 23-month trend shows a wide variation in dosage of more than a factor of 2 times. The typical effect of dosage on the wt% solids is seen with improved wt% with lower dosage. Flocculant dosage has been shown to inhibit compaction in paste-type thickeners, (Shaw & MacNamara, 2006). This same effect is seen in the Toromocho data. The trends have significant scatter in the data which can mask the relationships. The scatter is a result of the varying operating condition and stream character, such as PSD.

The plants efforts over the past 6-months have not yielded the desired improvement in thickener performance. Their position is understood when the yield stress is considered. The 23-month data shows the thickener yield stress ranges between 10 and 25 Pa. With only about 9% of all the sample collected are greater than 25 Pa, the clear majority is less than 25 Pa. The plant efforts to optimize the Bed Mass 1 target, the past 6-month, did not improve the yield stress with the majority of the samples collected during this period had a yield stress less than 20 Pa. This yield stress range will allow segregation and the suspension would behave as a Newtonian slurry. Therefore, the improvement in wt% solids is minor, still producing slurry with no increase in yield stress.

Trend analysis

The bench-scale tests and the process trend audit did not reveal any reason why the thickener could not produce higher wt% solids and yield stress. The material easily produced a non-Newtonian material in static and continuous lab tests. The bench-scale rheology results match the collected full-scale samples variability.

The next stage of the audit reviewed the thickener design. A thickener design must provide an effective dewatering mechanism and enough time to remove the water and compact the solids. An effective mechanism keeps the full volume of the bed in the thickener moving toward the discharge. The material near the wall should pass through the thickener with similar residence time as the central material.

A review of the Toromocho thickeners second Bed Mass 2 gauge located near the knuckle of the tank showed a significant process issue. The Bed Mass 2 provides an indication when the bed level is above the knuckle. The relationship between the Bed Mass 2 and the underflow density shows no trend. The Bed Mass 1 and the Bed Mass 2 relationship to the underflow wt% is compared in Figure 5. If the full bed volume is properly active, then the greater the Bed Mass 2 values should result in greater underflow wt%. Modeling the bed as an ideal plug flow, the Bed Mass 1 relationship should be similar to the Bed Mass 2, as it simply is reading the upper portion. This however is not the case, the Bed Mass 2 appears independent of the Bed Mass 1. Movement of the outer material to the discharge requires raking. The volume that can be 'pushed' with each revolution depends on the height, length and angle of the blades. The calculation of raking capacity reviews the volume of material that can be pushed by each blade compared to the discharge rate. The capacity of the current thickener mechanism's short blades is less than 10% of the underflow discharge rate (<120 m^3/h of the average 1200 m^3/h discharge), Figure 6. This low raking capacity is similar to a high rate thickener that produces slurry underflow and depends on gravity to keep the bed actively moving to the discharge. However, for paste-type thickeners that produce a yield stress, the solids become less mobile as the yield stress increases and require physically to be moved. This means for Toromocho, that up to 90% of the underflow will come from the most mobile material, the center zone of the thickener. With the main flow coming from the central area, the actual solids residence time of this flow is greatly reduced, therefore, producing the 10-25 Pa underflow.

Figure 5 The Bed Mass 1 and 2 versus wt% solids for Thickener #4

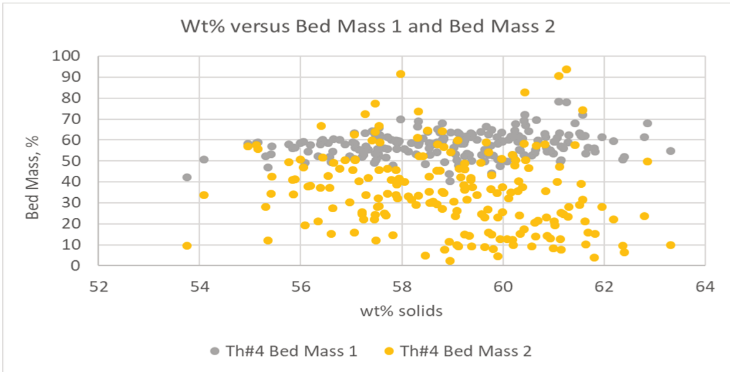
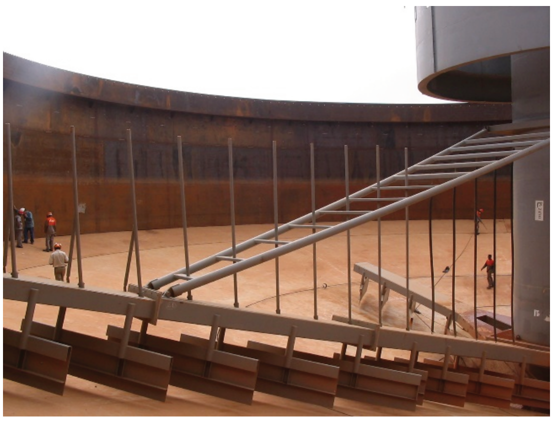


Figure 6 Current Toromocho 43m tailings thickener

Figure 7 Recommended WesTech HiDensity mechanism



CONCLUSIONS AND RECOMMENDATIONS

The requested audit of the Toromocho tailings thickener was successful in conducting bench-scale sizing tests on material representing the range of operation at the site. The results confirmed the full-scale operation, identified the effect of PSD on underflow density, and the benefit of flocculant dosage reduction. The audit produced evidence of preferential flow down the center of the thickener limiting the solids residence time.

The study results show that the original promised 69 wt% solids was not achieved. The PSD range is too fine to be able to produce 69 wt% solids in a high-density type thickener. The yield stress curve for even the coarsest sample (Th#2) would require a very high yield stress to reach 69 wt%, too high for the installed high-density thickener. The stream variability (PSD, mineralogy, etc.) is significant making a target wt% solids unpractical. An underflow target would best be defined by the yield stress.

Recommendation #1, retrofit the tailings thickener with the WesTech HiDensity high raking capacity and enhanced dewatering pickets mechanism, Figure 7. The ability of a thickener to produce non-Newtonian underflow depends on the solids residence time; dewatering and compacting flocculated solids is time and mechanism design dependent. The current thickener volume has only 2.5 – 4 hours retention time for the 1200 to 1600 dry tph throughput. Thickener performance is a combination of the time and the design of the mechanism; the dewatering pickets and the raking capacity. This available time is significantly less than the standard solids residence time WesTech would use to design a high-density thickener dewatering copper tailing. However, applying this residence time to the bench-scale sizing tests results provides the basis for the estimated underflow after retrofit.

Recommendation #2, retrofit with the WesTech EvenFlo™ feedwell. This feedwell has the advantages of the very large optimum mixing zone, improved clarity and reduction in flocculant consumption, (Johnson & Accioly,2017). The thickener performance starts with the feedwell design and operation. The audit of the Toromocho process confirmed the benefit of using minimum flocculant dosage. The efficiency of the EvenFlo will allow Toromocho to take advantage of lower dosages. This not only saves OPEX but will improve the underflow density. Optimizing the feedwell will optimize the thickener.

Recommendation #3, the operation of the thickeners will benefit from tighter controls. Controlling the thickener to have a steady bed level maintains the residence time and provides steady state operation. The key is to identify and maintain the bed level. Installing the MudMax bed level sensor will provide direct measurement of the compacting solids (Cook & Johnson, 2015). This straight forward control requires accurate bed level measurement.

WesTech paste-type thickener experience and the study's rheological data from the viscometer and the cylinder slumps results provide the basis to estimate the predicted. WesTech predicts that if the Toromocho tailings thickener is retrofit with the WesTech mechanism, EvenFlo, and MudMax bed level sensor, the underflow yield stress could be raised to the 35 to 55 Pa range. Therefore; if Toromocho tailings is similar to the four samples tested, the predicted underflow wt% solid for a 35 – 55 Pa yield stress would be 2 to 4 percentage points higher than the current thickener production. For example, if the material is like Th#1 material studied, the underflow would increase from an average of 57 wt% to 61 wt%. If the material is like the studied Th#2 material, the underflow would increase from an average of 64 wt% to 67 wt%.

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