Development of Mud Rheology Modifiers

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https://doi.org/10.71659/icsoba2025-aa023

Abstract

The use of flocculant to improve red mud settling in Bayer process mud washing circuit is critical for the effective and efficient operation of the circuit. However, the addition of flocculants has significant negative impacts on mud rheology, such as worse flowability and pumpability. These negative impacts could result in lower than desired underflow percent solids in settlers and washers. Syensqo has been developing mud rheology modifiers to address the issues related to mud flow-ability. In the process, proprietary methods were developed to replicate compacted mud in the laboratory, similar to what obtains in the settlers/washers in the refineries. This paper presents the progress made in improving mud rheology, highlighting how Syensqo's modifiers increased underflow solids by up to 5.1 % without compromising flowability, demonstrating both current achievements and future potential.

Keywords: Flocculant, Settling, Red mud settler, Rheology modifier

1. Introduction

The clarification process of the digested mud leaving the digesters, is one important step in the Bayer process. This is essentially the mud separation and soda recovery process.

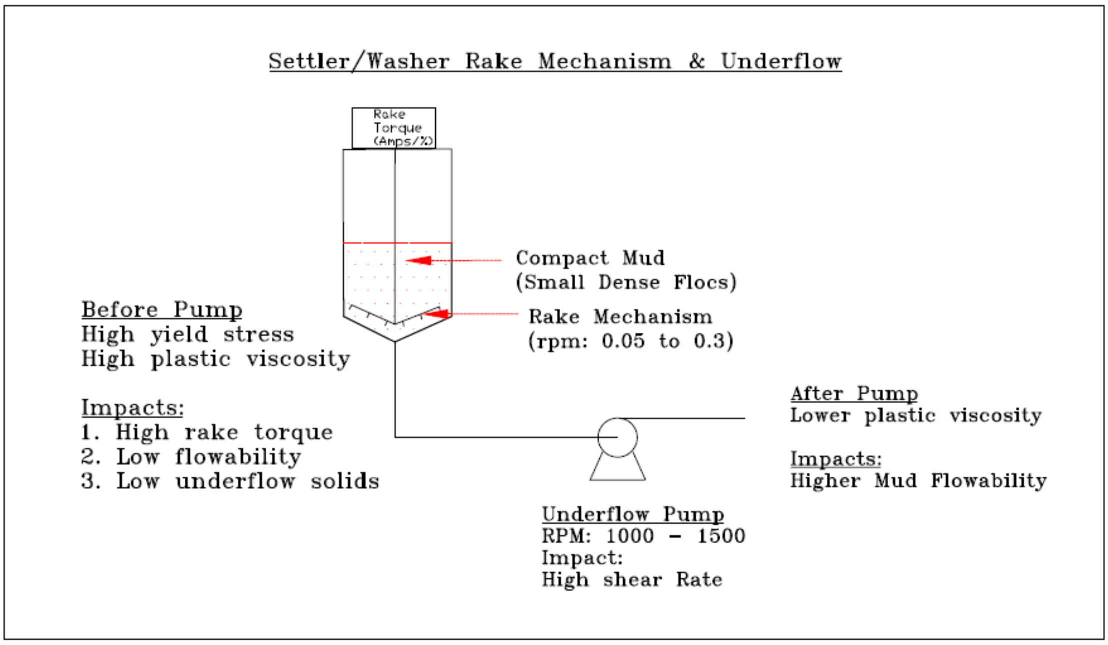

Figure 1. Typical settler/washer unit operations in an alumina refinery.

To efficiently enable the mud separation process, flocculation (the process where flocculants cause mud particles to attach and form larger, heavier particles) plays a major part. These large flocs increase in weight and settle out of the liquid (supernatant). However, once settled, they are broken down and compacted by the rake mechanism into small dense flocs (compact mud particles that are harder to move). These small dense flocs have poor mud rheology, meaning they do not flow easily due to high yield stress and high plastic viscosity. This poor flow behaviour can lead to high rake torque and plugged underflows, especially if there are attempts to increase underflow solids. It is an expensive process to turn around failed vessels, and the trade-off is low underflow solids resulting in low soda recovery. These problems tend to occur at the pump suction, since the high shear rate of the pump impeller would result in low plastic viscosity and better mud flowability [1, 2] at the discharge end (Figure 1).

The poor mud rheology, moving the mud from the vessel to the underflow pump is what Syensqo mud rheology modifiers seek to address. Syensqo's mud rheology modifiers are formulated to be used as rheo-flocculant. The mud rheology modifier is designed to flocculate the mud and improve the mud rheology. Optimum application would be determined at the refinery. The rheology modifier dosage may be slightly higher than the typical flocculant dosage in the refinery.

Syensqo is currently developing 1st generation of rheology modifiers under our CYQUEST® branding. These rheology modifiers interact with the mud during the bonding process known as polymer bridging. In this process, the polymer adsorbs onto suspended particles and it free ends attach to other particles, forming flocs. This interaction slightly weakens the adsorption mechanism between the rheo-flocculant and the mud particles, without negatively affecting the settling process (therefore, required settling rate will be achieved) [5].

2. Development of Laboratory Methods for Rheology Modifiers Evaluation

2.1 Lab-Scale Washer

A proprietary method was developed to test the rheology modifiers in the laboratory before testing in the refinery. This entailed developing a lab scale vessel to compact and create small dense flocs (mud). Compacted mud was generated, and flow-ability measurement was conducted on the mud. It should be noted that last stage washer mud was simulated for these tastings.

Figure 2. Lab scale washer vessel.

The substrate is mud sourced from a non-disclosed plant processing Jamaican bauxite Table 1 below outlines the major parameters for typical Gibbsitic bauxite in Jamaica.

Table 1. Major parameters for typical Jamaican gibbsitic bauxite.

Parameters	Values (Range)	Units
Gibbsite (as Al_2O_3)	40–44	%
Boehmite	1.5–4.9	%
Total Silica	1.5–4	%
Goethite (as Fe_2O_3)	45–85	%
Phosphorus	0.3–0.6	%

The collected pre-last washer stage underflow mud is mixed with the last stage wash water to generate the last washer feed stream containing approximately 60 g/L mud solids. This feed stream is then used to conduct settling tests, at a targeted settling rate. This initial settled mud contains large flocs (flocculated mud) similar to what happens in the washer's feed well. This flocculated mud is then transferred to the lab scale vessel (with rake mechanism) where it is compacted for 30 minutes. After 30 minutes the supernatant is removed using a vacuum siphon system, the supernatant is stored. The underflow is then collected and gravity filtered for 1 hour. Underflow solids of approximately 360 g/L (~30 % solids) are generated from this lab process and are used for mud rheology studies.

2.2 Mud Consistency/Flowability Measured

To measure mud flowability a consistometer is used as seen in Figure 3 below. The consistometer measures flowability by measuring the distance mud flows under its own weight, in a given time interval. It uses a similar concept as mud consistency used on mud stacking [3, 4]. The higher the yield stress the less the mud flows. The consistometer is utilized by placing 100 mL of mud in the gated compartment first. After the gate is released, the distance flowed (units: cm) in a given time interval is then measured.

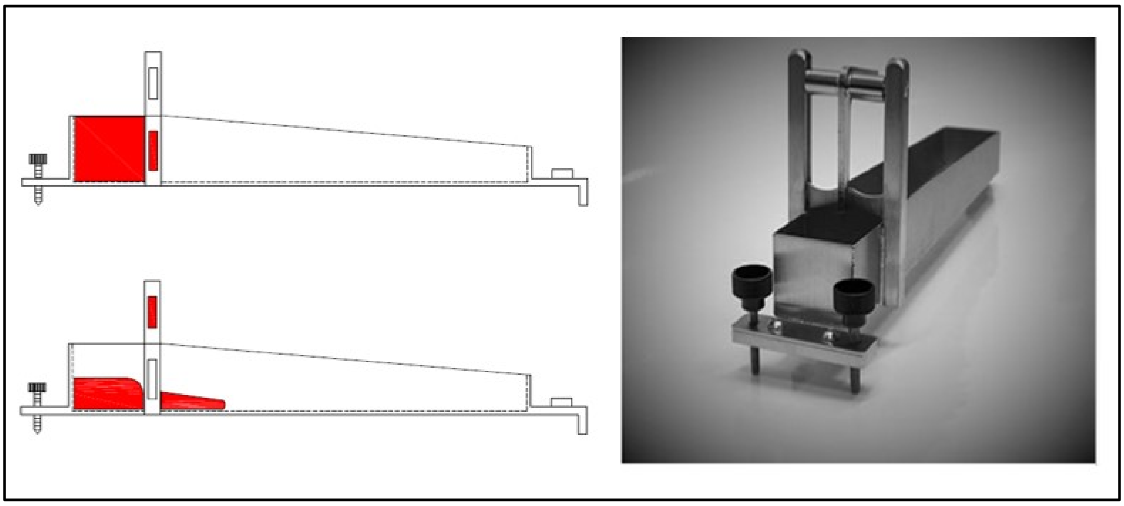

Figure 3. Consistometer. Left: side views, Right: perspective view.

Of the 360 g/L (30 % solids) mud generated 200 mL is then placed in a 250 mL bottle. The mud solids are then varied by diluting with its supernatant removed previously. The bottle is then shaken vigorously for 30 seconds to mix well. The 100 mL of this mud is then placed in a consistometer and the distance the mud flows in a given time interval (e.g. 3 minutes) is then measured. A flowability curve is then generated using flowability (cm) on the y axis and mud solids (%) on the x axis.

3. Results

3.1 Impact of Poor Mud Settling Ability on Flocculant Dosage and Mud Rheology

One observation that has been made over the years, was that as bauxite quality changes, the required flocculant dosage for a specified settling rate varies. Therefore, the first objective of the work was to understand how poor settling mud, due to poor bauxite quality, would influence the flocculant dosage and underflow mud rheology.

As shown in Figure 4, the poor settling mud required 242 g/t flocculant dosage to give 5 m/h settling rate, while the good settling mud required 127 g/t flocculant dosage to achieve the same settling rate. The poor settling mud resulted in worse mud flowability than the good settling mud at the same underflow solid level (Figure 5).

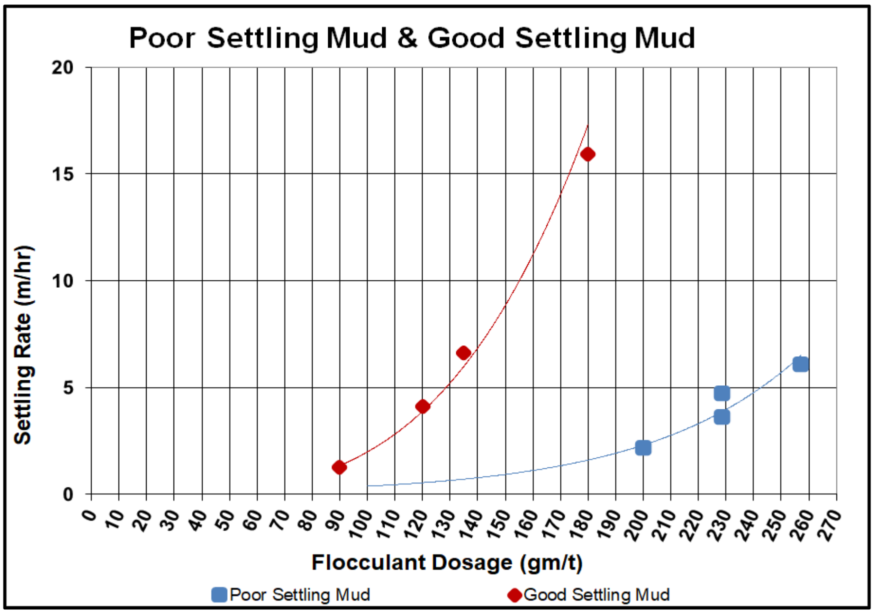

Figure 4. Settling rates of poor settling mud vs good settling mud.

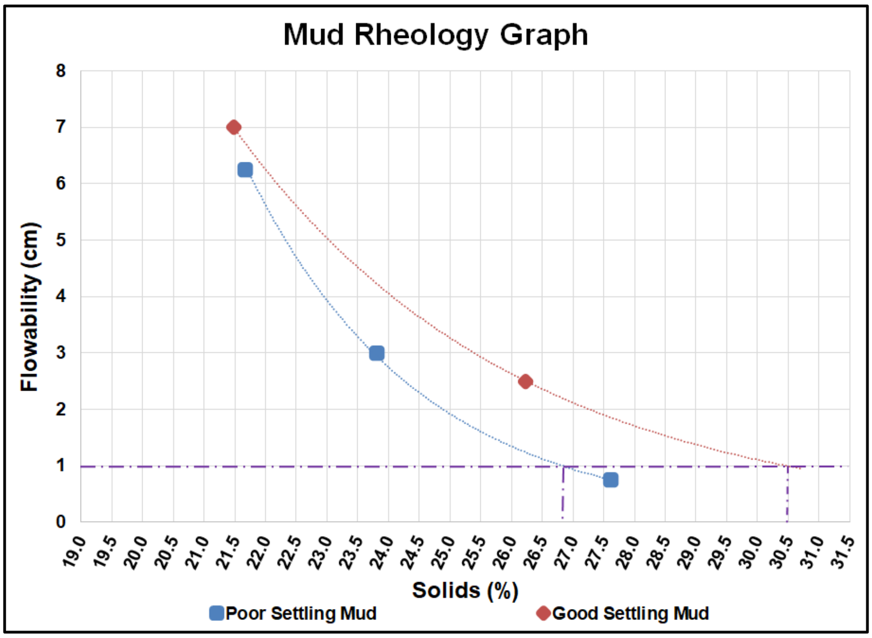

Figure 5. Rheology graph for poor settling and good settling mud.

3.2 Impact of Mud Rheology Modifiers on Mud Rheology

Mud rheology modifiers were used to determine its impact on the mud rheology (mud flowability). Two different muds were used for this study. In Figure 6, to achieve 1 cm flowability for Mud Batch 1, the underflow solids of untreated mud requires 29.49 % solids at most while the rheology modifier treated mud can compact to 34.6 % underflow solids. It should be noted that the flocculant dosage rate for the untreated mud was 204 g/t, The rheo-flocculant reagent dosage was 318 g/t. In Figure 7, to achieve 1 cm flowability for Mud Batch 2, the underflow solids of untreated mud requires 27.7 % at most while the rheology modifier treated mud can compact to 31.7 % underflow solids. It should be noted that the flocculant dosage rate for the untreated mud was 155 g/t, The combination rheo-flocculant reagent dosage was 249 g/t. Generally speaking, the mud rheology modifier can potentially allow refineries increase the underflow solids significantly while not impacting the flowability of the underflow mud.

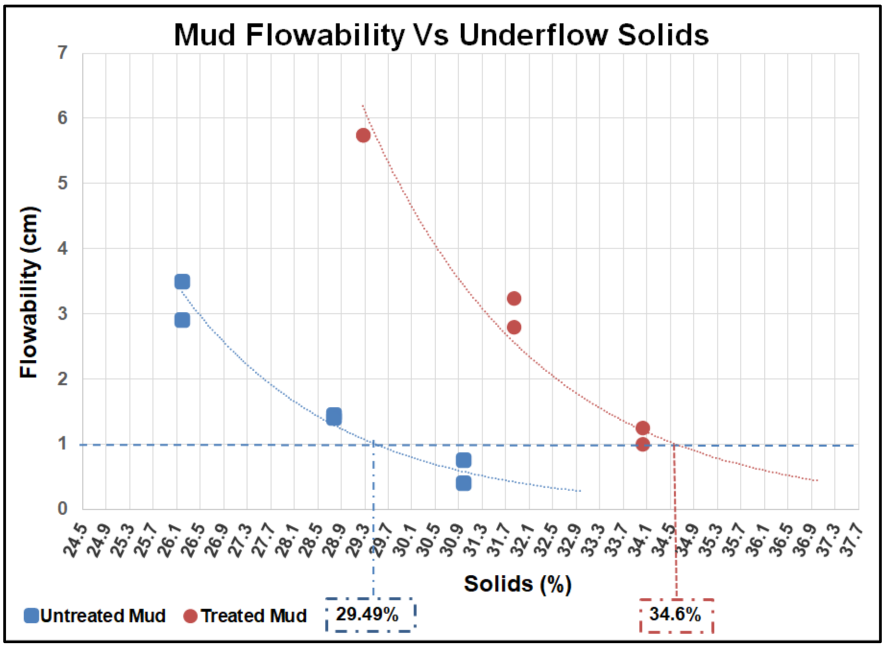

Figure 6. Rheology graph for untreated mud and rheology modifier treated Mud Batch 1.

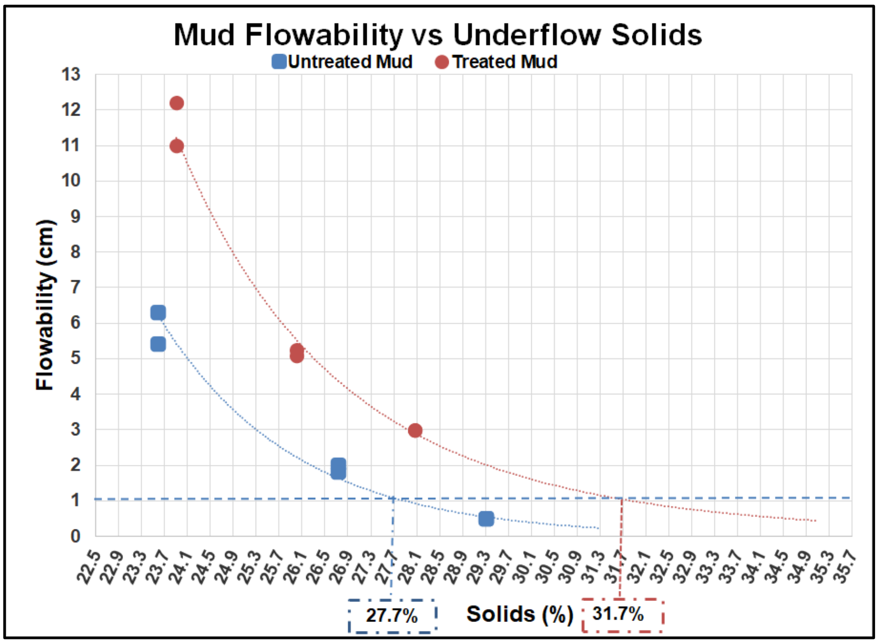

Figure 7. Rheology graph for untreated mud and rheology modifier treated Mud Batch 2.

4. Discussion

The poor settling mud in this case is due to the bauxite quality change, such as boehmite content increase (in low temperature Refinery operating at around 140 °C) and reactive silica content increase. This mud required 242 g/t flocculant dosage to give the required settling rate, which is almost double the flocculant dose for the good settling mud. As was expected of the poor settling mud, mud rheology was worse than that of the good settling mud that used less flocculant dosage. The mud rheology for the poor settling mud was giving a flow of 1 cm for underflow solids of 26.75 %, while the good settling mud gave the same flow of 1 cm for underflow solids of 30.5 %. This therefore indicates that poor settling underflow solids had to be reduced by 2.45 percentage points from 30.5 to 26.75 % to give the same flowability.

As seen in Figures 6 and 7, Syensqo's mud rheology modifier gave a good rheology response to flocculated mud in the vessels For Figure 6, the untreated mud was giving flows of 1 cm for underflow solids of 29.49 %, while treated mud was giving flows of 1 cm for underflow solids of 34.6 % solids, achieving a 5.1 percentage points solids increase compared to untreated mud. For Figure 7, the untreated mud was giving flows of 1 cm for underflow solids of 27.7 %, while treated mud was giving flows of 1 cm for underflow solids of 31.7 %, achieving 4 percentage points solids increase compared to untreated mud. The mud rheology modifiers capitalize on the opportunity that Spitzer *et al* [2] mentioned, stating that major mud rheology improvement can be achieved from the vessel discharge to the underflow pump.

It should be noted that the laboratory simulation is a batch operation as opposed to the dynamic continuous operations in the refineries. Therefore, it is expected that the underflow solids improvement recognized by Syensqo's mud rheology modifiers may be even greater in the refinery.

5. Conclusion

Poor settling mud causes higher flocculant dosage required for settling purposes. This in turn causes poor mud rheology. As a result, the refinery needs to adjust the vessel's underflow discharge rates to achieve lower underflow solids, so as to prevent rake failure or plugged underflows.

Syensqo's mud rheology modifiers are shown to help increase the underflow solids without negatively affecting the mud flowability. This increase in vessel underflow flow-ability would help to prevent or reduce underflow blockage; or refineries could also increase underflow solids improving their soda recovery programs, resulting in caustic savings.

6. References

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