IMPROVED THICKENER FOR RED MUD

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Abstract

With the ever-decreasing quality of bauxite being processed in Bayer plants and the drive for increasing production, the stress on the mud circuit of modern plants is greater than ever. In some of our plants, we observed that tank life is often limited by a rapid increase in rake torque or erratic torque variation. Higher mud and sand load speed up the failure. A pilot scale thickener was built at Université du Québec à Chicoutimi, Québec, Canada to help understand this behavior. Several tests were run under various configurations and evidence was found that, with time, a dense kernel tends to develop in the center of the tank. This kernel is composed of mud at a high concentration of solids and of sand. The kernel tends to cause an increase in rake torque, erratic underflow solids and also underflow blockages. This eventually leads to premature stoppage of the tank operation. We tested several rake configurations, varied operating parameters and feed well configuration in order to limit the formation of this kernel. An improvement to the design of the feed system was tested and found to significantly improve the operation of units fed with a high fraction of coarse particles in the feed slurry. This paper presents results obtained in the pilot thickener and in a plant thickener.

1. Introduction

The economical thickening of red mud slurry always poses a challenge to the alumina industry. The ever-decreasing quality of world bauxite reserves brings about a challenge with larger tonnage of mud to be processed in plants. Poorer bauxite often generates coarser residue, generally referred to as sands. At the same time, most plants push flows and caustic concentrations to increase production. This also results in higher mud tonnage, higher velocities and reduced residence time in thickeners.

Alcan's latest thickener technology is based on designing relatively narrow and tall tanks in order to achieve high underflow solids mud [Paradis 1997; Bagatto et al. 1989, 1991]. These Deep Thickeners can produce muds dense enough and viscous enough to support coarse particles and thus eliminate the need to separate the sand from the fine mud prior to feeding the thickeners, as is generally done in other technologies. This not only removes one unit operation from the circuit, but it also reduces caustic and alumina losses often associated with these operations. However, there is a limit to the amount of sand and to the coarseness of that sand, that can be handled in the Deep Thickeners. This limit depends on several factors such as the densities of the materials, the geometry of the thickeners and rakes, scaling and other process parameters. Under severe conditions and with time, some thickeners may experience instabilities and increases in the rake torque, and eventually blockages and stoppage of the tank because of that. Figure 1 displays such a trend of the rake torque over time for a mud washer. Note the instabilities indicating imminent failure. This failure can occur for tanks located anywhere in the mud circuit and after variable duration, hence, it is not thought to be related solely to scaling of the rake.

2. Laboratory work

Faced with the behavior described above, it was decided to put together a research program with the objective of understanding the mechanisms involved in the increase in rake torque and finding means to eliminate or at least control them. This work was done jointly between Alcan International, Arvida Research and Development Center (ARDC) and the Université du Québec à Chicoutimi (UQAC). A pilot scale thickener was built at UQAC. It consists of a 1/11th scale tank operated with mud from Alcan Vaudreuil plant in Jonquiere, Quebec, Canada. The thickener is fitted with a feed well, an instrumented rake, a flocculant pump, an underflow pump, an overflow pipe and is operated in continuous for up to 60 hours, simulating a typical last deep washer of the mud circuit. A schematic of the pilot settler, and its associated equipment, is presented in Figure 2. The lower section of the thickener is bolted on so that any cone bottom geometry can easily be tested. The rake is driven with a 2 hp drive and 900:1 gearbox, giving 6000 foot-pound at 1 rpm. A torque sensor, Omega TQ101-10K, continuously measures the total torque on the rake. Strain gauges and thermocouples can be installed on the dewatering elements fixed to the rake to give more information on their action and on the mud movement. The size of the thickener allows us to realistically reproduce the operation of a full size thickener while permitting an easier observation of the movement of mud, liquor and rake. It is also possible to easily sample the mud in any location in order to measure its characteristics.

2.1 *Laboratory trials*

To understand the action of the rake on mud, several trials were performed with the pilot thickener. Some of them are described below. Although the tests are done with mud from the last washer at room temperature, the observed behaviors are typical of the operation of any stage in the mud circuit, except for phenomena involving scaling of the rake structure over time caused by the alumina supersaturation.

2.2 *Rake geometry*

Since the torque is caused by the movement of the rake in the mud, it made sense to try modifying the geometry of the rake in order to minimize the torque. The rake is fitted with dewatering elements on each arm. The cone angle of

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the bottom of the thickener and of the rake is 30° from the horizontal. After getting data with this rake, we modified it twice, and did additional tests. The first modification was to remove every other element on both sides of the rake arm in such a way that they are staggered with respect to each other. This gives a complementary rake where the entire surface of the mud bed is raked once per revolution. The third configuration is called the reduced rake and is obtained by completely removing one rake arm from the complementary rake. This gives a rake with minimal structure but with large gaps between the elements. This design also leaves some concentric rings in the mud bed where no element ever rakes. Table 1 presents the parameters used for the tests. Note that in all cases, sand is added to accelerate evolution and increase the effects. The mud bed position is also kept high for all cases, totally submerging the rake. The observed behaviors can be interpreted as worst cases scenarios.

Results for the torques measured with these three rake configurations are presented in Figure 3. Note that the torque scale is arbitrary and serves to compare the three configurations. One can observe that the standard rake presents

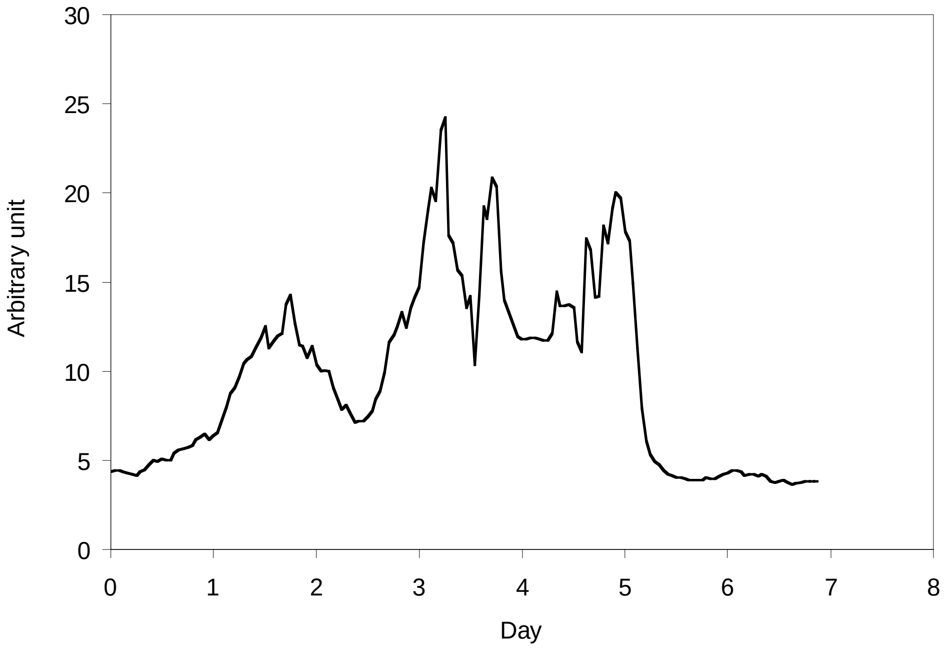

Figure 1 — Trend showing the failure of the tank caused by the rake torque increase

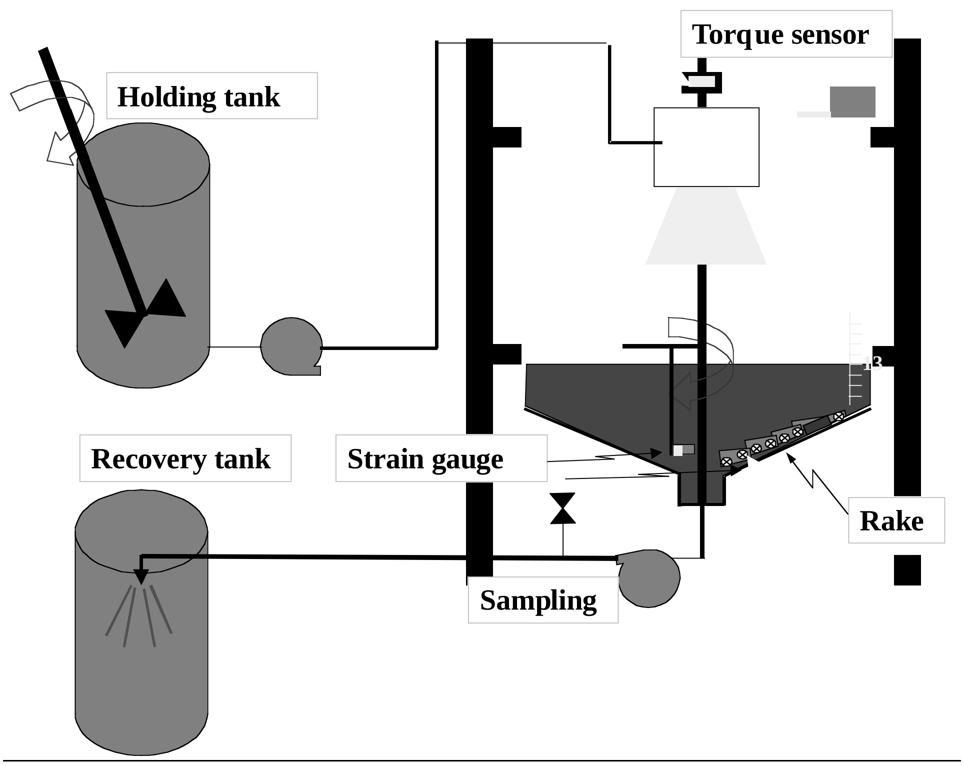

Figure 2 — Schematic of the pilot thickener at UQAC

Table 1 — Parameters for the thickener tests in relation to the geometry of the rake

	Original rake	Complementary rake	Reduced rake
Number of elements	10	5	3
Distance between elements (m)	0.1	0.2	0.2
Rpm of rake	0.3	0.3	0.3
Feed flow rate (L/min)	9.2	9.2	9.2
Feed solids (g/L)	50	50	50
Feed sand content (%)	20– 25	20–25	20–25
Flocculant flow rate (L/min)	0.6	0.6	0.6
Mud bed height over the cone (cm)	10	10	10
Underflow rate (L/min)	0.5–1.0	0.5–1.0	0.5–1.0
Cone angle (°)	30	30	30

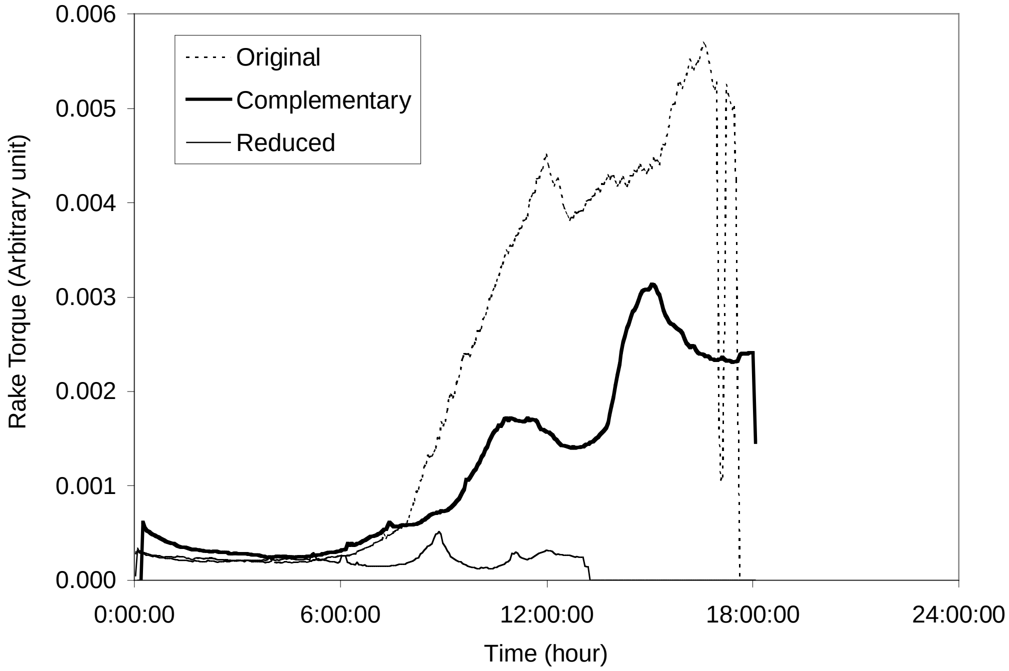

Figure 3 — Rake torque for three configurations

a very high torque increase after a few hours of operation, as the mud bed starts to rise. The complementary rake shows a modest increase in rake torque over time while the reduced rake displays a very small torque throughout the test. The average underflow solids obtained when the thickener had reached stability are given in Table 2. We can see that the reduced rake suffered a significant degradation of performance compared to the other configurations. Results for the complementary rake are comparable to those for the standard rake. The results were somewhat inconclusive, we decided to approach the problem from another point of view.

Table 2 — Average underflow solids for three rake configurations

	Original rake	Complementary rake	Reduced rake
Solids (%)	60	58	35

2.3 *Creation of kernel*

In the course of this test work, we always observed the accumulation of concentrated mud in the center of the thickener, around the rake. This kernel is very dense, hard, and difficult to break. It rotates with the rake. Figure 4 presents a picture of the kernel observed at the end of one test. We sampled it on a few occasions and found the solids content to be around 71% with a sand concentration of 63%. It is not certain that this kernel is causing the high torque but having such a concentrated mass of material in the mud bed, after only 24 to 48 hours of operation, cannot be good, especially for the stability of the underflow. Since the kernel is always present exactly underneath the feed well, one possible way to avoid its formation would be to move the feed well near the wall of the thickener, away from its center.

2.4 *Off-centered feed well*

Several tests were done to measure the impact of moving the feed well off center. Table 3 presents the parameters used for these tests. Tests 1 to 3 were done with the centered feed well and with sand concentrations ranging from 20% to 29%. All other parameters were kept constant. Tests 4 to 6 were done with the feed well located at half the radius of the thickener. Again, the sand concentration ranged from 12 to 28%, while all other parameters were kept constant.

Some results of the tests are presented in Figures 5 and 6 and in Table 4. Figures 5 and 6 show respectively that the torque and underflow solids content are more stable for the off-centered feed well (thick line) compared to the centered one (thin line). Note the large fluctuations in underflow solids for the centered feed well. The average underflow solids content is also generally higher for the off-centered feed well. A summary of the results is presented in Table 4. The instability index ***I***, defined by the equation (1) below, describes the extent of the variations in underflow solids. In this equation, μ_i isis the total solids fraction at time i and, Δt_i is the interval between two consecutive measurements. An index of 1 indicates that underflow solids are very unstable while an index of 0 points to very stable underflow solids.

$$\boldsymbol{I} = \frac{\sum_i \frac{|u_{i+1} - u_i|}{(u_{i+1} + u_i)} \Delta t_i}{\sum_j \Delta t_j} \qquad (1)$$

Note also that the % blockage represents the % of time the underflow pipe was blocked. No blockage was experienced with the off-centered feed well, indicating a homogeneous mud bed. On the other hand, the tests with the centered feed well suffered several instances of dense mud, highly concentrated in sand, blocking the underflow outlet.

For several tests, the mud bed was sampled at key locations to determine its homogeneity. Figure 7 presents the solids and sand concentrations at these locations for two typical tests under both configurations with a feed sand concentration of 28%. We can see that large variations in the solids content and in the sand concentration are present in the mud bed when the feed well is centered. Solid content varies from 49% to 71% and sand from 9% to 63%. The presence of the kernel can also be seen in these results by noting the high solids and sand concentration in the center of the picture for the case with the centered feed well. Moving the feed well away from the center of the thickener avoids the formation of the kernel and promotes a better homogeneity of the mud bed with solids in the range 42% to 49% and sand in the range 23% to 39%. Evidence of the presence of the kernel for the centered feed well was also seen in pictures taken at the end of the tests. No kernel was ever observed at the end of tests with the off-centered feed well.

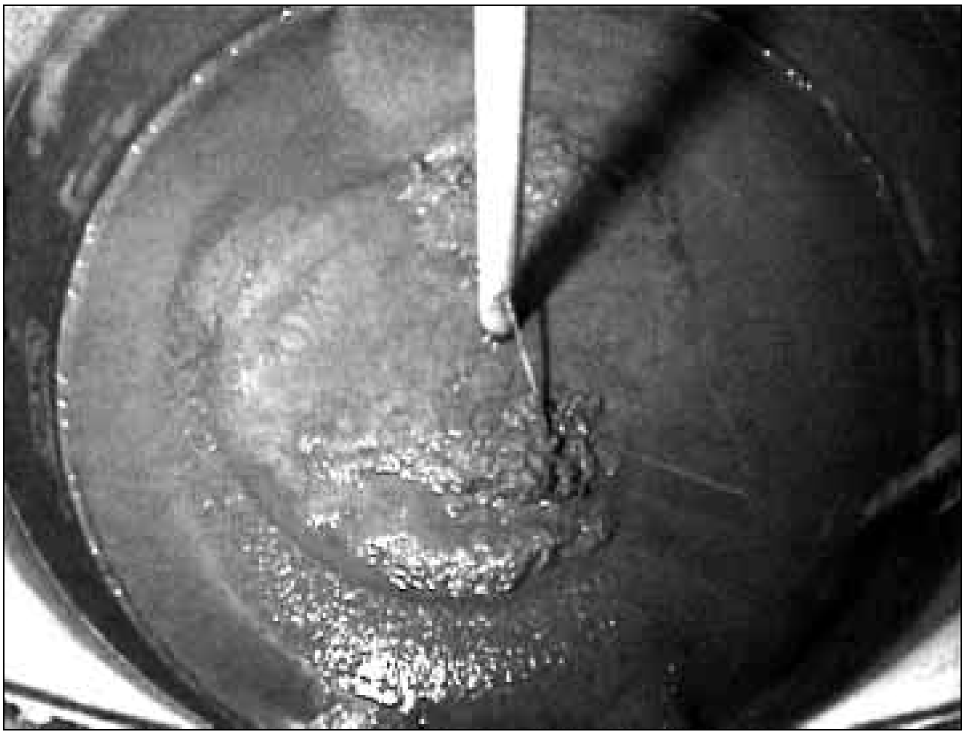

Figure 4 — Picture of typical kernel observed at the end of a test

Table 3 — Parameters for the thickener tests measuring the impact of the off-centered feed well

	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6
Position of feed well	Center	Center	Center	Half radius	Half radius	Half radius
Number of elements	5	5	5	5	5	5
Distance between elements (m)	0.2	0.2	0.2	0.2	0.2	0.2
Rpm of rake	0.3	0.3	0.3	0.3	0.3	0.3
Feed flow rate (L/min)	9.0	9.0	9.0	9.0	9.0	9.0
Feed solids (g/L)	50	50	50	50	50	50
Feed sand content (%)	29	20	22	12	12	28
Flocculant flow rate (L/min)	0.70	0.70	0.50	0.65	0.49	0.90
Mud bed height over the cone (cm)	10	10	10	10	10	10
Underflow rate (L/min)	0.54	0.76	0.49	0.50	0.46	0.54
Cone angle (°)	30	30	30	30	30	30

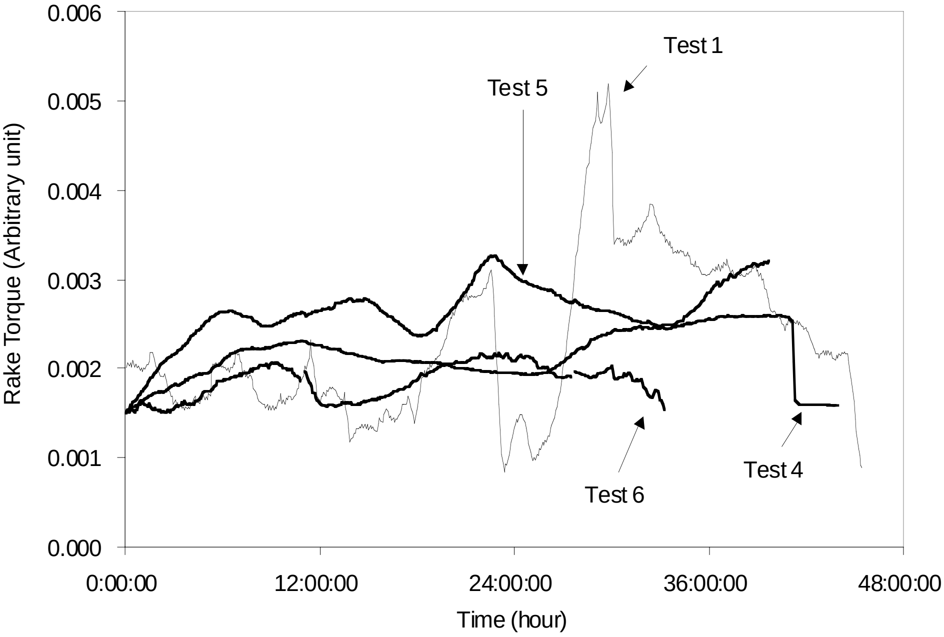

Figure 5 — Rake torque with the centered and off-centered feed well

Table 4 — Summary of results comparing the centered and off-centered feed wells

	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6
Position of feed well	Center	Center	Center	Half radius	Half radius	Half radius
Instability index	0.01	0.043	0.12	0.004	0.00278	0.00262
Average underflow solids (%)	55	55	49	55	55	60
Blockage (%)	2	5	16	0	0	0

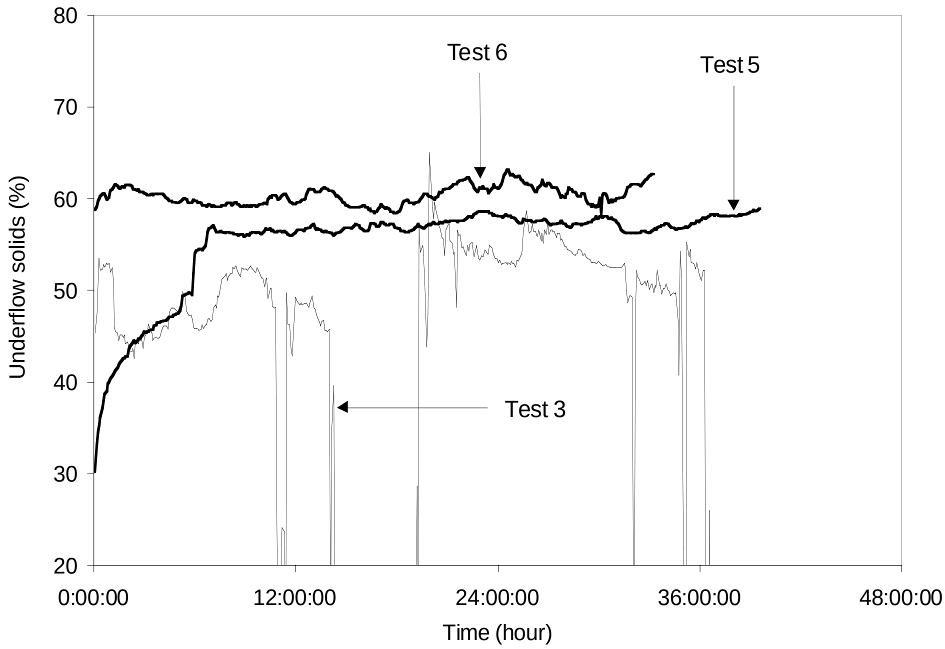

Figure 6 — Underflow solids content with the centered and off-centered feed well

3. Plant prototype

In view of the good results obtained in the pilot thickener, it was decided to modify a 1st stage mud washer at the Alcan Vaudreuil alumina plant to move the feed well at half the radius of the tank. All other process parameters and geometrical parameters remained the same. This prototype was installed in the fall of 2001 and operation with the off-centered feed well started in December 2001. Since then, the results have been very good. The same trend previously observed in the pilot thickener was noticed with the plant thickener. Operation is more stable and consistent. Blockages of the underflow were not experienced. The torque is more stable. The better homogeneity of the mud bed and the

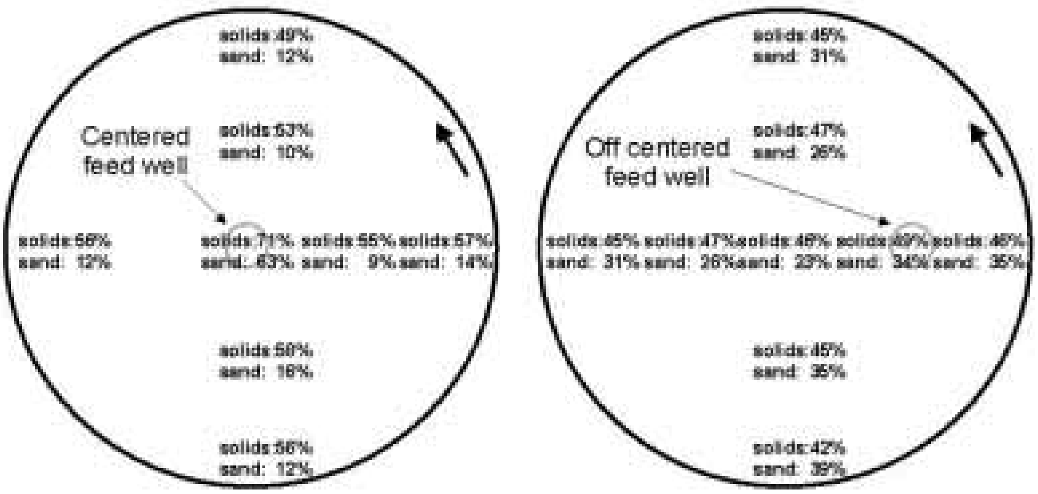

Figure 7 — Solids and sand concentration with the centered and off-centered feed well, for a feed sand concentration of 28%

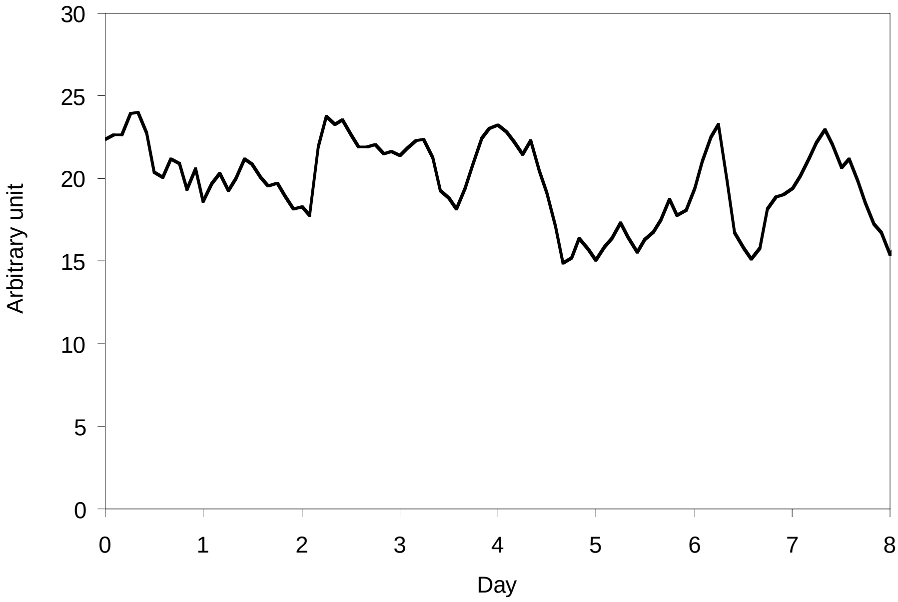

Figure 8 — Trends for the torque with the off-centered feed well

higher mud inventory in the thickener increased the underflow solids out of the thickener. The average was 40% solids for the centered feed well while it was 45% for the off-centered one, with periods when it reached 50% solids. Figure 8 presents trends for the torque with the off-centered feed well. It can be seen that the torque is generally higher but more stable than that observed with the center feed well (Figure 1).

4. Conclusion

The performance of a thickener fitted with an off-centered feed well is significantly improved compared to the one where the feed well is centered. The rake torque and underflow solids are more consistent. This improvement is caused by the better homogeneity of the mud bed observed when the feed well is not at the center of the tank. These benefits are more important when the sand concentration is high. A patent covering this invention was applied for [Peloquin et al.].

Having a more stable rake torque and a homogeneous mud bed allow the increase of the mud inventory in the thickener, which significantly improves compaction of the mud at the underflow, going from 40% to 45% solids. It also permits operation of the tank with the rake submerged in mud, hence decreasing the amount of scaling and increasing the turnaround time of the tank.

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